United Republic of Tanzania
Tanzania Electric Supply Company Limited

PREPARATORY SURVEY ON MTWARA NATURAL GAS THERMAL POWER PLANT AND TRANSMISSION LINES CONSTRUCTION PROJECT IN THE UNITED REPUBLIC OF TANZANIA

FINAL REPORT

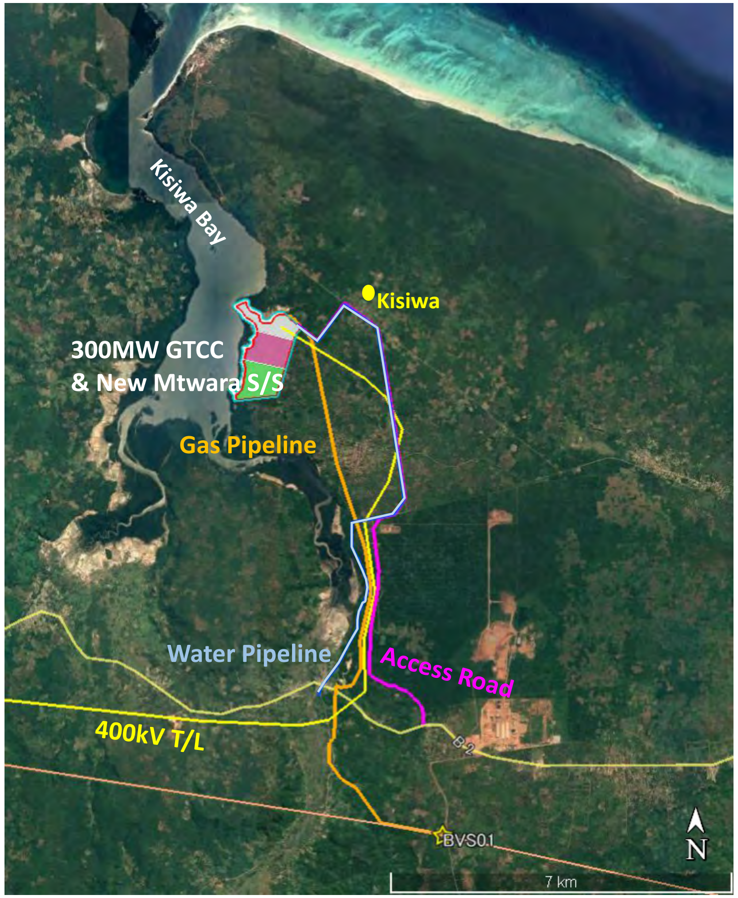
March 2020

Japan International Cooperation Agency

NEWJEC Inc.
The Kansai Electric Power Co., Inc.
ERM Japan Ltd.

6R
JR (P)
20-007

Exchange Rate : USD 1 = JPY 109, December 2019



Locations of Mtwara GTCC, S/S & Routes of 3-Infrastructures

Location Map

Preparatory Survey on Mtwara Natural Gas Thermal Power Plant and Transmission Lines Construction Project in Tanzania

Final Report

Table of Contents

List of Figures

List of Tables

Abbreviations and Definitions

Symbol	English
1.5CB	Double bus one and a half breaker
1CB	Double bus single breaker
3LG-O	Three Line Ground fault and Open
A/C	Air Conditioning
AC	Alternating Current
ACSR	Aluminum Conductors Steel Reinforced
AfDB	African Development Bank
AGC	Automatic Generation Control
AIS	Air Insulated Switchgear
AS	Aluminum-clad Steel wire
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AVR	Automatic Voltage Regulator
Basic Survey (2016)	Data collection survey of gas thermal power generation in the United Republic of Tanzania (JICA, 2016)
BADEA	Arab Bank for Economic Development in Africa
BCP	Boiler Circulating Pump
BD	Basic Design
BDL	Below Detection Limit
BH	Borehole
BS	British Standard
BSDG	Black Start Diesel Generator
BTIP	Backbone Transmission Investment project
BUR	Biennial Update Report
BVS	Block Valve Station
CBO	Community Based Organization
CCR	Central Control Room
cct.	Circuit
CCTV	Closed Circuit Television
CDO	Community Development Officer
CO_2	Carbon dioxide
COD	Commercial Operation Date
CoET	College of Engineering and Technology
CPI	Consumer Price Index
CPU	Central Processing Unit
CRB	Contractors Registration Board
CT	Current Transformer
CWP	Circulation Water Pump
DC	Direct Current
DCS	Distributed Control System
DD	Detailed Design
DED	District Executive Director
DEM	Digital Elevation Model
DGRC	District Grievance Resolution Committee
DIN	German Standards
DLN	Dry Low NOx

Symbol	English
DLP	Defects Liability Period
DMD	Deputy Managing Director
DMO	District Medical Officer
DO	Dissolved Oxygen
DPO	Development Policy Operation
DPs	Development Partners
DS	Disconnect Switch
DSCR	Debt Service Coverage Ratio
EAC	East African Community
E/N	Exchange of Notes
EDCF	Economic Development Cooperation Fund (South Korea)
EDG	Emergency Diesel Generator
EDM	Electricidade de Mozambique
EHS	Environmental, Health, and Safety
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIRR	Economic Internal Rate of Return
EIS	Environmental Impact Statement
EM-DAT	Emergency Events Database
EOH	Equivalent Operating Hours
EPC	Engineering, Procurement and Construction
ERM	ERM Japan Ltd.
ES	Earth Switch
EWURA	Energy and Water Utilities Regulatory Authority
FAC	Final Acceptance Certificate
FDI	Foreign Direct Investment
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
G7	Group of Seven
GASCO	Gas Supply Company
GC	Grid Code
GCB	Gas Circuit Breaker
GCC	Grid Control Center
GCP	Ground Control Point
GDP	Gross Domestic Product
GE	General Electric Company
GHG	Greenhouse Gas
GIS	Gas Insulated Switchgear
GL	Ground Level
GMCB	Generator Main Circuit Breaker
GPS	Global Positioning System
GSUT	Generator Step-up Transformer
GSW	Galvanized Steel Wire
GT	Gas Turbine
GTCC	Gas Turbine Combined Cycle
GTSC	Gas Turbine Simple Cycle
GTW	Gas Turbine World
GoT	Government of Tanzania

Symbol	English
H-GIS	Hybrid Gas Insulated Switchgear
HAT	Highest Astronomical Tide
HRSG	Heat Recovery Steam Generator
I&C	Instrumentation and Control
IBA	Important Bird Area
ICB	International Competitive Bidding
ICT	Information and Communications Technology
IDC	Interest During Construction
IEC	International Electrotechnical Commission
IED	Innovation Energie Développement (French Consultant)
IFC	International Finance Corporation
IHI	IHI Corporation
IKL	Iso Keraunic Level
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPB	Isolated Phase Bus
IPP	Independent Power Producer
IRA	Institute of Resource Assessment, University of Dar es Salaam
IRR	Internal Rate of Return
ISO	International Organization for Standardization
ITA	Instructions to Applicants
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
Kansai	The Kansai Electric Power Co., Inc.
L/A	Loan Agreement
LAN	Local Area Network
LCD	Liquid Crystal Display
LCoE	Levelized Cost of Electricity
LNG	Liquefied Natural Gas
Low Loss	low loss conductor
LTSA	Long Term Service Agreement
LV	Low Voltage
MBREMP	Mnazi Bay Ruvuma Estuary Marine Park
MCC	Millennium Challenge Cooperation (US)
MD	Managing Director
MED	Multi-Effect Desalination
MEM	Ministry of Energy and Minerals
MHPS	Mitsubishi Hitachi Power Systems, Ltd.
MNRT	Ministry of Natural Resources and Tourism
MOE	Ministry of Energy
MOU	Memorandum of Understanding
MP	Master Plan of Mtwara RAS
MSF	Multi-Stage Flash
MTUWASA	Mtwara Urban Water Supply and Sanitation Authority
MV	Medium Voltage
NBS	National Bureau of Statistics
NEMC	National Environment Management Council
NEP	National Energy Policy

Symbol	English
NEWJEC	NEWJEC Inc.
NFPA	National Fire Protection Association
NGO	Non-Governmental Organization
NGUP	Natural Gas Utilization Plan (The Project for Review of the Natural Gas Utilization Plan in Tanzania Final Report)
NHSDP	National Human Settlements Development Policy
NLUPC	National Land Use Planning Commission
NOx	Nitrogen Oxides
NPV	Net Present Value
O&M	Operation and Maintenance
OCHA	Office for the Coordination of Humanitarian Affairs
ODA	Official Development Assistance
OEL	Over Excitation Limiter
OEM	Original Equipment Manufacturer
OJT	On the Job Training
OPGW	Optical Ground Wire
PAC	Provisional Acceptance Certificate
PAP	Project Affected Person
PC	Power Complex
PET	Potential Evapotranspiration
PIU	Project Implementation Unit
PLC	Power Line Carrier
PP	Power Plant
PPE	Personal Protective Equipment
ppm	Parts per million
PPP	Public Private Partnership
PPRA	Public Procurement Regulation Authority
PQ	Pre-qualification
Project	Mtwara Natural Gas Thermal Power Plant and Transmission Lines Construction Project
PSMP	Power System Master Plan
PSMP 2016 Update	Power System Master Plan 2016 Update
PSS	Power System Stabilizer
PSSE	Power System Simulator for Engineering
PVC	Polyvinyl Chloride
QBS	Quality Based Selection
QCBS	Quality and Cost Based Selection
RAP	Resettlement Action Plan
RAS	Regional Administrative Secretary
RCMU	Resettlement and Compensation Management Unit
REA	Rural Energy Agency
RO	Reverse Osmosis
ROW	Right of Way
RPF	Resettlement Policy Framework
RSCB	Ruvuma River and Southern Coast Basin
RTU	Remote Terminal Unit
S/S	Substation
SAPP	Southern African Power Pool
SCADA	Supervisory Control And Data Acquisition

Symbol	English
SCF	Standard Conversion Factor
SDR	Social Discount Rate
SEP	Stakeholder Engagement Plan
SF_6	Sulfur hexafluoride
SIDA	Swedish International Development Cooperation Agency
SNC	Second National Communication
SPMT	Self-Propelled Modular Transporter
SPP	Small Power Project
SPT	Standard Penetration Test
ST	Steam Turbine
STATCOM	Static synchronous Compensator
Study	Preparatory survey on the Project
SWER	Single Wire Earth Return
T/L	Transmission Line
TA	Technical Advisor
TANESCO	Tanzania Electric Supply Company Limited
TANROADS	Tanzania National Roads Agency
Tanzania	United Republic of Tanzania
TARURA	Tanzania Rural and Urban Road Agency
TASAF	Tanzania Social Action Fund
TEDAP	Tanzania Energy Development and Access Project
TFS	Tanzania Forest Services Agency
TICAD	Tokyo International Conference on African Development
TMA	Tanzania Meteorological Agency
TOR	Terms of Reference
TPA	Tanzania Ports Authority
TPDC	Tanzania Petroleum Development Corporation
TPSC	Toshiba Plant Systems & Services Corporation
Tsh.	Tanzania Shillings
TTS	TANESCO Training School
TZS	Tanzania Shillings
UAT	Unit Auxiliary Transformer
UEL	Under Excitation Limiter
UNEP	United Nations Environment Program
UNFCCC	UN Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UPS	Uninterruptible Power System
USAID	United States Agency for International Development
USGS	United States Geological Survey
VAT	Value Added Tax
VEO	Village Executive Officer
VGRC	Village Grievance Resolution Committee
VPO	Vice President Office
WACC	Weighted Average Cost of Capital
WB	World Bank
WEO	Ward Executive Officer
WHO	World Health Organization
XLPE	Cross - linked Polyethylene cable

SUMMARY

SUMMARY

A. PURPOSE OF THE STUDY

In accordance with Power System Master Plan 2016 Updated by Ministry of Energy (MOE), the power supply method and procedure to Dar es Salaam region in a short-term and to the south-east region, including the Mtwara area, in mid and long terms are studied.

B. SCOPE OF THE PROJECT

The Project consists of 300MW class Gas Turbine Combined Cycle (GTCC) Power Plant, 400kV Transmission line (T/L), Two (2) 400kV Substations (S/Ss) and associated 3-Infrstructures (road, gas pipeline and water pipeline).

C. RELEVANCE OF THE PROJECT AT MTWARA

Current power demand center of Tanzania is Dar es Salam. Nevertheless, the reasons why 300MW class GTCC is planned to be constructed in the Mtwara region where locates around 500km away from Dar es Salam are as follows;

- Power demand: There are potential demands in the Mtwara and Lindi regions for cement, mining and LNG industries, etc. The GTCC will contribute the development of these industries, and power demand in the regions will close to around 300MW in 2030.
- Rural electrification: Rural electrification rate of Lindi region and Mtwara region was 41.0% and 29.2% in 2016, and will be drastically improved for both regions in 2025 with the completion of the GTCC and the development of distribution network in these regions.
- International Grid to Mozambique: There is an interconnection plan between Tanzania and Mozambique with Memorandum of Understanding (MOU). New Mtwara S/S is planned to be connection point of Mozambique and the T/L from Mtwara- Lindi- Somanga is one of the most important parts in the future national trunk line of Tanzania considering power export to Mozambique.
- Energy Security: There are long gas pipelines between Mtwara and Dar es Salaam, but the sending gas capacity is closing to full. Sending energy from Mtwara to Dar es Salaam in the form of electricity will contribute to securing energy in Dar es Salaam in case that gas pipelines have some trouble.
- GTCC Power Plant with highest efficiency: Seawater cooling system that provides the highest efficiency of GTCC among the condenser cooling system of steam turbine (S/T) can be adopted at Kisiwa Bay. The rise in efficiency of GTCC by adopting the seawater cooling system instead of the air cooling system is higher than the transmission loss expected between Mtwara to Dar es Salaam. The location in Mtwara is more advantageous than the location around Dar es Salaam where only air cooling system can be adopted.

D. MAJOR STUDY RESULTS OF THE PROJECT

1) GTCC

- 4 candidate Gas Turbine (GT) machines namely, H-100 (MHPS), LM6000PF+ (IHI (GE)), SGT-800 (Siemens) and 6F.03 (GE) are studied.

- The sea water cooling system is adopted as ST condenser cooling system that contribute to the best efficiency of GTCC.

- GTCC is arranged at the Kisiwa site with minimum necessary ground height of 5.4m due to adoption of the sea water cooling system.

- Geological conditions at the Kisiwa Site are good to construct the heavy equipment of GTCC and S/S.

- Gas supply and water supply to GTCC seems to be affordable for its 30 years' operation

2) T/L

- T/L routes from Mtwara-Lindi-Somanga (around 270km) are proposed with following considerations;
  (1) Avoidance of residential, high elevation, protected and swamp areas as much as possible,
  (2) Along the national road (for easy access),
  (3) Along the gas pipeline (to minimize land acquisition).

- T/L with 400kV, two circuits and 4 conductors of Bluejay are selected. However, LLC (low loss conductor) is considered as alternative.

- Porcelain type insulator is recommended from viewpoints of reliability and life cycle cost of 40 years.

- Geological conditions of T/L are generally good, but some areas are judged to be weak. Therefore, the foundations in such area should be designed based on the point geological surveys in the next step.

3) S/S

- The Kisiwa site is selected as the location of the New Mtwara S/S because heavy equipment can be carried by means of beaching. On the other hand, the area next to the Mahumbika S/S is selected as the location of the New Lindi S/S because the land is already owned by TANESCO and easy to connect with the existing 132kV transmission line.

- Double bus one and a half breaker (1.5CB[1]) system will be used for the New Mtwara and New Lindi S/Ss.

- The New Mtwara S/S needs to adopt Gas Insulated Switchgear (GIS) because it closes to the sea. On the other hand, for the New Lindi S/S, the Hybrid GIS (H-GIS) is preferable in terms of reliability.

1 Circuit Breaker

- The New Mtwara S/S adopts three phase transformers because it is easy to bring the site by beaching. On the other hand, considering the load limitation of the national roads, the New Lindi S/S will adopt the special three phase transformers (decomposable).

4) 3-Infrastructures

- 2 lanes paved road from the national road to GTCC site will be prepared by upgrading the existing 1 lane unpaved road together with improvement of drainage system and sharp corners, etc.

- A 12 inch new buried gas pipeline will be prepared from BVS[2]01 to GTCC site.

- A new well, a pump, a storage tank and a new water pipeline from the new well to GTCC site will be prepared.

E. TRANSPORTATION PLAN OF THE PROJECT

There are some hurdles to transport the heavy equipment to the Kisiwa site and Lindi S/S because capacity of the Mtwara port facilities is not enough and payload of the national road is limited. The solutions are as follows;

- For the GTCC and S/S at the Kisiwa Site ,heavy equipment is transshipped at offshore of the Mtwara port, carried to the Kisiwa site by barges and unloaded by means of the beaching method.

- Light equipment is transported to the Kisiwa site and Lindi S/S by road.

- Special three phase transformer (decomposable) is adopted to enable to transport it to Lindi S/S by road.

F. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS OF THE PROJECT

- Environmental Impact Assessment (EIA) reports of GTCC, T/L and 3-Infrastructures are submitted to National Environment Management Council (NEMC) to get the certificate from Minister of State for Environment.

- Land acquisition and resettlement plans for GTCC including S/S, T/L and 3-Infrastructures are studied in Due Diligence Report (DDR), Resettlement Policy Framework (RPF) and Resettlement Action Plan (RAP).

- No significant impact on noise, vibration, dust and waste, etc. during construction and operation phases is observed.

- As the seawater cooling system of GTCC discharges hot seawater to the Kisiwa Bay, the simulations of the seawater cooling system are carried out. The mixing zone with discharged hot seawater from ST condenser, which exceeds by 3 degree Celsius, is observed within the limited area, and there are no endangered species such as coral reefs, etc. The results satisfy the EHS (Environmental, Health and Safety) guideline of International Finance Corporation (IFC).

2 Block Valve Station

- Though potential impacts on an endangered bird species (Spotted Ground Thrust) and African elephants are limited, necessary countermeasures will be taken to minimalize and mitigate the risks.

G. Features of the Project

Japanese quality infrastructure application is reflected on the project as much as possible in terms of high energy efficiency, stable power supply and abatement of environmental burdens by use of domestic natural gas.

- Adopted technologies for GTCC are;
  - Seawater cooling system of steam turbine condenser
  - Dry Low NOx (DLN) Technology of GT
  - LTSA[3]/RMS[4] for GT to sustain quality operation of the GTCC

- Adopted technology for the transmission line is;
  - Porcelain type insulator

- Adopted technologies for the substations are;
  - Outdoor type GIS with low SF6[5] leakage rate < 0.1%/year
  - Special three-phase transformer for easy transportation
  - Oil gas spacer to connect transformers with GIS

H. Technology Transfer

Technology transfer (TT) to TANESCO is important to sustain the quality of infrastructure until the end of plant life. TT is planned to be implemented by the consultant, contractor(s) and in the LTSA of the Project.

- TT by Consultant
  - TT in design and supervision works
  - Overseas training on O&M[6] method, especially for seawater cooling system
  - Field visit of similar GTCC, transmission line and substation in consultant's home country

- TT by Contractor(s)
  - Training on O&M skills by OJT[7] and class room lectures
  - Overseas training on O&M methods at contractor(s)' factory

- TT in LTSA
  TANESCO will be given a chance to learn the inspection and replacement technology of GT from Technical Advisor (TA) during LTSA period, so that they can maintain the GTs without TA after the expiration of LTSA.

3 Long Term Service Agreement
4 Remote Monitoring System
5 Sulfur Hexafluoride
6 Operation and Maintenance
7 On the Job Training

1. Backgrounds of the Study

The annual average nominal Gross Domestic Product (GDP) growth rate of United Republic of Tanzania (hereinafter referred to as “Tanzania”) between 2000 and 2015 was 10.5% and is expected to be 5~10% for the next 10 years according to the International Monetary Fund (IMF)’s estimation. Therefore, Tanzania is expected to develop economically in the future. In December 2016, the Power System Master Plan 2016 Update (hereinafter referred to as “PSMP 2016 Update”) was issued by the Ministry of Energy and Minerals (MEM), the current Ministry of Energy (MOE), and the plan provides details on future power development based on the government’s target, one of which is to achieve a generation capacity of 4,915MW in Tanzania by 2020.

The power demand of south-east region, including the Mtwara area, is expected to be more than 300MW in the mid-to-long-term and this indicates that there is a high need to develop power sources in this region, not only to secure the supply locally, but also to realize the national power development as per the PSMP 2016 Update.

The Mtwara Natural Gas Thermal Power Plant and Transmission Lines Construction Project (hereinafter referred to as “the Project”) is important to achieve the government’s target, and to ensure the supply of power to Dar es Salaam region in a short-term. The preparatory survey for Mtwara Natural Gas Thermal Power Plant and Transmission Lines Project in Tanzania (hereinafter referred to as “the Study”) was implemented by JICA Study Team.

In response to the request from Tanzania Electric Supply Company Limited (hereinafter referred to as “TANESCO”) during the Preparatory Study in September 2018, JICA added the following items to the scope of the Study - the construction of access road including the collector road upgrading, installation of a new gas pipeline and installation of a new water pipeline (hereinafter collectively referred to as "3-infrastructures"). The study results are integrated into the Study report as Chapter 13.

2. Electric Power Industry and Proposed Power System

1) TANESCO had to purchase electricity from Emergency Power Producers (EPP) as a temporary countermeasure due to drought conditions in Tanzania. This put pressure on TANESCO’s finances due to their high price. Therefore, it is necessary to develop an efficient power plant of a certain capacity without EPP at the earliest in Tanzania.

2) In PSMP 2016 Update, the peak power demand of 2016, 2017, 2018, 2019 and 2020 are forecasted to be 1,250MW, 1,450MW, 1,680MW, 1930MW and 2,190MW respectively. Actual peak demand of 2016 was 1,041MW and the actual peak demand of 2017 was 1,051MW. However the total demand will increase due to several factors such as economic development, progress of the rural electrification and export of power by cross-border interconnections.

3) The current voltage classes of Tanzania are 220kV, 132kV, and 66kV for the transmission line, and the distribution lines are operated at 33kV and 11kV. The total route length of high voltage transmission network is 6,485km including the 670km Backbone transmission line. 400kV transmission line, which is constructed under the Backbone Transmission Investment Project (BTIP), is now operated at 220kV and it is being upgraded to operate at 400kV.

4) Estimated load of 400kV New Lindi substation is approximately 124.5MW in 2022 and 214MW in 2040. Estimated load of 400kV New Mtwara substation is about 42.8MW in 2022 and 142MW in 2040.

5) Power flow, short circuit current, voltage, and steady state and transient stability analyses for the Project have been carried out by a PSSE software for the years 2025, 2030, 2035 and 2040, and no problems have been observed. The calculation has been done with the data from PSMP 2016 Update and some updated information from TANESCO.

6) Rural electrification rate of Lindi region and Mtwara region was 41.0% and 29.2% in 2016 , and will be drastically improved in 2025 with the completion of the Mtwara Gas Turbine Combined Cycle (hereinafter referred to as “ GTCC”) Power Plant and the development of distribution network in these regions.

3. Site Selection

1) Although the Mikindani site was recommended by the Basic Survey (2016), TANESCO preferred to pursue the possibility of using the Kisiwa site that was ranked 2nd in the Basic Survey, mainly due to the expected adverse environmental issues of Mikindani site. This is because the Mikindani site has been designated as a residential area by the Land Utilization Master Plan through the Mtwara Regional Administrative Secretary (RAS) office after the Basic Survey (2016). TANESCO proposed to carry out further investigation of both sites.

2) As a result of investigation, it was noted that several crucial issues can be anticipated for the Mikindani site, mainly from the environmental and social aspects, due to its designation as residential area. On the other hand, such issues are not envisaged for the Kisiwa site due to its designation as power plant area. The outcome of simulation results indicates that the seawater cooling system can be adopted for the Kisiwa site. Therefore, the Kisiwa site is selected as the candidate site for the Mtwara GTCC Power Plant.

3) During this survey period, the transportation route survey was also conducted. As per survey results, heavy equipment such as Gas Turbine (GT), Steam Turbine (ST), Steam Drum, Generator, Transformer etc. will be transported to the site by barges after being transshipped at the Mtwara port and unloaded at the Kisiwa site by means of beaching. On the other hand, light equipment such as Steel Frame/Plate, Duct, Piping, Valves etc. will be transported by road from the Mtwara port.

4. Study on the Power Plant

1) There are several GT manufactures to supply GTs for the 300MW class GTCC in the world, however, from the viewpoint of machine type and GTCC configuration together with compatibility and reliability, 4 candidate GT machines namely, H-100 (MHPS)[8], LM6000PF+ (IHI (GE))[9], SGT-800 (Siemens)[10] and 6F.03 (GE)[11] are selected. They are studied in terms of output, efficiency, unit price, GTCC configuration, supply records, plant layout, etc.

2) Loss in unit output of the 3 candidate machines, in case of 1 GT trip, satisfies the allowable single unit capacity in 2024~25 based on the future power development plan of Tanzania.

3) Based on the results of comparative study of the condenser cooling system, the sea water cooling system is adopted. As for the configuration of the sea water cooling system, the water intake

8 Heavy duty type 1 block (2 GTs – 2 HRSGs – 1 ST)
9 Aero derivative type 2 blocks (2 × (2 GTs – 2 HRSGs – 1 ST))
10 Heavy duty type 2 blocks (2 × (2 GTs – 2 HRSGs – 1 ST))
11 Heavy duty type 1 block (2 GTs – 2 HRSGs – 1 ST)

tower system and the water discharge pipe system are selected after comparing the various configurations.

4) Plant water supply & treatment systems are studied. Required fresh water amount is estimated to be about 300 m^3/day[12]. Mtwara Urban Water Supply and Sanitation Authority (MTUWASA) will be in charge of water supply for the Mtwara GTCC Power Plant. MTUWASA declared that use of water for the Project is totally affordable with a new well. Water pipeline route, the construction period and the installation cost of the water pipeline are explained in Section 13.4.

5) Gas supply system is studied. Required gas amount is estimated to be about 51.9MMscfd[13] and the required gas pressure at GT is 30~50 bar depending on the GT models. Gas pipeline route from the Block Valve Station (BVS) No.1 up to the Kisiwa site was determined by Tanzania Petroleum Development Corporation (TPDC) with the agreement of Tanzania National Road Agency (TANROADS) and Dangote[14]. The diameter of gas pipeline is 12 inch and the gas supply pressure at valve station is 90 bar. It is determined that the gas supply amount of Tanzania is sufficient to operate the Mtwara GTCC Power Plant for 30 years and the gas quality also meets the requirements of GT fuel. Gas pipeline route, the construction period and the installation cost of the gas pipeline are explained in Section 13.3.

5. Route Selection for Transmission Line

1) The length of the 400kV transmission line from Mtwara to Somanga is around 270km. The candidate routes are divided into eight (8) sections and studied in consideration of the following:

   a) Pre-FS by USAID (2015),
   b) Avoidance of residential, high elevation, protected and swamp areas as much as possible,
   c) Along the national road (for easy access),
   d) Along the gas pipeline (to minimize land acquisition).

2) Recommended route and alternative route were determined and mutually agreed between TANESCO and JICA Study Team with signed minutes.

6. Site Selection for Substation

1) Location of the New Mtwara Substation and the New Lindi Substation are selected from 3 candidate sites respectively.

2) The Kisiwa site is selected as the location of the New Mtwara Substation because heavy equipment can be carried by means of beaching, in the same way as the Mtwara GTCC Power Plant, and also because the negotiation for land acquisition has progressed. However, it is necessary to consider countermeasures against the sea salt damage, because the Kisiwa site is located at the seaside area. Full-GIS substation is adopted to cope with sea salt damage.

3) The area next to the Mahumbika Substation is selected as the location of the New Lindi Substation, because the land is already owned by TANESCO and also because it is easy to connect to the existing 132kV local grid. In addition, the New Lindi Substation may be able to share resources, such as O&M staffs, with the Mahumbika Substation.

12 If water supply for residences in the power plant is required, necessary water amount is around 360m3/day.
13 Million standard cubic feet per day
14 The prehistory of the gas pipeline issue is explained in Section 13.1 of this Summary

7. Site Condition of the Project on Land, Marine and Climate

1) The Kisiwa site is a rolling terrain with an altitude of 0m to 30m above the sea level. Mangrove forests have formed along the seashore line of the Kisiwa bay except at the tip of cape, where it is a sand-covered coastline. The tip will be utilized as the beaching area for the heavy equipment.

2) Topographic survey was conducted by satellite photography with a map scale of 1:2500 for approximately 3km^2 at the Kisiwa site.

3) Most sections of 400kV transmission line route (270km) run close to the national road. The route has a gentle topography without high and/or steep mountains, but there are a few swamp areas.

4) Mean seawater level in the Kisiwa bay is 2.0 m, high seawater & low seawater level = mean seawater level ±1. 6m, and the highest seawater level is 4.1 m. The sea depth around the planned intake mouth is about 15m and the depth at the planned discharge mouth is about 5m.

5) With regard to natural disasters around the project area, there are no records of earthquake, however, floods regularly occur.

6) Rivers flow into the Kisiwa bay in the rainy season, but the rivers dry up during dry season. Both shallow and deep groundwater are found in the coastal zone and in the river sediment zones of the Mtwara region. Raw water for the Project is planned to be supplied from deep wells near the Mbuo River. Water quality meets the quality of Tanzania drinking water supplies and the World Health Organization (WHO) Guidelines.

7) Geological survey of three (3) boreholes is carried out at the Kisiwa site. The results show that the geological conditions of the site are good because the layer with N-value more than 50 can be found within 20m of boring.

8) Geological survey of four (4) boreholes is conducted along the route of the 400kV transmission line, and one (1) borehole is surveyed at the New Lindi Substation. The geological conditions are generally good because N-value with more than 30 can be found within 10m of boring in most areas. However, some areas are judged to be weak, therefore, the geological survey for each steel tower will be required in the next step.

8. Basic Design of Power Plant, Transmission Line and Substations

1) The GTCC power plant with gas-fired (without oil-fired), bypass stack and black start generator, without auxiliary boiler is selected.

2) Site layout is studied for heavy duty type and aero-derivative type gas turbines. The Mtwara GTCC Power Plant is located at the tip of a cape and the seawater cooling system is considered for both the types.

3) With regard to electrical and control system, air cooled generator and blushless exciter are recommended with the adoption of Distributed Control System (DCS).

4) As the Kisiwa site is planned to be future GTCC power complex, the site is divided into 3 areas. The Project area (A-1) including future GTCC No.2 is around 34 ha. The ground level of A-1 is designed at 5.4 m (the highest seawater level (4.1m) + margin (1.3m)). However, it is time and cost consuming if all of A-1 is kept at 5.4m. Therefore, the A-1 has 2 levels, i.e. the level at

GTCC area is 5.4 m and that at other areas of A-1 is 8.6 m.

5) Judging from the future power flow situation mentioned in the PSMP2016 Update, the Bluejay conductor is recommended mainly due to its economic benefit. However, TANESCO wants both the Bluejay conductor and the Low Loss conductor (LLC) to be studied in the report. Therefore, LLC is studied as an alternative to Bluejay conductor in the report. The results of the Study shows that, the LLC has advantages only after 23 years of operation, in case the additional construction of around 600MW power generation in the Mtwara region is carried out as mentioned in PSMP2016 Update.

6) The porcelain type insulator has more merits compared to the glass type insulator for 40 years of operation, in terms of reliability and life cycle cost.

7) Four circuit tower design will be applied on the section between the New Mtwara Substation to the New Lindi Substation. 2 circuits with four conductor of 400 kV transmission line will be installed on the higher part of the tower and then 2 circuits of additional 132 kV transmission line will be installed on the lower part of the same tower.

   Two circuits with four conductor tower design will be applied on the entire section between the New Lindi Substation to 400kV Somanga Substation. Two transposition towers will be installed along the section.

8) Double bus one and a half breaker (1.5CB) system shall be used for the New Mtwara Substation, as it will be the interconnecting point for Mozambique. Adaption of 1.5CB is also recommended for the New Lindi Substation because the New Lindi Substation will play an important role for the domestic 400kV trunk system in the future.

9) The New Mtwara Substation needs to adopt Gas Insulated Switchgear (GIS) because it closes to the sea. On the other hand, for the New Lindi Substation, the Hybrid GIS (H-GIS) is preferable in terms of reliability, safety and resistance to air pollution including salinity.

10) The New Mtwara Substation needs to adopt three phase transformers because it closes to the sea, and it is easy to bring heavy equipment. On the other hand, considering transport along local roads, the New Lindi Substation shall adopt the special three phase transformers with light weight.

9. Project Implementation and Organization Structure for Operation & Maintenance

1) TANESCO has been financially in deficit for most of the period that the JICA Study Team looked back. On the income side, the tariffs have doubled in the past decade. However, this did not help TANESCO's financial position. Now that it is currently in the phase of heavy investment, continued government support in this regard is desirable.

2) In the past, when TANESCO's cash flow became difficult, the GoT had borrowed Development Policy Operation (DPO), a sector loan, from World Bank (WB), and provided management support to TANESCO with the following conditions.

   - Strengthening the country’s ability to bridge the financial gap in the power sector
   - Reducing the cost of power supply and promoting private sector participation in the power sector
   - Strengthening the policy and institutional framework for the management of the country’s natural gas resources

3) Regarding the tariff, there is a system to have it reviewed every year by the Energy and Water Utilities Regulatory Authority (EWURA) under the MOE. TANESCO has been investing in power supply improvement to meet the increasing demand, and EWURA approved the revision of the tariff commensurate with the management condition of TANESCO in 2016. However, since the GoT's policy is strongly in favor of industrial development measures, the increase of electricity tariff was not approved by the GoT. This resulted in continued management difficulties for TANESCO.

4) The construction and O&M organization for the Mtwara GTCC Power Plant will be similar to those of the Kinyerezi II Power Plant. Before the operation of the GTCC, it is important to establish the O&M procedure on how to manage the performance of facility and detect troubles in advance for stable facility operation.

5) Seawater cooling system for ST is the technology to be introduced as first time in Tanzania. The past thermal power plants of TANESCO are limited to GTs simple cycle or gas engines without ST. Although Tanzania's first GTCC was constructed as the Kinyerezi II Power Plant in the recent year, air-cooled condensing system of ST was adopted. Therefore the technology transfer for the seawater cooling system of ST is planned in the Project. It is also necessary to learn the operation and maintenance management of the entire power plant.

6) Long Term Service Agreement (LTSA) and Remote Monitoring System (RMS) for GT are recommended to ensure the operation performance at the initial stage. The capacity building support program from foreign utilities who have vast experience in GTCC power plants' operation is recommended in the next phase.

7) Since equipment of the 400kV transmission line are static equipment without the lubricant or insulation gas, they are not subject to periodic parts replacement, disassembly inspection, etc. However, it is necessary to check the soundness of facilities and the condition of trees under the line by regular patrols.

8) At the construction stage of 400kV substations, the construction team can be in charge of both the New Mtwara and the New Lindi Substations because the distance between the two Substations is only around 50 km and the team can travel between the two Substations. TANESCO needs to expand the maintenance team for the increased substation facilities in the Mtwara area.

10 Project Implementation Plan (It is currently not open to public)

11. Project Cost and Economic and Financial Analysis (It is currently not open to public)

12. Environmental and Social Considerations

1) Environmental Impact Assessment (EIA) was carried out for the Mtwara GTCC Power Plant. Noise, vibration, dust and wastes will be generated during construction phase. Clearing and levelling of around 160ha for the power plant complex will result in habitat loss. Also, the influx of workers during the peak of construction may increase risks to community health, safety and security and may also put pressure on the existing access roads and social services. During operation, potential significant impacts including wastewater discharge (including thermal seawater discharge) and solid wastes will be generated. Wastewater will be treated to meet the required standards prior to the release into the environment, and typical wastes (e.g. waste oil, sewage, general wastes) will be contracted out to certified waste management companies for

disposal. Air pollutants will be limited to NOx gases. An inventory of greenhouse gas emissions will be monitored and reported annually.

2) For the 400 kV Transmission Line, an EIA was also carried out. Impacts during construction phase are expected to be more significant compared to the impacts during operation phase. Noise, vibration, dust and wastes will be evident particularly at construction sites and access roads. Clearing of the ROW (52m width of the 270km transmission line) will result in habitat loss and fragmentation. The influx of 100,000 workers during the construction, may increase risks to community health, safety and security and may also put pressure on the existing infrastructure and social services. During operation, significant impacts will be limited to potential impacts on an endangered bird species (Spotted Ground Thrust) and African elephants and risks to community safety and security, due to the presence of transmission line towers and electric wires.

3) TANESCO is going to acquire a land of around 160 ha for their power complex area which can accommodate several power plants. Part of this power plant complex area will be used for the Mtwara GTCC Power Plant. 11 household out of the entire affected 140 household (784 people) will need resettlement. The valuation reports for the power plant site have been approved by the chief government valuer in December 2016 and April 2018. Therefore, the Due Diligence Report (DDR) was prepared by the Study to check the compliance with the JICA Guidelines for Environmental and Social Considerations (April, 2010) (JICA Guidelines). Measures to bridge the gap between Tanzanian legislation for land acquisition and the JICA Guidelines were proposed in the DDR, such as payment of compensation in full replacement cost, livelihood restoration, and monitoring and grievance mechanism.

4) The proposed transmission line will require acquiring complete 52m ROW whereby the permanent land acquisition will take place. 62 household will need resettlement. About 700 towers are expected to be constructed throughout the line. The proposed Mtwara substation will be constructed within the area of the proposed Mtwara GTCC Power Plant, and the total land about 150m x 144m for the Mtwara Substation will be acquired as a part of land acquisition process for the power plant. The proposed Lindi Substation will be constructed next to the existing land owned by TANESCO, therefore no land acquisition will be required. The Resettlement Policy Framework (RPF) was prepared by the Study to bridge the gap on compensation policy between Tanzanian legislation for land acquisition and the JICA Guidelines. As mentioned in the DDR, payment of compensation in full replacement cost, livelihood restoration, monitoring and grievance mechanism were also proposed in the RPF.

5) The series of stakeholder meetings including focus group meetings for women were conducted through the Study at the scoping stage and the draft final report stage. In total, 3,580 stakeholders have participated, such as affected people, governmental bodies from national to local levels and NGOs. A number of topics were discussed such as environmental pollutions, biodiversity issues, land acquisition and compensation, economic potentials and loss of livelihood. These findings was considered during the Study and will be taken care during the implementation of the Project.

13. Infrastructures for Mtwara GTCC Power Plant

< **Access road including the collector road upgrading>**

1) Major specifications of the village road including access road after upgrading are as follows:

• Class of road: DC-6
• Width of carriageway: 6.5m (3.25 × 2)

• Maximum vertical slope: 4%
• ROW: 40m
• Construction period: Around 10 months

2) The road will be paved by asphalt concrete and its shoulder and the footway will be paved by gravel. Drainage facilities for the road will be rehabilitated by concrete side drains and road crossing culverts.

3) Routes of the road will be improved as follows;

   i) Alignments of two sharp corners will be improved for vehicles to pass smoothly and safely

   ii) Intersection area with B-2 National Road will have an additional right-turn lane for vehicles to turn right easily

4) There are two cultural and natural structures near the Namgogoli village i.e. a Baobab tree and a primary school. The route will be a little bit detoured around these objects.

5) Since the period for construction will be limited, targeted route will be divided into three (3) sections and the selected contractors will construct each section independently.

<Gas pipeline >

6) Major specifications of the gas pipeline are as follows;

• Diameter: 12 inch
• Thickness: > 9.9 mm
• Material: API 5L X65 (with outer polyethylene coated)
• Gas flow velocity: 6.0 m/s
• Pressure loss: 0.1 MPa
• ROW: 30m
• Construction period: Around 14 months

7) Route 1 is selected mainly due to social aspects and avoidance of Dangote land. As explained in 3), only a small part of the gas pipeline goes through the Dangote and TANROADS lands Therefore, TPDC could conclude land use agreements with them.

8) It is confirmed through the visual survey and the satellite image that, there are no obstacles for the construction of the gas pipeline. At one point on the route, there is the slope like a small valley, therefore, appropriate measures are recommended such as planning of vegetation on backfilled surface to prevent landslides.

9) Almost all gas pipelines will be buried. The depth of the gas pipeline is 1.5m below the ground. At the road crossing section, the gas pipelines will be placed at the depth of 1.5m and 2m under the collector road and the national road respectively, and they will be protected by the sleeve pipe. The distance between the gas pipeline and the water pipeline is 0.4m (the gas pipeline is lower).

10) At the road crossing section, the sleeve pipe will be installed by the horizontal drilling method that has already been carried out in Tanzania.

< Water pipeline >

11) Major specifications of the water pipeline are as follows;

• Pipe diameter: DN 110 (inside diameter = 92 mm for HDPE, 101mm for uPVC)

- Pipe inside velocity: ca. 0.6 m/s for HDPE, 0.5m/s for uPVC
- Material: HDPE PN12.5 for transmission pipe, uPVC PN10 for raw water transmission pipe and distribution pipe
- Pump total lift: 99 m
- Capacity of the storage tank: 150 m^3
- ROW: 2m
- Construction period: Around 9 months

12) Water supply system for the Mtwara GTCC Power Plant consists of No.3 well, the existing balancing tank (common use of No1 and No.2 wells), a transmission pump in the existing pump house, a new transmission pipe, a new storage tank next to the existing storage tank and a new distribution pipe.

13) The new storage tank and the existing storage tank will be connected by connection pipes with valves, therefore, water can be shared between the power plant and villages.

14) Necessary water amount for the power plant is 360 m^3/day[15]. The pumping test results of No.3 well by MTUWASA indicate that, it cannot be determined if the well has sufficient quantity of water, therefore, the step drawdown pumping test and interference test for the existing No.1 and No.2 wells are necessary during the B/D (Basic Design) stage.

15) Water quality of No.3 well satisfies the Tanzanian national standard. However, as the electrical conductivity (EC) is close to the upper limit of the standard, water quality test is necessary during the B/D stage.

16) If the capacity and water quality of No.3 well are identified to be insufficient during the B/D stage, an additional or alternative well shall be considered and constructed

17) The new water pipeline will be buried 1 m below the surface, within 2m inside of the edge of ROW (40m) of the upgraded collector road. The existing water pipeline will be relocated next to the new water pipeline.

< Environmental Checklist of the Associated Facilities >

18) Regarding the Access road including the collector road upgrading

    EIA report for Access Road has been prepared according to the local regulations as well as the JICA guideline. EIA report will be submitted to NEMC, and EIA certificate will be obtained. The main environmental and social impact associated with Access road project is expected during the construction stage, such air, noise, soil erosion, waste and water. Mitigation measures are proposed to mitigate the expected impact. The proposed access road is not located within the protected area and no significant impacts are expected on flora and fauna. It is expected that 165 PAPs and 41 houses would be affected by the project. RAP is prepared according to the legal requirements of Tanzania and JICA guideline to ensure that appropriate compensation will be provided to affected people.

19) Regarding the Gas Pipeline

    EIA report for Gas Pipeline has been prepared according to the local regulations as well as the JICA guideline. EIA report will be submitted to NEMC, and EIA certificate will be obtained. The main environmental and social impact associated with Gas pipeline project is expected during the construction stage, such as air, noise, soil erosion, waste and water. Mitigation

15 Water supply for residences in the power plant (60m^3/day) is included in 360m^3/day.

measures are proposed to mitigate the expected impact. The proposed pipeline route will disturb a vegetation area, and there are no protected areas within the project area. It is expected that 144 PAPs and 8 houses would be affected by the project. RAP is prepared according to the legal requirements of Tanzania and JICA guideline to ensure that appropriate compensation will be provided to affected people.

20) Regarding the Water Pipeline

EIA report for Water Pipeline has been prepared according to the local regulations as well as the JICA guideline. EIA report will be submitted to NEMC, and EIA certificate will be obtained. The main environmental and social impact associated with Water Pipeline project is expected during the construction stage, such as air, noise, soil erosion, waste and water. Mitigation measures are proposed to mitigate the expected impact. The Water Pipeline is not located within the protected area and ecologically sensitive area. It is expected that 2 PAPs would be affected by the project. RAP is prepared according to the legal requirements of Tanzania and JICA guideline to ensure that appropriate compensation will be provided to affected people.

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUNDS OF THE STUDY

The annual average nominal GDP growth rate of United Republic of Tanzania (hereinafter referred to as “Tanzania”) between 2000 and 2015 was 10.5% and is expected to be 5 ~ 10% for the next 10 years according to the IMF’s estimation. In December 2016, the Power System Master Plan 2016 Update (PSMP 2016 Update) was issued by the Ministry of Energy and Minerals (MEM), which is the current Ministry of Energy (MOE), as per the political guideline of Tanzania government. It is a power system master plan that is based on the status of economic development including gas development. In addition, “Final report on the project for formulation of power system master plan in Dar es Salaam and coast regions and review of power system master plan 2012 in the United Republic of Tanzania : review of power system master plan 2012” (hereinafter referred to as PSMP Review) was issued by JICA in March 2017. These master plans are future plans from 2016 ~ 2040 based on the government’s target. One of key targets is to achieve a generation capacity of 4,915MW by 2020 in Tanzania.

Tanzania has some independent power systems, which are not connected to the national grid. Currently these systems are being connected to the national grid, and progress has been made in rural electrification as well. The maximum power demand of the national grid was about 850MW in 2012, and it reached 1,041MW in 2016, and 1,051MW in February 2017. Total generation capacity of the national grid was 1,431MW in September 2017. The breakdown was: around 45% of hydro power, around 49% of gas-fired power, and around 6% of oil-fired power. In addition, total generation capacity of the independent grid was about 82MW. In the independent system, it was frequently necessary to carry out load shedding during the peak load because of the insufficient power supply. According to the “Tanzania five year development plan – phase II (2016/17 ~ 2020/21)”, power generation development is one of the policies with top priority, by which the generation capacity will grow to 4,915MW by 2020 and to 10,000MW by 2025. Furthermore, gas-fired power plants are the major power sources.

In this situation, Dar es Salaam, which is the economic center, accounts for about 50% of Tanzania’s electricity demand, and for about 11% of total population of Tanzania in 2016[1]. The power supply to Dar es Salaam is a critical issue.

The Mtwara Natural Gas Thermal Power Plant and Transmission Lines Construction Project (hereinafter referred to as “the Project”) will ensure power supply to Dar es Salaam region as highlighted by the PSMP 2016. The preparatory survey (hereinafter referred to as “the Study”) for the Project was carried out by JICA Study Team.

The power demand of south-east region including the Mtwara area in Tanzania is projected to be more than 300MW in the mid-to-long-term and it indicates that there is a high need to develop the power sources in this region not only to supply power to this region, but also to secure robustness of the national grid as per the PSMP 2016 Update. Furthermore, “Inter-utility memorandum of understanding for the construction of the Tanzania-Mozambique interconnector and for trade in power and telecoms” was signed between Tanzania Electric Supply Company Limited (TANESCO) and Electricidade de Mozambique (EDM) on June 27th, 2018. In this inter-utility memorandum, it is mentioned that the 400kV transmission line will be constructed from the Mtwara Gas Turbine Combined Cycle (GTCC) power plant in Tanzania to Namialo in Mozambique, in order to supply power to the south-east region of Africa. TANESCO has arranged

[1] Data of PSMP2016 Updated (P18).

the feasibility study including preparation of bid documents for the 400kV transmission project between Dar es Salaam and Somanga. The feasibility study is still under way as of September 2019.

With regard to 3-Infrastructures (road, gas pipeline, and water pipeline), they were added during the Study, as it was requested by TANESCO in October 2018. The study results are integrated into the Study report as Chapter 13.

1.2 PURPOSE OF THE STUDY

The Study is carried out to set up a new Japanese ODA project. In the Study, the necessary surveys are carried out to evaluate the Project as an ODA project in terms of objective, project cost, project implementation structure, operation/maintenance structure, and environmental/social considerations, etc.

1.3 SCOPE OF WORKS

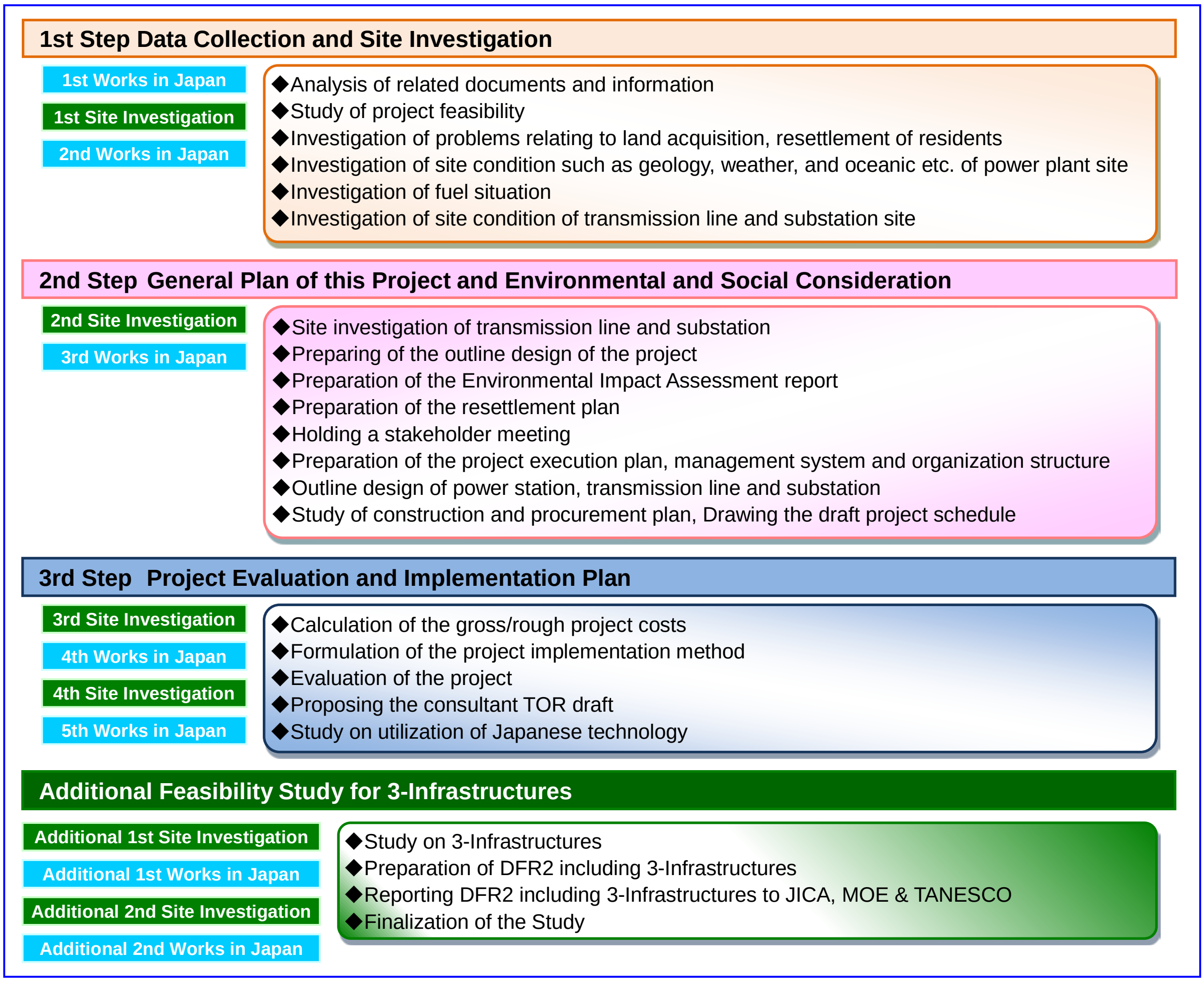
Major study items of the Study are as follows;

- Site selection for the GTCC power plant and 400kV substations
- Route survey for the 400kV transmission line
- Survey on site conditions for the power plant, substations and the transmission line
- Data collection of social/economic conditions and the power sector in Tanzania
- Power system planning and analysis
- Transportation route survey for heavy equipment
- Gas and water supply plan
- Basic design of the power plant, the transmission line and substations
- Organization structure of O&M
- Project implementation program
- Cost estimation and economic and financial analysis
- Environmental and social considerations
- Study on 3-Infrastructure (road, gas pipeline and water pipeline)

1.4 STUDY SCHEDULE

As shown in Figure 1-1, the study flow originally consists of three steps. The 1st step is data collection and site investigation. The 2nd step is preparing the general plan of the project, and environmental and social considerations. The 3rd step is project evaluation and implementation plan. JICA Study Team conducted the 1st, 2nd, and 3rd site investigations. In addition, the team conducted the 4th site investigation in July 2018 for 1 week to explain the draft final report (DFR).

During April 16 ~ April 27 2018, MOE, TANESCO and TPDC staff (totally 6 persons) visited Japan to learn about the cutting-edge technology for the GTCC power plant, high voltage T/L and the GIS, including factory tour of GT, LLC, insulator, GIS, etc.



Source: JICA Study Team

Figure 1-1 Study Flow

During the 3rd Step, the additional feasibility study for 3-Infrastrures (road, gas pipeline and water pipeline) was included, as a result of discussion between TANESCO and JICA. The additional 1st site investigation by JICA Study Team was carried out in December 2018 for around 10 days.

1.5 ORGANIZATIONAL FRAMEWORK FOR THE STUDY

TANESCO is the main counterpart of the Study. TPDC, TARURA and MTUWASA joined as counterparts after the 3-Infrastructures was added to the Study. Table 1-1 shows the updated organization of counterparts.

Table 1-1 Organization of Counterparts

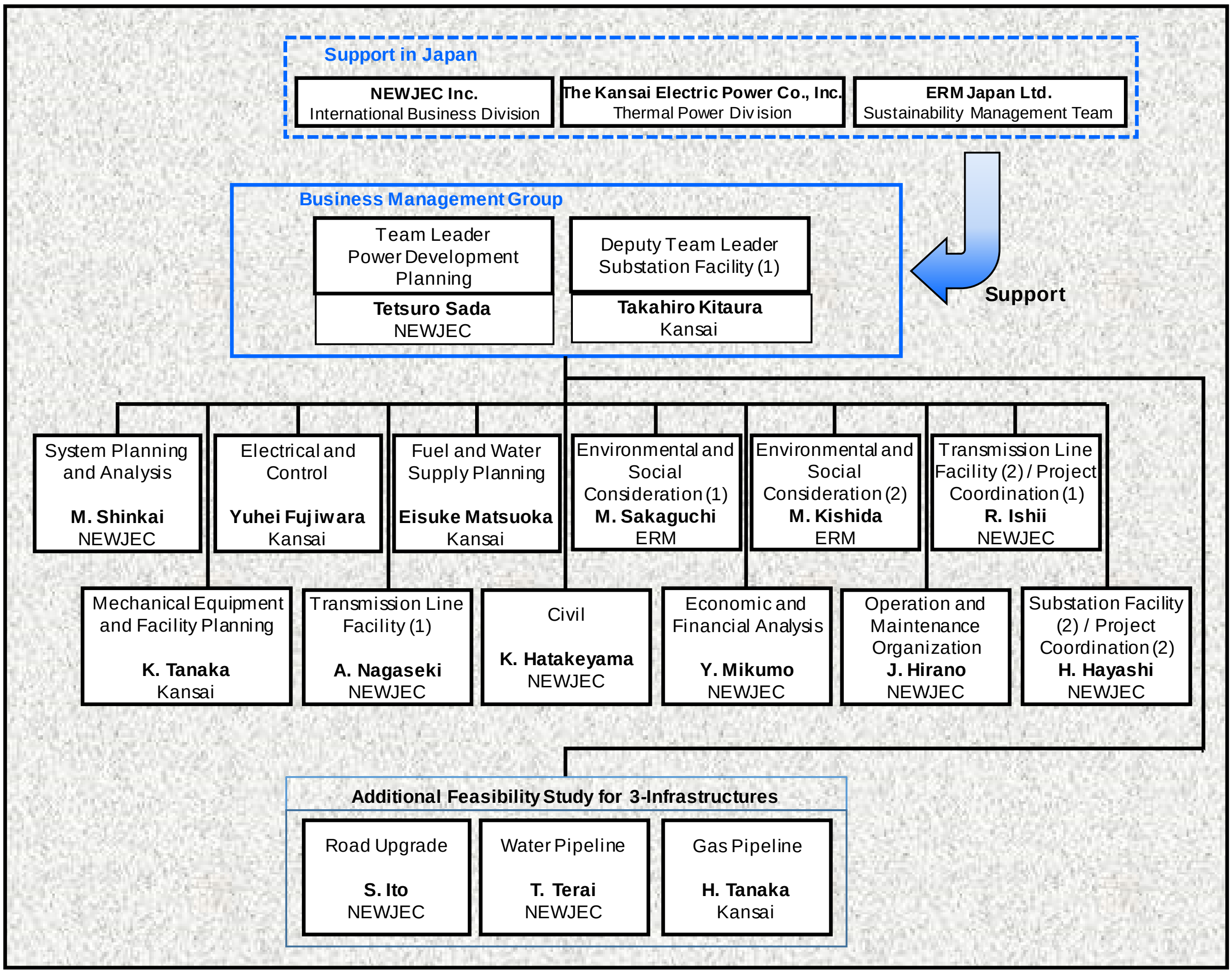
POSITION	NAME	COMPANY
Leader	Costa Rubagumya	TANESCO
Deputy Leader	Meksesius Kalinga	ditto
System Planning and Analysis	Fokas Daniel / Fortunatus Kihaka	ditto
Mechanical Equipment and Facility Planning	Abdallah Chikoyo	ditto
Fuel and Water Supply Planning	ditto	ditto
Electrical and Control	Fortunatus Kihaka	ditto
Civil	Elineema Mkumbo	ditto
Transmission Facilities	Alex Gerald	ditto
Environmental and Social Consideration	Agnes Masanja Izaria Luvanda	ditto
Economic and Financial Analysis	Marianus Mgendera	ditto
Operation and maintenance Organization	Ambakisye Mbangula	ditto
Substation Facilities	Reinhard Rweikima / Nuru Twaha	ditto
Gas Pipeline	Dora Ernest	TPDC
Road	Maulid Mwishwa	TARURA
Water Pipeline	Lukelo Wandelage	MTUWASA
Environmental Impact Assessment and Resettlement Action Plan for 3-Infrastructures	Tluway Sappa	TANESCO

Source: TANESCO

The organization of JICA Study Team is shown in Figure 1-2. Three Japanese companies have joined the Study, NEWJEC Inc., the Kansai Electric Power Co. Inc., and ERM Japan Ltd. This team comprises of totally 14: 8 consultants from NEWJEC, 4 consultants from Kansai, and 2 consultants from ERM.

The deputy team leader was changed from Mr. Okuda to Mr. Kitaura in September 2017. In addition, the mechanical equipment and facility planning was also changed from Mr. Okuda to Mr. Tanaka in September 2017.

To address the additional feasibility study for 3-Infrastructures, three (3) more consultants were added to Study Team in December 2018.



Source: JICA Study Team

Figure 1-2 Organization of the Study Team

CHAPTER 2

ELECTRIC POWER INDUSTRY AND PROPOSED POWER SYSTEM

CHAPTER 2 ELECTRIC POWER INDUSTRY AND PROPOSED POWER SYSTEM

2.1 SOCIAL ECONOMIC SITUATION IN TANZANIA

2.1.1 Population Movements

According to the Tanzania National Bureau of Statistics (NBS), the population of Tanzania in 2017 was 51.56 million, and since 2012, the rate of increase has been 2.79%/year on an average. The population by region is shown below.

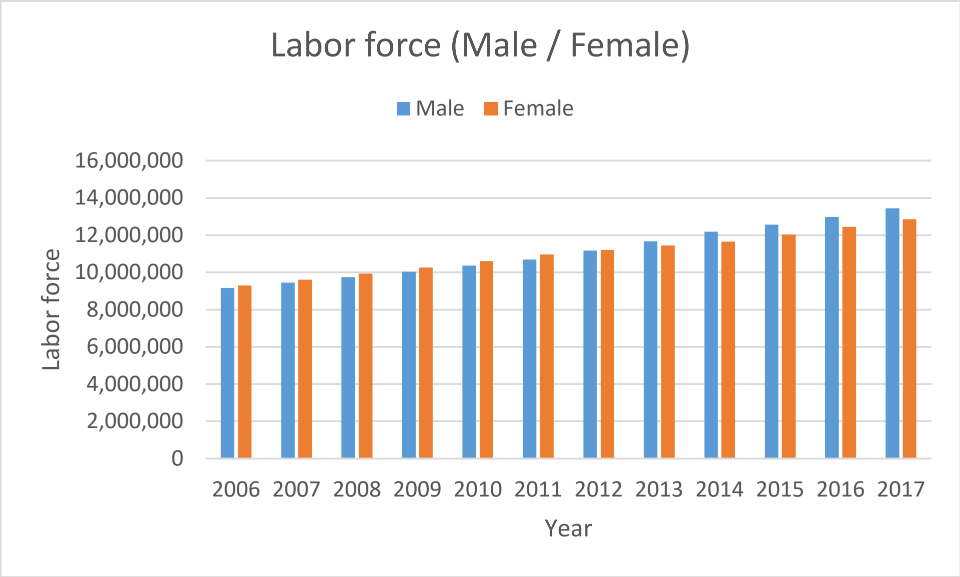
The population ratio is highest in the metropolitan area of Dar es Salaam region with 11.2%. In this region, the population growth rate is also extremely high at 5.78%/year, and the population density has been increasing even after the census.

Table 2-1 Population by Region in 2017

	Region	Population	Composition Ratio		Region	Population	Composition Ratio
1	Arusha	1,943,196	3.8	17	Njombe	730,555	1.4
2	Dar es Salaam	5,781,557	11.2	18	Kaskazini Pemba	225,952	0.4
3	Dodoma	2,312,141	4.5	19	Kusini Pemba	206,148	0.4
4	Geita	1,983,653	3.8	20	Pwani	1,224,120	2.4
5	Iringa	996,105	1.9	21	Rukwa	1,179,149	2.3
6	Kagera	2,879,231	5.6	22	Ruvuma	1,530,955	3.0
7	Katavi	663,685	1.3	23	Shinyanga	1,701,220	3.3
8	Kigoma	2,399,121	4.7	24	Simiyu	1,736,839	3.4
9	Kilimanjaro	1,790,113	3.5	25	Singida	1,539,286	3.0
10	Lindi	905,947	1.8	26	Songwe	1,173,667	2.3
11	Manyara	1,670,191	3.2	27	Tabora	2,652,514	5.1
12	Mara	1,972,173	3.8	28	Tanga	2,286,528	4.4
13	Mbeya	1,929,359	3.7	29	Zanzibar North	219,980	0.4
14	Morogoro	2,495,462	4.8	30	Zanzibar South	127,744	0.2
15	Mtwara	1,351,038	2.6	31	Mkoa wa Unguja Mjini Magharibi	732,408	1.4
16	Mwanza	3,217,328	6.2	-	**Total**	**51,557,363**	

Source: NBS – Tanzania National Bureau of Statistic

The labor force population as of 2017 was estimated to be 26.3 million, accounting for 51% of the total population. The labor force by gender is shown in the figure below - the value for both male and female are at high levels.



Source: World Development Indicators (World Bank)

Figure 2-1 Estimated Labor Force Population

According to the composition ratio of number of employed persons by occupation, in Dar es Salaam, it can be noted that the following fields are 3 to 4 times the national average: Legislators and administrators, professionals, office clerks, service workers and shop sales workers, plant and machine operators and assemblers. The percentage of employed persons in the above fields is more for Dar es Salaam even in comparison with the values of “other urban” and “rural areas”.

On the other hand, the composition ratio of the number of workers in agricultural and fishery is predominantly higher in the case of “other urban” and “rural areas".

Manufacturing and service industries are concentrated in Dar es Salaam, and it is confirmed by the characteristics of the working population mentioned above.

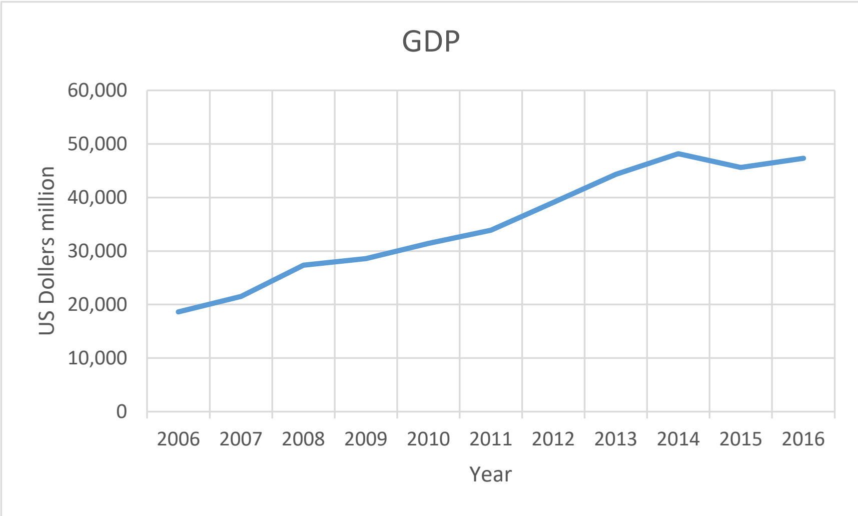
Table 2-2 Percentage of Currently Employed Persons Aged 15+ Years by Sex, Occupation and Area, Tanzania Mainland, 2014

	Occupation	Dar es Salaam	Other Urban	Rural	Total
Male	Legislators and administrators	2.0	1.0	0.4	0.7
	Professionals	4.3	2.3	0.5	1.3
	Technician and associate professionals	3.8	4.3	1.0	2.1
	Office clerks	2.5	0.8	0.1	0.5
	Service workers and shop sales workers	25.7	18.2	3.3	9.5
	Agricultural and fishery workers	3.6	34.2	84.6	63.2
	Craft and related workers	24.5	16.6	4.1	9.4
	Plant and machine operators and assemblers	16.7	8.8	1.8	5.2
	Elementary occupations	16.9	13.9	4.3	8.1
	Sub Total	**100.0**	**100.0**	**100.0**	**100.0**
	Number	**1,109,525**	**2,531,630**	**6,502,245**	**10,143,400**
Female	Legislators and administrators	1.2	0.4	0.0	0.2
	Professionals	2.5	0.7	0.0	0.4
	Technician and associate professionals	5.1	3.6	1.3	2.3
	Office clerks	4.1	1.9	0.0	0.9
	Service workers and shop sales workers	28.0	21.5	3.3	10.1
	Agricultural and fishery workers	4.3	41.5	88.8	69.4
	Craft and related workers	5.4	5.9	1.2	2.8
	Plant and machine operators and assemblers	0.8	0.4	0.0	0.2
	Elementary occupations	48.7	24.1	5.1	13.7
	Sub Total	**100.0**	**100.0**	**100.0**	**100.0**
	Number	**817,842**	**2,599,792**	**6,469,105**	**9,886,739**
Both Sexes	Legislators and administrators	1.7	0.7	0.2	0.5
	Professionals	3.5	1.5	0.3	0.9
	Technician and associate professionals	4.3	4.0	1.2	2.2
	Office clerks	3.2	1.3	0.0	0.7
	Service workers and shop sales workers	26.7	19.9	3.3	9.8
	Agricultural and fishery workers	3.9	37.9	86.7	66.3
	Craft and related workers	16.3	11.2	2.6	6.1
	Plant and machine operators and assemblers	10.0	4.5	0.9	2.7
	Elementary occupations	30.4	19.1	4.7	10.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Total Number		**1,927,368**	**5,131,422**	**12,971,349**	**20,030,139**

Source: Integrated Labor Force Survey Analytical Report 2014 (NBS)

2.1.2 Economy

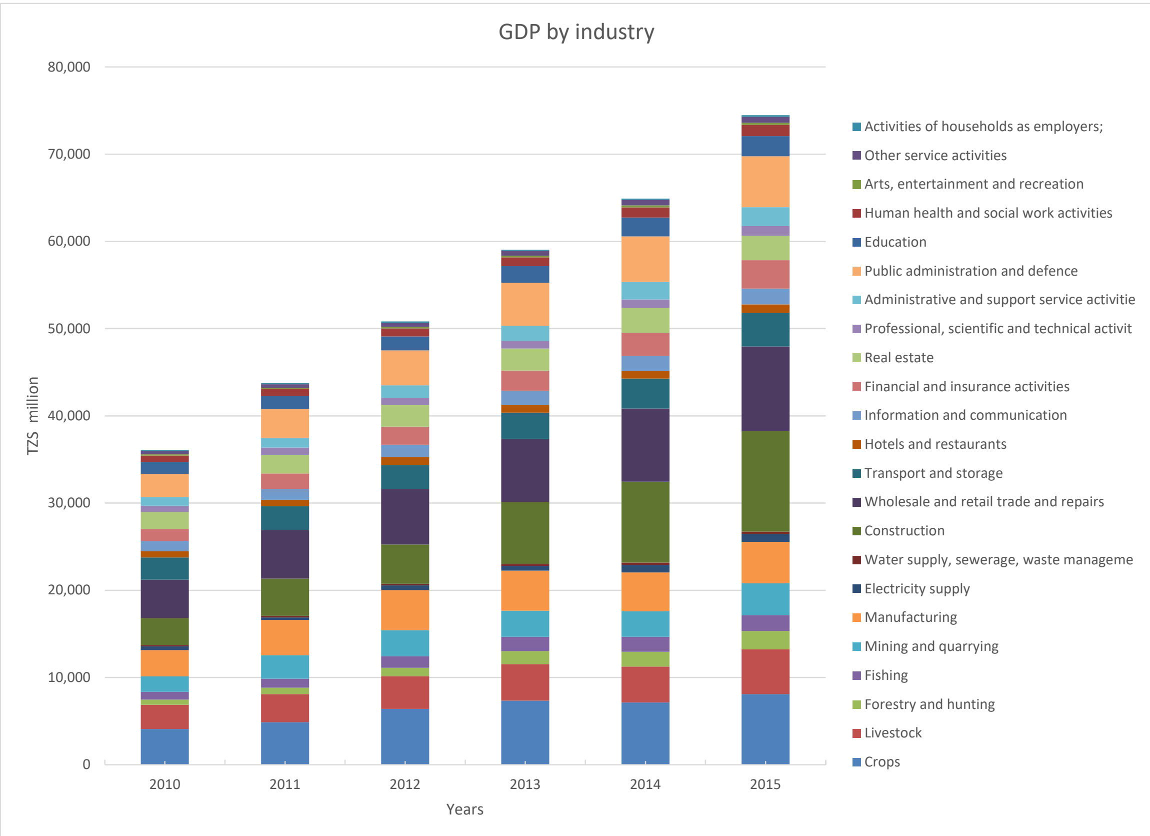
Gross Domestic Product (GDP) in 2013 was US$ 47,340 million, about US$ 918 per capita. The trend of production in the recent years is shown in the figure below (Price real value in 2000, US$).



Source: World Development Indicators (World Bank)

Figure 2-2 Trend of GDP

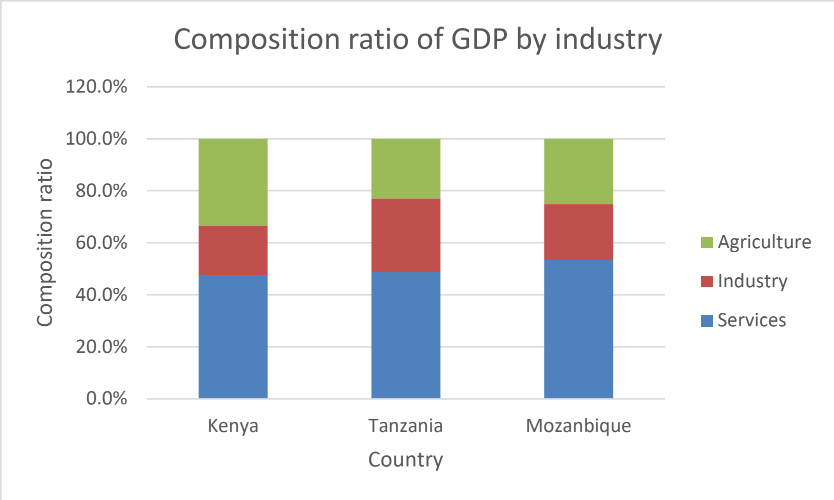
The trend of production by industry in the recent years is shown in the figure below (Price real value in 2000, US$).



Source : Bank of Tanzania (Dec. 2016)

Figure 2-3 Trend of GDP by Industry

In addition, the composition ratio of GDP by industry in Tanzania and the neighboring countries, for the year 2015 is shown below. Tanzania has a slightly higher composition ratio of industries than its neighboring countries.



Source: World Development Indicators (World Bank)

Figure 2-4 Composition Ratio of GDP by Industry

According to the income per capita by region, Dar es Salaam's value is the highest, and the values of Mtwara and Lindi are about 60% of Dar es Salaam's value. This result also shows that many high-value-adding industries are present in Dar es Salaam.

In 2009, Ruvuma's Income was half of Dar es Salaam's Income, which increased to 70% in 2014. Ruvuma has many jewelry and gold production sites, and recently uranium vein was found.

Table 2-3 Income per Capita by Region

Region	Income per Capita	Year					
		2009	2010	2011	2012	2013	2014
Dar es Salaam	1000TSh/Person	2,133	2,363	2,757	2,384	2,647	2,829
Mtwara		688	951	1,010	1,279	1,390	1,543
Lindi		768	914	1,061	1,341	1,504	1,677
Ruvuma		1,103	1,176	1,447	1,701	1,914	2,082

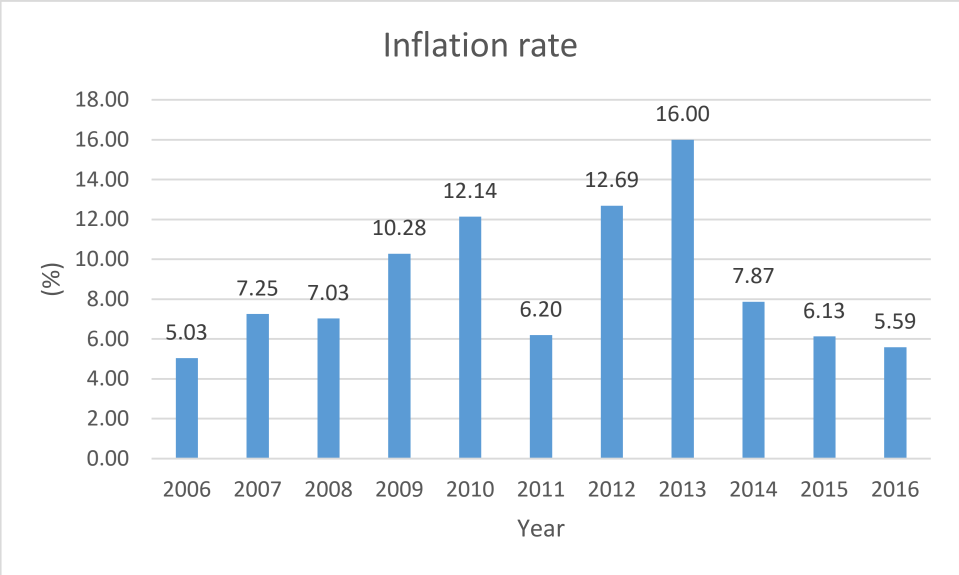
Source: Integrated Labor Force Survey Analytical Report 2014 (NBS), JICA Study Team

The rate of change of Consumer Price Index (CPI) for each year is shown below.

Although the rate declined temporarily in 2011, it had showed a rising trend from 2006 to 2013.

Especially in 2012 and 2013, it showed a high inflation due to the following.

- A slump in the agriculture sector caused by unseasonable weather.
- Rise in fuel prices due to high crude oil prices
- Rise in import prices caused by depreciation of exchange rate.



Source: World Development Indicators (World Bank)

Figure 2-5 Inflation Rate

In July 2010, the Bank of Tanzania set a long-term inflation target of less than 5%.

Prices in the East African Community (EAC) are in an environment, where it is hard to be affected by worldwide prices, and Tanzania is particularly capable of suppressing food prices.

Generally, the domestic food prices depend on global price such as food price or crude oil price, but food prices are suppressed in EAC countries. EAC countries export 60% of domestically produced grain to areas within EAC, and this situation seems to contribute to the suppression of food prices.

As a result, the inflation rate of Tanzania has remained stable in the recent years.

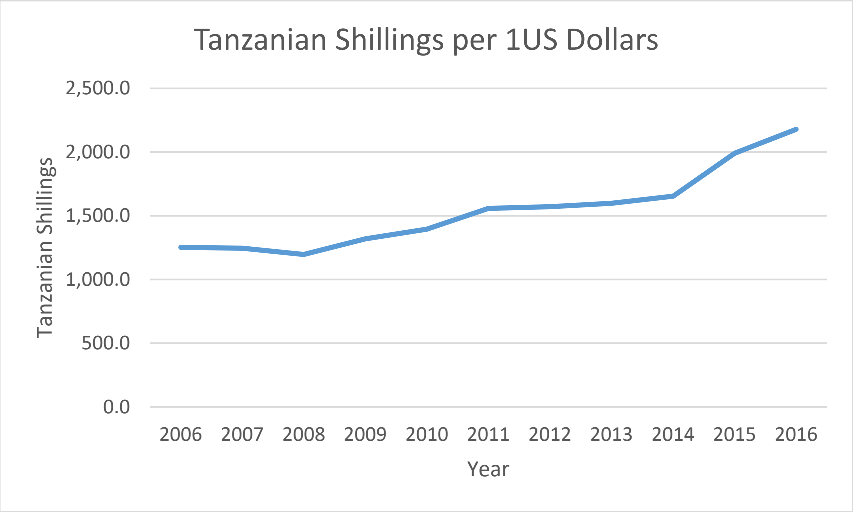
Table 2-4 Inflation Rate of Tanzania and Neighboring Countries

Country	Dec. 2017	Jan. 2018	Feb. 2018	Mar. 2018
Tanzania	4.0	4.0	4.1	3.9
Kenya	4.5	4.8	4.5	4.2
Uganda	3.3	3.0	2.1	2.0

Source: NBS – Tanzania National Bureau of Statistic

Actually, the government of Tanzania has been controlling food prices, in addition to controlling production costs through stable supply of electricity from around 2012. In addition, as a monetary tightening measure, the lending rate of the commercial banks and the deposit reserve ratio were raised.

The Bank of Tanzania's average exchange rate during 2016 against the US dollar is 2,177.1 TSh. (per 1 US$), and in the recent years, the exchange rate has been rising. TSh. is low against the principal currencies. A weak TSh, leads to an increase in import cost for Tanzania, because Tanzania is importing many petroleum products and materials etc.



Source: World Development Indicators (World Bank)

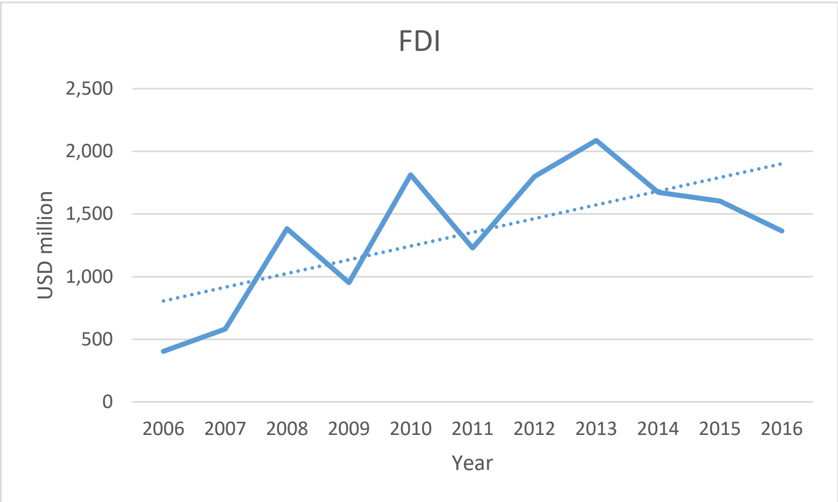
Figure 2-6 Exchange Rate Tanzanian Shilling vs US Dollar

The trend of investment by foreign countries in the recent years is shown below.

It temporarily declined in 2009 and 2011, and although there are some variations, it shows a rising trend generally. However, recently it decreased a little.

Although, Foreign Direct Investment (FDI) was at its peak in 2013, it has started to decline after that. This trend seems to be influenced by the deterioration of business environment in Tanzania caused by exemption problems etc. In addition to this, according to "WORLD INVESTMENT REPORT 2017" (UNCTAD), FDI inflows have declined in African countries that were gas and oil producers such as Equatorial Guinea or The Democratic Republic of the Congo including Tanzania, due to lower crude oil price.

This has resulted in an investment refrain, leading to a decline in FDI. Tanzania, which is a country rich in natural resources, also seems to be largely affected because of the above reason.



Source: World Development Indicators (World Bank)

Figure 2-7 Foreign Direct Investment in Tanzania

According to the latest information on direct investment (Stock) by region (published in 2008), Dar es Salaam has the highest investment (60.0% of composition). And the second highest is Shinyanga (12.3%), the third highest is Mwanza (9.7%). The investment amount of these three regions accounts for 82% of the total investment.

Dar es Salaam is a substantial center in terms of economy. Infrastructure such as Dar es Salaam port, which is a logistics base, is being improved at a higher rate when compared to other areas. Therefore, the investment is concentrated in this area.

The investment in Shinyanga and Mwanza is large because of the investment in the mining sectors such as gold and diamonds, and the investment in fishing. The fishery processing facility in Lake Victoria is underway.

Table 2-5 Distribution of FDI Stock by Region (US$ Million), 2005 – 2008

Region	2005	% for 2005	2006	% for 2006	2007	% for 2007	2008	% for 2008
Dar es Salaam	2,243.8	50.6	2,477.0	51.3	3,396.1	57.1	3,618.7	58.0
Shinyanga	661.2	14.9	752.5	15.6	775.2	13.0	765.5	12.3
Mwanza	561.3	12.7	636.7	13.2	620.7	10.4	608.0	9.7
Arusha	268.3	6.0	266.0	5.5	332.6	5.6	355.4	5.7
Morogoro	147.1	3.3	162.7	3.4	186.6	3.1	189.1	3.0
North Unguja	92.1	2.1	89.8	1.9	119.1	2.0	132.9	2.1
Tanga	53.0	1.2	66.1	1.4	6.4	1.6	113.2	1.8
Iringa	46.1	1.0	81.9	1.7	101.5	1.7	106.7	1.7
Urban West	130.2	2.9	85.6	1.8	90.2	1.5	105.0	1.7
Kagera	56.8	1.3	57.8	1.2	81.6	1.4	81.6	1.3
Kilimanjaro	67.5	1.5	67.4	1.4	69.8	1.2	63.4	1.0
South Unguja	26.4	0.6	22.8	0.5	24.3	0.4	26.7	0.4
Mbeya	24.7	0.6	11.9	0.3	14.1	0.2	25.7	0.4
Manyara	13.9	0.3	15.6	0.3	17.5	0.3	19.5	0.3
Mara	31.2	0.7	21.7	0.5	13.8	0.2	16.9	0.3
Pwani	9.7	0.2	5.6	0.1	4.5	0.1	4.6	0.1
Tabora	2.5	0.1	2.3	0.1	2.6	0.0	2.4	0.0
South Pemba	1.3	0.0	1.9	0.0	1.7	0.0	2.2	0.0
North Pemba	1.1	0.0	1.2	0.0	1.4	0.0	2.1	0.0
Ruvuma	0.4	0.0	0.4	0.0	0.4	0.0	0.3	0.0
Singida	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Mtwara	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**4,438.7**	**100.0**	**4,827.1**	**100.0**	**5,950.0**	**100.0**	**6,239.9**	**100.0**

Source: Tanzania Investment Report (NBS)

According to the government of Mtwara region website (As of December 2017), Mtwara currently has foreign investment for the development of Mtwara port and Dangote cement plant. In addition, the Mtwara region has abundant natural resources, including not only traditional mining but also the new high economic growth fields of oil and gas, and the investment opportunities are beginning to increase.

2.2 POWER GRID

2.2.1 National Grid

TANESCO is the transmission line owner and operator in Tanzania. The highest voltage of the power grid of Tanzania was 220kV in April 2018. Iringa-Dodoma-Singida-Shinyanga Back Bone Transmission Investment Project (BTIP) was completed in October 2016 with financing from the WB, JICA, African Development Bank (AfDB), Korea EDCF (Economic Development Cooperation Fund) and the European Investment Bank (EIB). These transmission lines are designed for 400kV operation, but it is operated at 220kV at present. The preparation for 400kV operation is under progress. Construction works of transmission lines and substations of 220kV system, which are under the phase 1 of the BTIP project, are completed. The project is now in phase 2, which is the outline design stage for the construction of 400kV substations, system upgrading from 220kV to 400kV for the ZTK (Zambia, Tanzania, and Kenya) interconnection project.

The voltage class in the current system is 220kV, 132kV, and 66kV for the transmission line, and the distribution line is operated at 33kV and 11kV. In Dar es Salaam, there are three new substations, namely, Muhimbili, Jangwani, and Mwananyamala. The construction of these new substations, the reinforcement of the existing Ilala substation and the expansion of the existing Msasani substation was supported by JICA. JICA also supported the reinforcement of the existing 132kV transmission line from Ubungo substation to Ilala substation, and the construction of 33kV distribution lines- from Makumbusho substation to Msasani substation, from New City Center substation to Muhimbili substation, from Tegeta substation to Jangwani Beach substation, and from Makumbusho substation to Mwananyamala substation. Moreover, the renewal of two substations- Lawati and YMCA, reinforcement of two substations- Trade School and Kiyungi, and construction of two new substations- KCMC (Kilimanjaro Christian Medical Center) and Makuyuni in Kilimanjaro region were also supported by JICA.

The length of transmission line for each voltage including the 670km backbone line is as below.

Table 2-6 Length of Transmission Line (End of May 2017)

Voltage	Length (km)
400kV	670
220kV	3,610
132kV	1,662
66kV	543

Source: TANESCO website

At the end of May 2017, the number of high voltage grid substations was 50 and there were 5 off grid substations. Total capacity of substations was 3,883.4MVA.

Tanzania is pushing forward several transmission projects to build their trunk line.

The national grid map as of April 2018 is as follows;

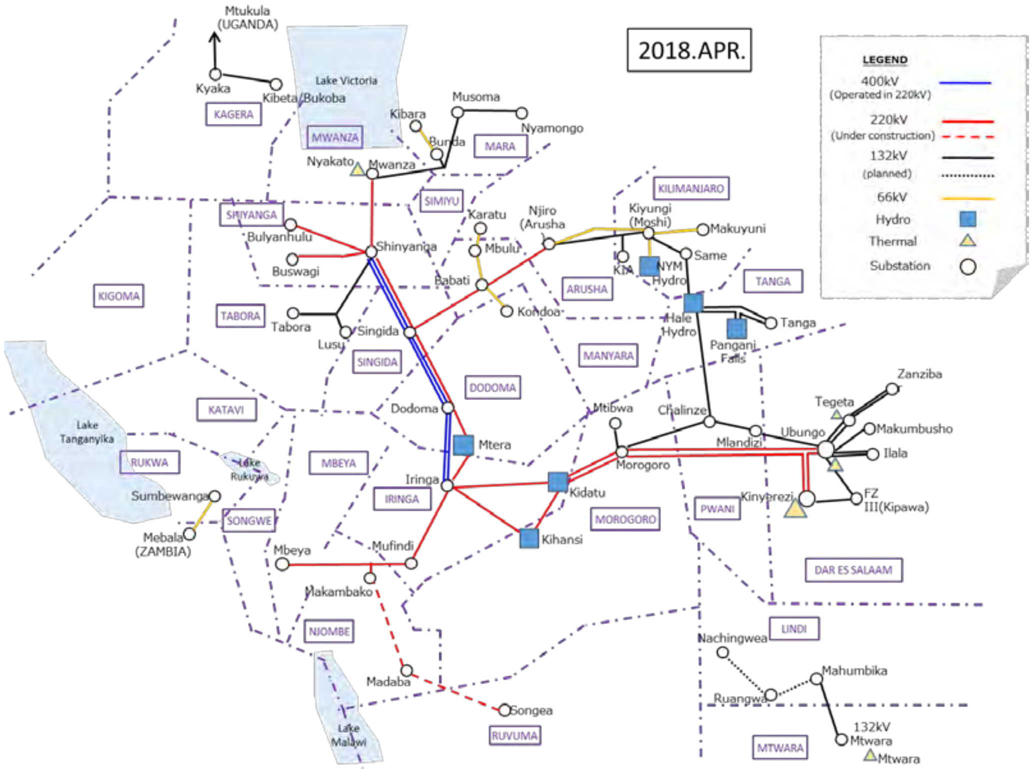


Figure 2-8 National Grid Map of Tanzania in April 2018

Source: Made by JICA Study Team from JICA report "the Project for Formulation of Power System Master Plan in Dar es Salaam and Coast Regions and Review of Power System Master Plan 2012" (March 2017) and updated information by TANESCO

The transmission loss in the recent years is shown in Table 2-7.

Table 2-7 Transmission Loss in Tanzania

Loss	2012	2013	2014	2015	2016	2017*
Transmission Loss (%)	6.12	6.2	6.13	6.21	6.15	5.92

Source: TANESCO website. The period of 2017 is from Jan. to June.

The total transmission and distribution loss of neighboring countries in 2014 are shown in Table 2-8.

Table 2-8 Transmission and Distribution Loss of Neighboring Countries in 2014

Loss	Tanzania	Kenya	Zambia	Zimbabwe	Mozambique	(Average)
Transmission and Distribution Loss (%)	17.7	17.6	15.0	16.4	14.7	(16.3)

Source: World Bank website, Open Data, Electric power transmission and distribution losses (% of output)

According to the information from TANESCO, the loss was 17.0% (5.99% of transmission loss and 11.12% of distribution loss) in 2018.

2.2.2 Transmission Line and Substations related to Mtwara System

In the Mtwara system, lately, the construction of two 132kV substations and a 132kV transmission line has been completed, and they have been in operation since August 2017. One of substations is 132kV Mtwara substation in Mtwara and the other is 132kV Mahumbika substation in Lindi, and the 132kV transmission line connects both the substations. These facilities were constructed by TANESCO in order to supply power to these area.

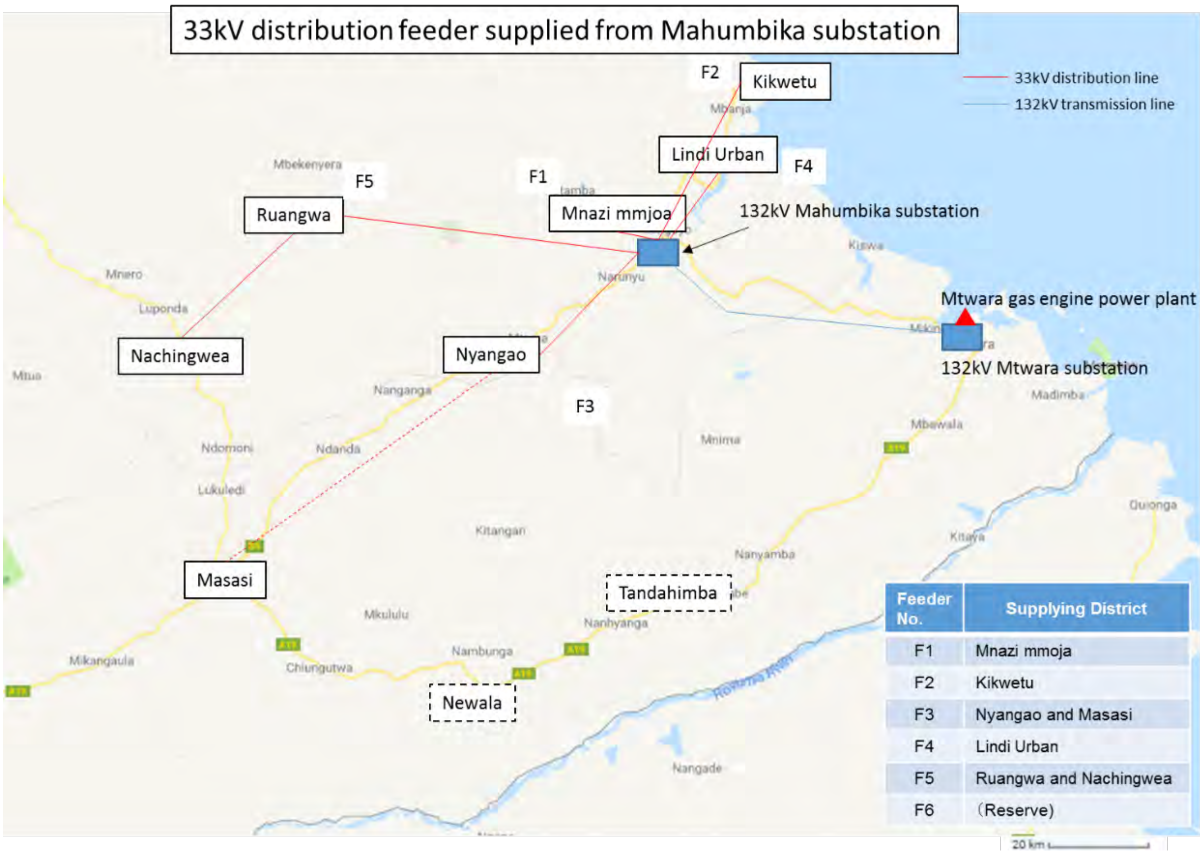
The 132kV Mtwara substation is located in Mtwara downtown area and it has a 132/33kV, 20MVA transformer and five 33kV distribution feeders. Adjacent to this substation, a 33kV substation connected to a gas engine power plant is present.

The 132kV Mahumbika substation is located near Mingoyo in the southern part of Lindi and it has five 33kV distribution feeders and one reserve feeder for future expansion.

As for the 132kV transmission line, the line length is 80km, and the conductor is a single ACSR (Aluminum Conductors Steel Reinforced). The layout of conductors is horizontal-parallel configuration (see Figure 2-9), therefore it is difficult to upgrade to two or more circuit lines on the existing line. Most part of the line is placed along the existing gas pipeline.

Figure 2-9 The 132kV Transmission Line between Mtwara and Mahumbika

The 33kV distribution line from Mahumbika substation feed electricity to Lindi Urban, Lindi Rural (Kikwetu and Mnazi mmjoa), Nyangao, and Ruangwa.



Source: Made by JICA Study Team based on information from TANESCO

Figure 2-10 33kV Feeders from the 132kV Mahumbika Substation

The distribution line to Nyangao will be extended to Masasi in the near future, and the line to Ruangwa has already been extended to Nachingwea. The remaining reserve feeders will be used for Newala and Tandahimba in the future.

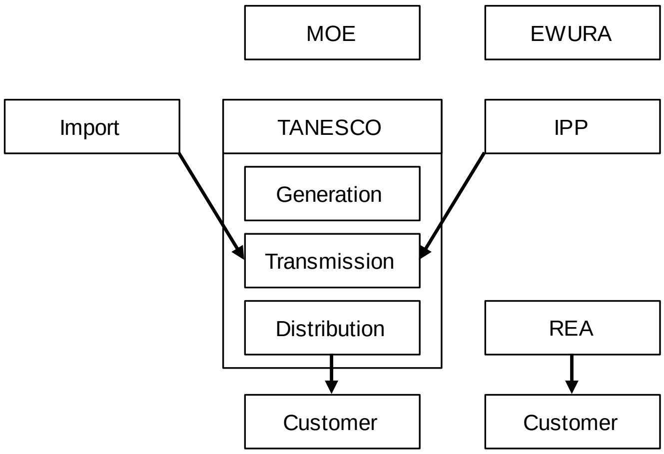
The peak demand was around 7.4MW in Lindi and 10MW in Mtwara, as of November 2017.

Although the peak demand of these areas was deemed to be around 17MW, the existing gas engine generators (2MW×11=22MW) could not generate power at their full capacity due to some malfunction. Therefore load shedding was constantly carried out, in order to deal with the shortage in supply capacity. Considering the growing power demand in these areas, the expansion of power generation has to be carried out immediately.

2.3 CURRENT STATUS OF ELECTRIC POWER SECTOR

2.3.1 Electric Power Sector

The structure of the power sector in Tanzania is shown in Figure 2-11. TANESCO is a major electricity supplier, controlled by MOE (Ministry of Energy) and EWURA (Energy and Water Utility Regulatory Authority). Electricity is also supplied by IPP and international import via the transmission lines of TANESCO. REA (Rural Energy Agency) an agency that plays a major role in rural electrification. The REA is explained in detail in Section 2.4.2.



Source: JEPIC (Japan Electric Power Information Center)

Figure 2-11 Structure of Power Sector in Tanzania

Tanzania issued the development plans, aimed at transitioning from the conventional agriculture to industrial-based economic development. These plans are called the Tanzania Development Vision 2025 and the Tanzanian Five Year Development Plan. Infrastructure development is the target of these plans. National Energy Policy 2015, issued in December 2015, defines several targets such as efficient use of energy resources, strengthening of supply reliability and enhancement of transmission and distribution network, therefore, the promotion of renewable energy and rural electrification are important targets for the government in the electrical sector.

The government of Tanzania developed the PSMP (Power System Master Plan) in 2007, and the PSMP was updated in 2009 and 2012 as well. The latest update was done in December 2016 as PSMP 2016 Update, taking into consideration the efficiency and possibility of developing hydro power, thermal power, and renewable power generation from the available national energy resources. PSMP 2016 explains in detail the power development plan, with the target of achieving a generation capacity of 4,915MW by 2020. However the total generation capacity was 1,517MW as of May 2018. It seems that the implementation of power generation development has been delayed, thus making it difficult to achieve the target. In PSMP 2016 Update, the demand forecast for peak power in 2016, 2017, 2018, 2019 and 2020 are mentioned as 1,250MW, 1,450MW, 1,680MW, 1930MW and 2,190MW respectively. Actual peak demand in 2016 was 1,041MW, and it was1,051MW in 2017. However the total demand will increase due to several factors such as economic development, progress of the rural electrification, and increase of export by cross-border interconnections.

2.3.2 Power Development Plan

The power development plan in PSMP 2016 Update is as follows;

Table 2-9(1) Optimal Generation Expansion Plan (PSMP 2016 Update)

	Status	Name of plant	Owner	Year of operation	Type	Installed Capacity(MW)
Thermal	Existing Thermal	Ubungo 1	TANESCO	2007	GasEngine	102
		Tegeta	TANESCO	2009	GasEngine	45
		Ubungo 2	TANESCO	2012	GT	105
		Zuzu Diesel	TANESCO	1980	DG	7
		Songas 1	IPP	2004	GT	42
		Songas 2	IPP	2005	GT	120
		Songas 3	IPP	2006	GT	40
		Tegeta IPTL	IPP	2002	DG	103
		Symbion Ubungo	IPP	2011	GasEngine	112
		Nyakato (Mwanza)	TANESCO	2013	DG	63
		Mtwara	TANESCO	2007/10	GT	18
		Kinyerezi I	TANESCO	2015	Gas-GT	150
	On going	Kinyerezi I Extension	TANESCO	2017	Gas-GT	185
		Kinyerezi II	TANESCO	2017	Gas-C/C	240
	Variable Thermal Candidates	Somanga Fungu (Kilwa E)	IPP	2018	Gas-GT	210
		Somanga Fungu (Kilwa E)	IPP	2019	ST add-on	110
		Kinyerezi III(Ph1) 1-3	PPP	2018	Gas-GT	300
		Kinyerezi III(Ph2) 1-2	PPP	2018	Gas-C/C	300
		Kinyerezi IV 1-2	PPP	2020	Gas-C/C	330
		Mtwara (TANESCO)	TANESCO	2019	Gas-C/C	300
		Somanga (PPP)	PPP	2022	Gas-C/C	300
		Somanga (TANESCO)	TANESCO	2020	Gas-C/C	240
		Bagamoyo(Zinga)	IPP	2027	Gas-C/C	200
		Future CGT1(1-3)		(2036)	Gas-CGT1	110 *
		Future CGT3(1-10)		(2030)	Gas-CGT3	470 *
		Mchuchuma-1		(2018)	SBCL	150 *
		Ngaka 1-2+3		(2023)	SBCL	200 *
		Ngaka (Exp)1-7		(2034)	ASUB	300 *
		Kiwira 1-2		(2020)	SBCL	200 *
		Kiwira (Exp)1-2		(2028)	ASUB	300 *
		Mchuchuma(Exp)1-6		(2026)	ASUB	300 *
		Rukwa 1+Exp		(2024)	ASUB	300 *
Renewable		**Geothermal**	TGDC	(2025)	Geo	50
	Renewable	Singida Wind		(2017)	Wind	50
		Singida Wind		(2018)	Wind	75
		Njombe Wind		(2019)	Wind	100
		Dodoma solar		(2019)	Solar	50
		Singida Wind		(2020)	Wind	75
		Singida Wind		(2020)	Wind	100
		Shinyanga/Simiyu Solar		(2020)	Solar	150
		Singida Wind		(2021)	Wind	50

Note: * means installed capacity per unit

Source: PSMP 2016 Update

Table 2-9 (2) Optimal Generation Expansion Plan (PSMP 2016 Update) (Cont.)

	Status	Name of plant	Owner	Year of operation	Type	Installed Capacity(MW)
Hydro	Existing hydro	Hale	TANESCO	1967	Dam	21
		Nyumba Ya Mungu	TANESCO	1968	Dam	8
		Kidatu	TANESCO	1975	Dam	204
		Mtera	TANESCO	1988	Dam	80
		Uwemba	TANESCO	1991	Dam	0.843
		New Pangani Falls	TANESCO	1995	Dam	68
		Kihansi	TANESCO	2000	Dam	180
		Mwenga SPP	SPP	2012	Run of river	4
	Planned hydro	Rusumo	TANESCO	2019	Dam	27
		Lower Kihansi Extension	TANESCO	2019	Dam	120
		EA Power SPP	SPP	2019	Run of river	10
		Darakuta SPP	SPP	2015	Run of river	0.24
		Mapembasi SPP	SPP	2019	Run of river	10
	Variable Hydro Candidates	Malagarasi Stage-III	TANESCO	2024	Dam	44.7
		Mpanga		2031	Dam	160
		Iringa-Nginayo		2026	Dam	52
		Iringa-Ibosa		2026	Dam	36
		Mnyera Ruaha		2028	Dam	60.3
		Mnyera-Pumbwe		2030	Dam	122.9
		Mnyera-Kwanini		2029	Dam	143.9
		Mnyera-Kisingo		2031	Dam	119.8
		Mnyera-Taveta		2030	Dam	83.9
		Mnyera-Mnyera		2029	Dam	137.4
		Songwe Manolo		2028	Dam	88.1
		Kakono		2027	Dam	87
		Songwe Sofre		2034	Dam	79.5
		Masigira		2032	Dam	118
		Ruhudji		2032	Dam	358
		Rumakali	TANESCO	2033	Dam	222
		Kikonge		2034	Dam	300
		Stieglers Gorge Ph-1		2035	Dam	1048
		Stieglers Gorge Ph-2		2037	Dam	1048
		Upper Kihansi		2034	Dam	47

Source: PSMP 2016 Update

These development plans have been proceeded to the construction stage, after the several procedures for each project such as conducting feasibility study, conclusion of the power purchase agreement, approval of environment and social impact assessment, and securing funds.

Table 2-10 lists the status of all power generation projects. The projects which are considered in the system study have been marked in the last column of the table. The system model to be studied in Section 2.7, is designed as simple as possible for the purpose of calculation. However, related elements such as adjacent generators and generators connected to the adjacent 400kV grid have to be considered, in order to confirm the behavior of these generators. These generators are close to the Mtwara system electrically, so their behavior may affect the stability of the Mtwara power system.

Table 2-10(1) Status of Power Generation Projects

Type	Project	Installed capacity (MW)	Expected Year	Status	Note	Considered in reliability study
Gas	Kinyerezi I	150	2016	-	Under operation	○
	Kinyerezi I Expansion	185	2018	A	Under Construction	○
	Kinyerezi II	240	2018	-	Under Operation	○
	Somanga Fungu 1	210	2020	C	To be concluded Implementation Agreement and Financial Close	○
	Somanga Fungu 2	110	2020	C		○
	Somanga(PPP)	300	2020	C’	World Bank dispatched a transaction advisor	○
	Somanga(TANESCO)	330	2020	D	FS on progress FS for Transmission line is now under review for upgrade	○
	Kinyerezi III Phase-1	300	2021	C	Implementation modality from PPP to EPC with financing has delayed the project	○
	Kinyerezi III Phase-2	300	2021	C		○
	Kinyerezi IV	330	2021	C	Implementation modality from PPP to EPC with financing has delayed the project	○
	Mtwara (TANESCO)	300 class	2022	D	The study of this Project	○
	Mkuranga	300	2022	F	Previous MoU is expired	○
	Bagamoyo (Zinga)	225	2027	C’	Kamal Group	–
	Future CGT1	110 x 3	2030	F	Considered in the study of this Project	○
	Future CGT3	470 x 15	2035	F	Considered in the study of this Project	○
Coal	Mbeya	300	2020	B	MoU as precursor PPA signed	–
	Kiwira	200	2025	C	Funded by STAMICO	–
	Mchuchuma	600	2025	E	Tanzania China International Resources Ltd.	–
	Ngaka	200 x 3	2030	F	Considered in the study of this Project	○
	Ngaka Expansion	300 x 5	2035	F		○
Hydro	Stiegler’s Gorge Ph-1	262 x 4	2020	A[1]	EIA has been submitted and in the final stage of approval Under processing of contracting contractor	○
	Stiegler’s Gorge Ph-2	262 x 4	2021			○
	Rusumo Falls	27	2020	A	Joint development project with 3 governments of Tanzania, Rwanda and Burundi WB committed financing for the power plant AfDB committed financing for the transmission line Tanzania will take 27MW as 35% of total	–

Source: JICA Study Team. Based on information from TANESCO website, a brief report for the meeting between MOE and Energy development partner group, the presentation, “Overview of the energy sector in Tanzania” by MOE January 2018, etc.

Status:
- A : Under construction
- B : Preparing for concluding with contractor, FS completed, EIA approved, Financing closed, Bidding commenced
- C : FS completed, EIA approved
- C’ : FS completed, EIA not yet approved
- D : Under FS
- E : FS completed, but to be updated
- F : Other (Pre-FS included)

[1] Construction works such as road and bridge have started. Financing seems to be partially closed.

Table 2-10 (2) Status of Power Generation Projects (Cont.)

Type	Project		Installed capacity (MW)	Expected Year	Status	Note	Considered in reliability study
Hydro	Kakono		87	2022	B	AfDB has booked in their portfolio to co-finance with AFD	–
	Ruhudji		358	2023	C’	Procurement of consultant to update FS is in progress	–
	Malagarasi stage III		45	2023	C	Procurement of consultant for updating FS, detailed design and preparation of bidding document is in progress. Procurement of transaction advisor is also in progress.	–
	Rumakali		222	2025	C’	Procurement of consultant to update FS is in progress	–
	Masigira		118	2025	C’	Joint project with Chinese companies.	–
	Songwe	Manolo (Lower)	178	2028	C	Two governments of Tanzania and Malawi will recruit participants including development partners and investors	–
		Sofre (Middle)	159	2034	C’		–
		Bipugu (Upper)	29	-	C’		–
	Mpanga		160	2031	C	Joint development project with RUBADA and Sinohydro Corporation Ltd. Of China	–
	Masigira		118	2032	C’	Joint development project with Tanzania and Chinese private companies	–
	Lower Kihansi Expansion		120	2019	F	Government will secure finance	–
	Upper Kihansi		47	2034	F		–
	Kikonge		300	2034	F	Negotiation with UK AID through CRIDF and African water Facility to perform s joint feasibility study	–
	Iringa	Ibosa	36	2026	F	Joint development project with RUBADA and K-water of South Korea	–
		Nginayo	52	2026			–
	Mnyera	Ruaha	60	2028	F	Joint development project with RUBADA and Queiroz Galvao of Brazil	–
		Mnyera	137	2029			–
		Kwanini	144	2029			–
		Rumbwe	123	2030			–
		Taveta	84	2030			–
		Kisingo	120	2031			–
Geothermal	Ngozi		200	2021	D		–
	Kisaki		50	2021	F	Direct use for heating in the brine	–
	Luhoi		50	2021	F	Direct use for heating in the brine	–
Renewable	Shinyanga		150	2020	C	FS funded by AFD, PV	–
	Shingida		100	2020	F	Funded by China Exim Wind Power	–
	Dodoma		55	2019	F	PV	–

Source: JICA Study Team. Based on information from TANESCO website, a brief report for the meeting between MOE and Energy development partner group, the presentation, “Overview of the energy sector in Tanzania” by MOE January 2018, etc.

Status:
- A : Under construction
- B : Preparing for concluding with contractor, FS completed, EIA approved, Financing closed, Bidding commenced)
- C : FS completed, EIA approved
- C’ : FS completed, EIA not yet approved
- D : Under FS
- E : FS completed, but to be updated
- F : Other (Pre-FS included)

For the hydropower development, there seem to be several challenges involved, such as environmental issues and restriction in candidate sites in the case of large scale development, due to the land conditions; this excludes projects which are under development.

As for renewable energy such as photovoltaic, wind power and geothermal, although they are being developed, there seem to be some challenges involved in making renewable energy as the mainstream of electric supply immediately. This is because, renewable energy has issues such as instability and low density of energy when compared to the conventional power sources.

On the other hand, during the period when the main supply was dependent on domestic hydro power, TANESCO had to purchase electricity from Emergency Power Producers (EPP) as a temporary countermeasure due to drought conditions in Tanzania. This put pressure on TANESCO's finances due to their high price. This fact is fresh in the memory, and it is a common recognition that EPP is not preferred as the main power supply because it is expensive.

Meanwhile, it seems that it is definitely necessary to develop an efficient power plant of a certain capacity at the earliest in Tanzania. Moreover, the implementation of a high voltage bulk power system will help to not only install new power plants, but also to develop a high voltage power system nationwide, as mentioned in PSMP 2016 Update. Based on such a situation, it can be said that the power source, which is highly expected to be developed in the future, is the gas-fired power plant.

The development of the thermal power plant is an urgent matter to supply electricity for the increasing power demand of Tanzania. The installed capacity was 777MW in 2016 when PSMP 2016 Update was issued, and it is 934MW in 2018 (EWURA Web site). However, the planned installed capacity of the thermal power plant is 4,003MW in 2020, and 4,938MW in 2025, which are indicated in PSMP 2016 Update. The Mtwara GTCC power plant is one of the thermal power plants, which was planned in PSMP 2016 Update. It shall have an installed capacity of 300MW in 2019.

Some of the thermal power projects, which were planned for development in PSMP 2016 Update, seem to have a delay in development. In order to secure the national power capacity, it is necessary to continuously develop the potential gas-fired power plants as planned in PSMP 2016 Update. Currently, the Ngaka coal-fired power plant seems to be delayed and is not progressing as per the schedule mentioned in PSMP 2016 Update.

The current status of thermal power development and the plans of PSMP 2016 Update for this decade are shown below;

Table 2-11 Comparison of Thermal Power Development Plan of PSMP 2016 Update and Current Status

Power plant	Installed Capacity (MW)	Completion year		Difference (Year)
		PSMP 2016 Update	Current status	
Kinyerezi III Ph-1	300	2018	2021	3
Kinyerezi III Ph-2	300	2018	2021	3
Kinyerezi IV	330	2020	2021	1
Somanga Fungu Ph-1	210	2018	2020	2
Somanga Fungu Ph-2	110	2019	2020	1
Mkuranga	300	-	2022	-
Somanga (PPP)	300	2018	2020	2
Somanga (TANESCO)	240(330)*	2022	2020	Ahead by 2
Mtwara	300	2019	2022	3
Ngaka (Coal) Phase-1	600	2023	2030	7
Mchuchuma	600	2020	2025	5
Kiwira	400(200)**	2020	2025	5
Mbeya (Rukwa)	300	2024	2020	Ahead by 4

* 240MW (PSMP 2016 Update), 330MW (current status)

**400MW (PSMP 2016 Update), 200MW (current status)

Source: PSMP 2016 Update and TANESCO

Table 2-12 Expected Thermal Power Plant Capacity in 2020 and 2025 (MW)

Type	2020		2025	
	PSMP 2016 Update	Current status	PSMP 2016 Update	Current status
Total of thermal power	4,000	1,847	4,938	3,360
Total of gas-fired power	2,837	1,547	2,975	2,269

Source: PSMP 2016 Update and TANESCO

The progress of thermal power development is behind schedule, and is not as per the schedule mentioned in PSMP 2016 Update.

On the other hand, the Stiegler's Gorge hydro power plant (2,100MW) is progressing fourteen years ahead of its schedule mentioned in the PSMP 2016 Update. This hydro power will start operating in 2021. It appears that the development of this large hydro power plant will be able to compensate for the delay in the development of thermal power in terms of development capacity. However, the hydro power plant cannot supply the necessary power generation (kilowatt-hour) at all times. This is because of the restriction in reservoir operation and the decrease of stored water during drought. The development of various generation sources should be continued and it should not depend too much on a particular project, in order to mitigate the impact of the project.

The impact, caused by the progress of large scale hydro power on the overall plan, should be considered in the next power system master plan. The next PSMP will update the power development plan and review the priority of development. In the coming years, it is highly necessary to implement the power plants, which were planned in PSMP 2016 Update, considering the low plant factor of hydro power and the delay in development.

Some thermal power development plans of PSMP 2016 Update seem to shift to the EPC plus finance scheme, because of the contractor withdrawing from the Independent Power Producer (IPP)/Public Private Partnership (PPP) project for their business reasons and the difficulty in securing finance under the PPP scheme. Considering the rapidly increasing power demand in the country, it is urgently necessary to reinforce generation capacity in short term including gas power plant to supply power to the demand. The Mtwara GTCC power plant project, which will be implemented by TANESCO, can be one of the highly prioritized candidates in this situation.

It is necessary to implement several development projects for the rapid development of thermal power plants, in order to supply power for the rapidly increasing demand; and the development should be carried out TANESCO for early construction and operation. The Mtwara GTCC power plant project, which will be managed by TANESCO, is one of the highly prioritized projects under the thermal power development plans of PSMP 2016 Update.

Several projects such as development of mining industries are planned for the Lindi and Mtwara area, but those projects will be implemented only when abundant power is supplied to those areas. Therefore, the development of power supply is expected to stimulate the potential demand in the local areas.

The 400kV transmission lines and substations that will be constructed under the Mtwara GTCC project, will become a part of the national power trunk line. These systems will be the connecting point to the national grid and will be connected to the coal-fired power plant and the hydro power plant which are planned in the southwest of Tanzania, as mentioned in the PSMP 2016 Update, and it will also be the connection point to the cross border transmission line with Mozambique. These transmission lines and substations will play important roles in the national grid of Tanzania.

The reliability study should consider the power plants that are planned around Somanga, Kinyerezi and Mtwara, and some of the plants will be connected to the 400kV grid. In the study, the latest status of power development is reflected. This status is shown below;

Table 2-13 Power Development Plan for the Study of this Project

Status	No.	Name of plant	Owner	Year of operation	Type	Installed Capacity (MW)	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Existing Thermal	1	Kinyerezi I	TANESCO	2016	Gas-GT	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	Retire				
	2	Kinyerezi II	TANESCO	2018	Gas-C/C	240	30	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	Retire		
Ongoing	3	Kinyerezi I Extension	TANESCO	2018	Gas-GT	185		185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	Retire		
Variable Thermal Candidates	4	Somanga Fungu (Kilwa E)	IPP (Kilwa)	2020	Gas-GT	210				210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210
	5	Somanga Fungu (Kilwa E)	IPP (Kilwa)	2020	ST add-on	110				110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
	6	Kinyerezi III(Ph1) 1-3	EPC + Finance	2021	Gas-GT	300					300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
	7	Kinyerezi III(Ph2) 1-2	EPC + Finance	2021	Gas-C/C	300					300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
	8	Kinyerezi IV 1-2	EPC+Finance	2021	Gas-C/C	330					330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330
	9	Mtwara JICA	TANESCO	2022	Gas-C/C	300						100	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
	10	Somanga (PPP)	TANESCO JV	2020	Gas-C/C	300				300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
	11	Somanga (TANESCO)	TANESCO	2020	Gas-C/C	330				330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330
	12	Mkuranga	TANESCO JV	2022	Gas-C/C	300						300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
	13	Future CGT1(1-3)		2030	Gas-CGT1	110 *														110	220	220	330	330	330	330	330	330	330	330
	14	Future CGT3(1-10)		2035	Gas-CGT3	470 *																			940	1,880	1,880	2,820	2,820	3,760
	15	Ngaka 1-2+3		2030	SBCL	200 *														600	600	600	600	600	600	600	600	600	600	600
	16	Ngaka (Exp) and (Exp2)		2035	ASUB	300 *																			600	600	600	600	600	1,800
Variable Hydro Candidates	17	Stieglers Gorge Ph-1		2020	Dam	1048				262	1048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048
	18	Stieglers Gorge Ph-2		2021	Dam	1048					262	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048	1,048

Above table is updated Generation expansion plan of PSMP2016 for Mtwara study with consideration for latest information.
* stands for unit capacity

Total capacity of each year in this table is not much with PSMP2016 plan.
This table is only for Mtwara system study, not considered with total system.

Future CGT-1: 2030: 110*1, 2035: 110*3
Future CGT-3-1: 2035: 470*2
Future CGT-3-2: 2040: 470*6=2820
Ngaka : 2030:200*3
Ngaka(Exp): 2035: 300*2
Ngaka(Exp2): 2040: 300*4

2.3.3 Grid Development

TANESCO has grid expansion plan based on PSMP 2016 Update. The project list is shown as follows;

Table 2-14 Grid Expansion Projects in Tanzania

No.	Project Name	Detail	Length	Source of Funding	Status
1	400kV North East Grid	Kinyerezi-Chalinze-Segera Arusha Involving 220kV TL	682km	GoT – 15% China Exim bank – 85%	Soliciting funds
2	220kV Makambako –Songea transmission line	Involving 33kV TL and 220/33kV S/S	250km	SIDA & GoT	Under construction
3	400kV North West Grid	Mbeya-Sumbawanga-Mpanda-Kigoma-Nyakanazi with substations	1,148km (Ph-1 340km Ph-2 568km Ph-3 240km)	AfDB, AFD	Soliciting funds
4	400kV Singida-Arusha transmission line	Involving 400/220kV S/S	414.4km	AfDB, JICA	Detailed design stage
5	400kV Chalinze-Dodoma transmission line	Involving rural electrification	350km	Not firmed	Under FS
6	220kV Bulyanhulu-Geita transmission line	Involving substation and 33kV T/L	55km	BADEA, OFID, GoT	On going
7	220kV Geita-Nyakanazi transmission line	Involving rural electrification	144km	KfW, AFD, EU, GoT	Bidding for EPC in progress
8	Reinforcement of Power distribution in Dar es Salaam Region	Involving 33/11kV Distribution Control Center, Substation and underground cable T/L		Government of Finland	In progress
9	Reinforcement of Power Distribution in Dar es Salaam Region	Involving rehabilitation of 132/33/11 S/S, 2nd circuit from Ubungo – Ilala, etc.		JICA	In progress
10	220kV transmission line (90MW Rusumo Falls Hydro)	3 countries- Tanzania, Rwanda, and Burundi, share power. Each country will construct T/L from the power station	98.2km	World Bank, AfDB, GoT	Bidding for EPC in progress
11	220kV Masaka-Mwanza Transmission line	558km in Tanzania, 82km in Uganda Involving some 220kV substation extension and construction	640km	Not yet	FS completed Some portion is under progress KfW has shown interest to facilitate upgrade of FS
12	220kV Kyaka – Nyakanazi transmission line	Involving terminal substations Connection to two power plants (Kakono and Rusumo)	232km		Pre-FS is available. Financing is needed to full FS
13	400kV Mtwara – Mozambique Interconnection	MOU between governments is under going	300km		After MOU, FS will be supported by SAPP
14	400kV Kasama (Zambia)-Mbeya-Iringa transmission line		292km	Soliciting fund, discussion among Governments, WB, AFD	EIA is completed
15	400kV Nyakanazi-Kigoma-Sumbawanga transmission line		765km	Soliciting fund	
16	400kV Somanga-Kinyerezi transmission line	Original plan was designed as 220kV for Kilwa's Somanga Fungu	198km	World Bank has been involved, upon request by the government	FS has been reviewed and the consultant is updating the necessary documents for the upgrade to 400kV

Source: JICA Study Team. Based on information from TANESCO website, a brief report for the meeting between MOE and Energy development partner group, the presentation, "Overview of the energy sector in Tanzania" by MOE January 2018, etc.

The location of these transmission projects are shown in Figure 2-12.

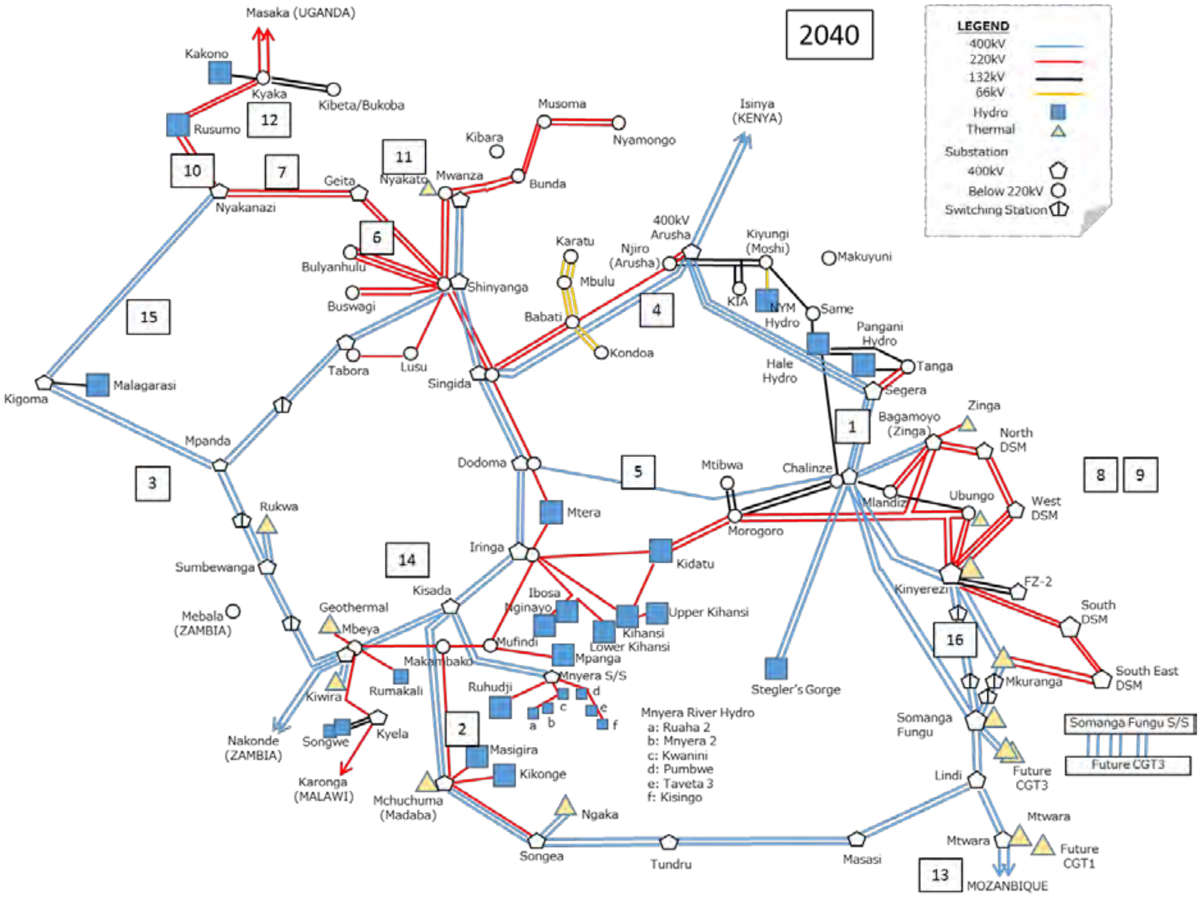


Figure 2-12 Location of Transmission Projects on the Planned Grid Map for 2040 in PSMP 2016 Update

As described in Table 2-14, the progress of 400kV Somanga-Kinyerezi transmission line project, for which the F/S has been reviewed, is still unclear. This transmission line project is the key to realize the Mtwara project, because, this line will connect Mtwara power system to the national grid. Therefore, the status of this transmission line project should be observed carefully.

North West Grid Project is implemented to secure and supply electricity from the abundant generation sources in the North Western area. This project consists of four packages, as follows;

1. 220kV Geita – Nyakanazi transmission line (No.6)
2. Regional Rusumo hydro power project – 220kV transmission line component for Tanzania(No.10)
3. 220kV Masaka – Mwanza transmission system (No. 11)
4. North West Grid : 400kV Mbeya -Sumbawanga -Katavi -Kigoma -Nyakanazi (No.14 & 15)

North West Grid package is planned as follows;

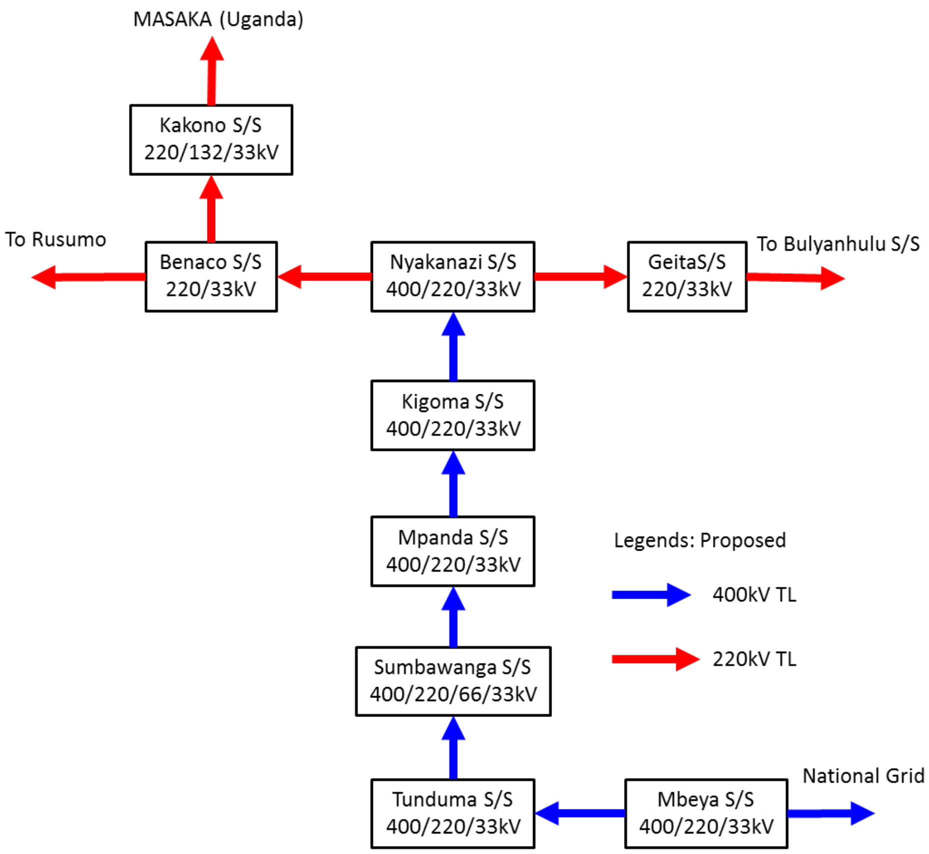
An overall electrification plan for western Tanzania and the surrounding regions has been developed to explore the possibilities, for both the short term and long term, based on which a decision has been made on the optimum development cost for the region and surrounding countries.

The scope of the project includes connecting 8 district headquarters, of which 3 are regional headquarters, to the national grid.

Further, the transmission line will provide a ring feeder to the national grid and possibly connect the grid to the neighboring countries for both export and import of electric power. It will also be used for the transmission of electric power from the planned generation sites including the Malagarasi hydro power plant, the geothermal power plant in Mbeya area and the coal power plant in Sumbawanga area.

Apart from the transmission line, the project scope also includes construction of six substations, which are; Mbeya substation, Tunduma substation, Sumbawanga substation, Mpanda substation, Kigoma substation and Nyakanazi substation.

Below is a diagram showing the routes of North West grid projects



Source: TANESCO: North West grid projects overview

Figure 2-13 North West Grid Projects Routes

2.4 CURRENT DEVELOPMENT STATUS IN TANZANIA

While the big development projects, such as the Stiegler's Gorge hydro power is underway, some planned IPP projects have been withdrawn; and the financing challenges have delayed some projects, which are a part of the power development in Tanzania. Meanwhile, the thermal power development projects seem to be shifting from PPP/IPP scheme to EPC plus finance scheme, such as in the case of Kinyerezi II. EPC plus finance scheme is a scheme in which the project is conducted by the EPC contractor and the finance for the project is prepared by EPC.

As of now, the power development is being carried out by TANESCO through the government, IPP or PPP. But the success of the Kinyerezi II shows that the EPC plus finance scheme is effective for rapid power development. Therefore, such a development scheme seems to be a suitable scheme for power development.

2.4.1 Activities by the Development Partners

The WB conducts various activities to support the electric power sector of Tanzania. The Tanzania Development and Access Expansion Project (TEDAP) and BTIP are some of such activities. Their activity covers a broad area of electric supply elements in terms of both hardware and soft component, such as generation, transmission, and development of distribution facilities and capacity development. Especially international interconnection, rural electrification, and capacity building are key points of development. The WB is now contributing to the electric power sector of Tanzania through several programs such as Energy Sector Capacity Building Project (ESCBP), Tanzania Rural Electrification Expansion Program (TREEP), and Zambia-Tanzania-Kenya (ZTK) Transmission interconnector.

TEDAP was carried out by the WB from the view point of propelling electrification, and the WB is conducting not only off-grid electrification, but also improving the on-grid system such as implementation of 132kV transmission line and substations and reinforcement of distribution network in Dar es Salam, Kilimanjaro, and the surrounding area.

Other than the WB, several development partners support the electric sector in Tanzania. Major partners and their activities are shown in the following Table 2-15. Most of these activities have been completed.

Table 2-15 Major Development Partners and their Activities

Country (Organization)		Activity area and contents	Note
United States	USAID	Technical assistance, capacity building	Improvement of energy access by the Power Africa Initiative.
	*MCC	Rehabilitation and implementation of distribution network Hydro power FS Construction of 132kV transmission line, PV.	
Canada		Capacity building for PPP and gas sector through ESCBP (Energy Sector Capacity Building Project)	Cooperation with WB
Germany	BGR	Technical assistance, capacity building Renewable energy and energy efficiency program (geothermal)	
	GIZ	Renewable energy and energy efficiency program	
	KfW	220kV transmission line and substation construction	
French	AFD	Rural electrification Hydro power, renewable energy (PV) development Cross-border interconnection (Uganda, Zambia)	
Netherland		Rural electrification	
Norway		Capacity building (hydro power development) Hydro power FS and construction Rural electrification Technical assistance and capacity building (hydro power) Cross-border interconnection (Zambia)	
Sweden	Sida	Rural electrification FS of hydro power and transmission line Rehabilitation of hydro power Capacity building (Zanzibar)	Cooperation with WB
Finland		Implementation of distribution network at Dar es Salaam (including substation and new control center)	
South Korea	EDCF	Bidding documents, bidding support Construction of 132kV transmission line and substation (as a part of TEDAP)	Cooperation with WB
		Expansion of BTIP substation	Cooperation with WB, JICA, AfDB, and EIB
Japan	JICA	Transmission line of BTIP Master Plan Reinforcement of distribution network at urban area Capacity building (transmission and distribution)	Cooperation with WB, EDCF, and AfDB in BTIP
EU		Rural electrification (Energy access) Electrification through mini-hydro power and transmission and distribution line Capacity building (electrification)	
OFID		Rural electrification	
AfDB		Construction of Bulk System (BTIP) Implementation of distribution network Technical assistance and capacity building (SCADA, rural electrification) Project management (consultancy services)	The New Deal on Energy for Africa

Source: JICA Study Team Based on information from TANESCO, USAID, AfDB, a brief report for the meeting between MOE and Energy development partner group, and the JICA reports the Project for Formulation of Power System Master Plan in Dar es Salaam and Coast Regions and Review of Power System Master Plan 2012 (March 2017).

*Remark: MCC had already ended the support in Tanzania.

2.4.2 Rural Electrification

The distribution lines from the 132kV Mahumbika substation to the rural areas are now under construction. Rural electrification in Tanzania is planned by Rural Energy Agency (REA), which is the authority organized by the government. REA also stands for rural electrification program. There are several expansion plans for the distribution lines. JICA Study Team confirmed the electrification plans of the below mentioned areas during the survey in December 2017. This shows that the electrification through the extension of distribution lines seems to be progressing steadily. Phase I and Phase II of REA have been carried out. Electrification program for Lindi and Mtwara region has been prepared under REA phase III.

The new power demand, realized by the Phase II, is estimate to be 1,100kW in Mtwara region and 4,530kW in Lindi region. There is another electrification program called REA Phase III, and the ceremony to start this program was held in August 2017. Hence the electrification through the expansion of distribution lines in these area seems to move forward.

"Energy Access Situation Report, 2016 Tanzania Mainland" issued by NBS and REA shows the percentage of population, accessing the electricity grid in Lindi and Mtwara. The details are as shown below;

Table 2-16 Status of Accessing Electricity in 2016

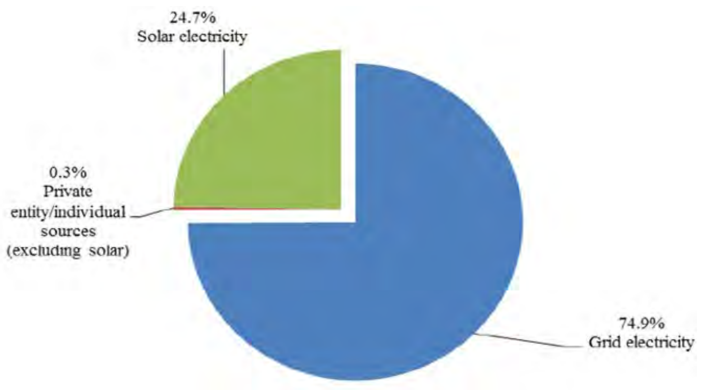
Region	Total			Rural		Urban	
	Population	Accessing	Not Accessing	Population	Accessing	Population	Accessing
Lindi	962,153	52.5%	47.5%	773,965	41.0%	188,188	100.0%
Mtwara	1,828,940	46.4%	53.6%	1,247,095	29.2%	581,844	83.1%
Dar es Salaam	6,008,135	100.0%	0.0%	-	-	6,008,135	100.0%
Total	49,042,052	67.5%	32.5%	30,444,796	49.3%	18,597,257	97.3%

Source: Energy Access Situation Report, 2016 Tanzania Mainland: NBS, REA

The electrification in the urban area of Mtwara region is more than 80%, but the electrification in the rural area of Mtwara region is less than 30%, then the average electrification percentage in the entire Mtwara region is less than 50%. As for the Lindi region, the electrification of the Lindi urban area is 100%, but the electrification in Lindi rural area is over 40%, and the total average of electrification in the entire Lindi region is over 50%.

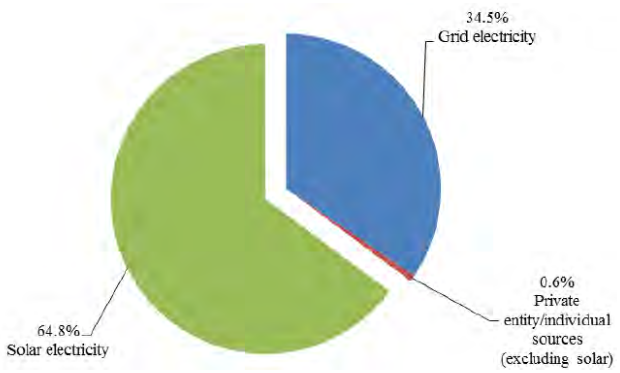
The population of rural area is larger than that of urban area for both regions, and it is vital to promote the electrification of rural area. The cost of constructing a distribution grid in the rural area is higher than urban area, because the population per unit length of the distribution line in the rural area is lower than in the urban area.

74.9% of electrified household in Tanzania mainland is supplied by the connected grid and 24.7% is supplied by solar generation. Only 34.5% of household in rural area is supplied electricity by the connected grid, almost 64.8% is supplied by solar generation.



Source: Energy Access Situation Report, 2016 Tanzania Mainland: NBS, REA

Figure 2-14 Percentage Distribution of Household Connected to Electricity by Main Source of Energy; Tanzania Mainland



Source: Energy Access Situation Report, 2016 Tanzania Mainland: NBS, REA

Figure 2-15 Percentage Distribution of Rural Household Connected to Electricity by Main Source of Energy

The percentage of electrification by grid connection and solar power in the Lindi and Mtwara region is shown in the following table. This table indicates that the current electrification in rural area is supplied by solar power generation. This confirms that there is a potential for further electrification through the expansion of distribution grid, which will lead to a more reliable grid connected supply.

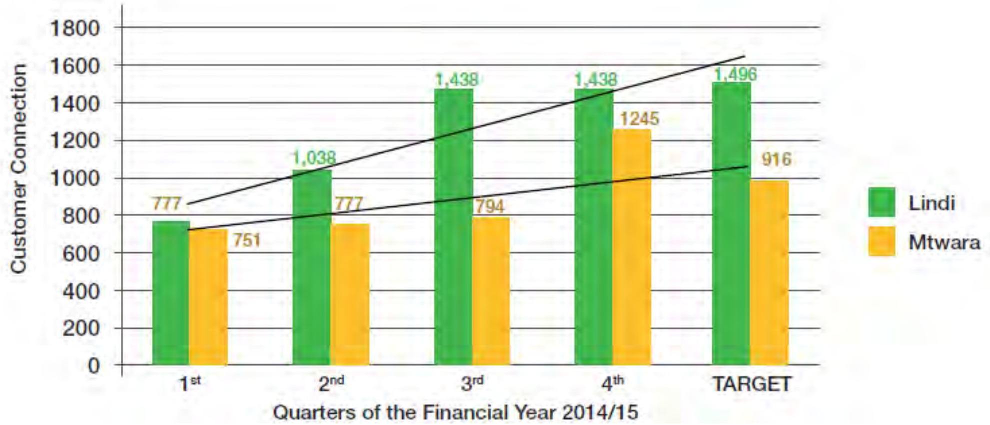
Table 2-17 Percentage Distribution of Household Connected to Electricity by Region and Source of Energy

Region	Grid	Solar Power
Lindi	24.5	75.5
Mtwara	38.9	61.1
Lindi Rural	12.4	87.6
Mtwara Rural	1.4	98.6
Dar es Salaam	99.3	0.7

Source: Energy Access Situation Report, 2016 Tanzania Mainland: NBS, REA

The distribution grid expansion projects in Tanzania are pushed forward by the REA. The expansion in the Lindi and Mtwara region is planned in Phase II and Phase III of REA projects.

The annual report of REA, published at the end of June 2015 reports that the implementation of electrification projects in the villages of Lindi involves the construction of 33kV for 24.5km and Low Voltage (LV) lines for 70.3km, installation of 24 transformers of 33/0.4kV, in which 1,394 customers out of the 1,496 initial customers will be connected by single phase and the remaining 102 by three phase. At the end of the reporting period 1,438 (96%) customers were connected. As for the Mtwara region, the report also states that the scope for Mtwara region involves, the construction of 33kV line for 0.4km, and LV for 47.75 km, and installation of 25 distribution transformers of 33/0.4kV; and upon its completion it will connect to 916 initial customers of which 834 will be single phase and 82 will be of three phase. At the end of the reporting period 1,245 (136%) customers were connected.



Source: REA Annual report 2014/2015

Figure 2-16 Customer Connection Progress for Rural Electrification Projects in Lindi and Mtwara

The implementation of distribution network under Phase II has been carried out, and the subsequent Phase III project is also under progress. The starting ceremony for Phase III was held at Lindi in August of 2017. This shows that the expansion of distribution network is under progress in Lindi and Mtwara.

The electrification of each district in Lindi and Mtwara from 2017 to 2019 through REA Phase III, had been planned in the prefeasibility study, carried out by TANESCO as shown below;

Table 2-18 Expected Total Connection and Estimated Load Demand

District	Year-2017		Year-2018		Year-2019	
	Total Connection of Household	Load-kW	Total Connection of Household	Load-kW	Total Connection of Household	Load-kW
Mtwara Rural	22,125	10,016	28,762	13,021	35,400	16,026
Masasi	12,062	6,037	15,681	7,849	19,300	9,660
Nanyumbu	2,436	1,097	3,166	1,426	3,897	1,756
Newala	18,154	8,633	23,600	11,223	29,046	13,812
Tandahimba	15,878	6,753	20,641	8,779	25,404	10,805
Mtwara Total	**70,654**	**32,537**	**91,850**	**42,298**	**113,046**	**52,059**
Lindi Rural	10,793	5,207	14,031	6,768	17,269	8,330
Kilwa	5,476	2,496	7,118	3,244	8,761	3,993
Nachingwea	17,277	8,073	22,460	10,494	27,644	12,916
Liwale	3,120	1,906	4,056	2,478	4,992	3,050
Ruangwa	10,267	4,529	13,347	5,887	16,427	7,246
Lindi Total	**46,934**	**22,210**	**61,014**	**28,873**	**75,094**	**35,535**

Source: Draft report Prefeasibility study for Tanzania Rural Electrification - REA Phase III

The demand of Mtwara region is forecasted to be 52MW in 2019, in contrast to 33MW in 2017, as per the draft report of REA Phase III, issued by TANESCO. When REA Phase III is completed, there will be a demand for power supply, but the supply capacity of the existing gas engine power plant located in Mtwara downtown is not enough to meet the projected demand. However, the Mtwara GTCC power plant, studied in this project, will have sufficient capacity to meet such a demand.

The future demand forecast, studied in this project, takes into account the demand, which has a certain realization probability, and the reliability study also has been conducted, taking into consideration this forecasted demand.

In the report regarding rural electrification-National Electrification Program Prospectus, issued by the French consultant, Innovation Energie Développement (IED), along with the financial support of Noradin in July 2014, it is stated that the settlements reached by the grid will become 5,526 through REA's electrification, and the number of electricity customers in Tanzania will reach to around 2.1 million because of the grid.

Table 2-19 Electrification by Grid Extension

	Settlements reached by the grid	Thereof Development Centers	Length of MV line (km)	Length of SWER* line (km)	Number of customers in 2022
Turnkey II	1,484	219	11,637		781,251
Turnkey III	2,996	177	4,413	2,733	1,086,759
Turnkey IV	1,046	266	5,441	793	280,887
Total	**5,526**	**662**	**21,491**	**3,526**	**2,148,897**

*SWER: Single Wire Earth Return

Source: National Electrification Program Prospectus, Final Version - July 2014

The electrification project in each phase (turnkey) for Lindi and Mtwara are as follows;

Table 2-20 Distribution of Grid Extension Program in Lindi and Mtwara

Name	Turnkey II		Turnkey III Optimization				Turnkey IV Last Development Centers			
Period	2014-2015		2016-2019				2020-2022			
Supply Type	3-phase supply		3-phase supply		SWER supply		3-phase supply		SWER supply	
Region	Settle-ment	Thereof Develop-ment Centers	Settle-ment	Thereof Develop-ment Centers	Settle-ment	Thereof Develop-ment Centers	Settle-ment	Thereof Develop-ment Centers	Settle-ment	Thereof Develop-ment Centers
Lindi	43	14	45	3	48	1	45	23	28	0
Mtwara	44	6	101	6	123	6	45	14	43	0
National Total	1484	219	1740	146	4256	31	772	266	274	0

Source: National Electrification Program Prospectus, Final Version - July 2014

At the end of the Turnkey IV program, 15 development centers, a certain scale of settlement, a unit of settlement to be electrified, would still not be connected to the grid. One center is in a vicinity of the potential hydro plant. The other 14 centers are located in remote and dry areas. They are considered candidates for off-grid electrification by diesel-PV hybrid systems.

2.5 DEMAND FORECAST IN MTWARA AND LINDI

2.5.1 Regional Survey

The power supply necessity was rapidly growing in Mtwara and Lindi regions after the survey for PSMP 2016 Update. Therefore TANESCO conducted a regional survey again for the future development by visiting regional government offices and collecting information by conducting interviews with the regional officials in 2016. Furthermore, experts from TANESCO and JICA Study Team jointly conducted a regional demand survey to confirm and update the previous survey, and to study the necessity of a new substation in Lindi region, and to confirm the capacity of new substations in these regions. The survey was conducted in Lindi and Mtwara from 11 December to 14 December 2017, and 21 and 23 March 2018.

Survey team visited TANESCO regional offices, several regional government offices, and two major cement factories to collect development information by means of interview to update the TANESCO's survey, conducted in the previous year.

The organizations interviewed by the survey team are as follows;

Table 2-21 Organization List (Interviewed by TANESCO and JICA Expert)

No.	Organization
1	TANESCO Mtwara Regional Office
2	TANESCO Lindi Regional Office
3	TANESCO Mahumbika Substation
4	Tanzania Government, Mtwara Regional Commissioner's Office
5	Mtwara Municipal Council
6	Mtwara District Council
7	Tanzania Government, Lindi Regional Secretary's Office
8	Lindi District Council
9	Lindi District Commission
10	Tanzania Government, Lindi Regional Commission
11	Mtwara Cement
12	Dangote Cement

Most of the projects, listed by TANESCO's previous survey, are progressing, and several new development projects have been added to the list. Updated list is shown in Table 2-22. Some projects need more supply capacity, therefore, the development of some projects depends on the completion of Mtwara GTCC power plant. Hence, the demand of some future projects such as Liquefied Natural Gas (LNG) & industrial park, mining industry (nickel, graphite, and uranium), and cement industry are expected to manifest after 2022, when the Mtwara GTCC will be completed.

Table 2-22 (1) Update Demand Verifications of Lindi and Mtwara - Year 2017

Red part are information from Planning Engineer of TANESCO Mtwara regional office.
Blue part are information from Mtwara regional council, Mtwara municipal council, and Mtwara district council.
Green part are information from Lindi TANESCO Lindi regional office, Lindi Regional secretary and Lindi District Maager

REGION	DISTRICT	S/N	INDUSTRY	Demand (kW) 2016	2017	2018	2019	2020	2021	2022 or later	REMARKS	
MTWARA	MTWARA	1	Tanzania Port Authority(TPA) - Mtwara and Expansion		2,000						Port expansion project	
		2	NHC Project (Mtwara Municipal)	500	1,100						30 Units to be completed in August 2015 & Other project to be completed in 2017	
		3	Sauti university Mtwara		200						University Expansion	
		4	PPF Offices and Buildings	1,000							Arleady connected with electricity	
		5	BOT Building - Mtwara	800							Arleady connected with electricity	
		6	Southern Zonal Hpital (Hospital ya Rufaa)					1,000			New Hospital	
		7	Mtwara Fertilizer Factory						1,500		New Fertilizers Industry	
		8	Rehabilitation of Mtwara Air Port						200		Air Port Expansion / Increase of Electricity use	
		9	Rural Water Projecta	1,306							Various Rural water projects currently using Generators and Solar.	
		10	Mtwara Urban Water Supply and santation Authority			6,000					Rehabilitation and Expansion of the pumps capacity	
		11	Rukia S. Lipangala	70							Milling machines	
		12	Harun A. Haule		70							
		13	OLAM Tanzania Ltd	400								
		14	TPA - Mtwara		500	500					Port Expansion	
		15	NHC (Another project)		500							
		16	Dangote							45,000	Supply will be begun after starting of Mtwara GTCC.	
		17	Mtwara Cement				3,000				Update at 3rd. survey visit	
		18	NMB		500							
		19	Mtwara Cashew nut Factry				300				Cashew nut factory: refered standard example	
		20	HWTE investment				300				Cashew nut factory: refered standard example	
		21	Micronics prosessing				300				Cashew nut factory: refered standard example	
		22	Mohamed Enterprice				500				Cashew nut factory (bigger than avobe three)	
		23	Modern Market				200				3 or 4 flats (stories), 200-250kW	
		24	Investment center				500				11 flats (stoeries)	
		25	Stone Crasher				100				DB shaplyer stone crasher	
		26	Welding				1,400				70X20kW	
		27	Blick factory				10					
		28	Carpentry				1,060				Faniture , 106X10kW	
		29	Salt Factory				100					
		30	Plastic factory				50					
		31	Brewery				1,500					
		32	Casava prosessing industry				100					
		33	Urban residence				1,920				2000 households x 0.96kW(70kWh/730h)	
		34	Kitere Agro prosessing factory				80				refered other illigation project	
		35	Mahulunga Illigation scheme				80				refered other illigation project	
		36	Benjamin Mkapa foundation				2,500				Hospital & University	
		37	Mbuo water project				2,500				30 villages (already)	
		37	Mtwara Industrial Area				6,000				70 industries: refered EPZA of Dar es Salaam(5MVA-50industiries)	
	total			4,076	4,870	6,500	22,500	1,000	1,700	45,000	85,646	A
	NEWALA	1	Makonde Plateau Water Supply and Sanitation Authority			7,000		2,000			Expansion project are ongoing	
		2	Contruction of 2km, 11 kV line at Butiama Area	80								
		3	Contruction of 2km, 11 kV line at Nagwalaa Area	80								
		4	Extension of existing network to tye development area(Newala town,Mahuta, Kitangali, Mkunya and Nagaga	160							Extension of the existing medium Voltage distribution lines to electrify various areas and additions of ditribution transformers.	
		5	Electrification of Mcholi village	80								
		6	Electrification of Makokwe Village	80								
		7	Electrification of Mtungulu Village	80								
		8	Electrification of Makonga and Lengo Villages	80								
	total			640	-	7,000	-	2,000	-	-	9,640	B

Some year of supply is undetermined.
Some will be connected after 2022.

Table 2-22(2) Update Demand Verifications of Lindi and Mtwara - Year 2017

Red part are information from Planning Engineer of TANESCO Mtwara regional office.
Blue part are information from Mtwara regional council, Mtwara municipal council, and Mtwara district council.
Green part are information from Lindi TANESCO Lindi regional office, Lindi Regional secretary and Lindi District Maager

REGION	DISTRICT	S/N	INDUSTRY	Demand (kW) 2016	2017	2018	2019	2020	2021	2022 or later	REMARKS	
MTWARA	MASASI	1	M/S Bucco Investment								Rehabillitation and expansion of the plant capacity	
		2	Electrification of Mtandi Area	80							Extension of the existing medium Voltage distribution lines to electrify various areas and additions of ditribution transformers.	
		3	Electrification of Migongo Area	80								
		4	Electrification of Mkuti Area	80								
		5	Electrification of Nyasa Area	80								
		6	NHC Masasi Project		250						Estate Development by NHC (Low cost Houses)	
		7	Various development of new area called Ndanda whereby various land will be established for residentials,Schools,Industries,Hospitals etec		2,000						Establishment of Ndanda Town and associated services	
		8	Power supply to newly Health Centres		410						Power Supply to Health Centres	
		9	Proposed water Project in Masasi Rural			400					Increase water supply capacity to Masasi Rural areas	
		10	Nach resource							13,000	Graphite	
		11	REA phase II in Masasi District	600							Electrification Projects	
	total			920	2,660	400	-	-	-	13,000	16,980	C
	TANDAHIMBA	1	Kitama Farmers Association Party		80						Planned to expand and increse use of electricity	
		2	Electrification of Kitama and Miuta Villages	140							Electrification Projects	
	total			140	80	-	-	-	-	-	220	D
LINDI	LINDI URBAN	1	Lindi Airport rehabilitation and expansion		500						Airport Expansion	
		2	Water supply projects in Lindi		1,200	1,200		1,200			Water supply expansion projects in phases	
		3	Ng'apa water project				500				15 villages	
		4	Islamic University				1,000			Year of supply is	Reffered to Bagamoyo Univ.	
		5	Lindi reffelal hospital				1,000			undetermined.	reffered to Mtwara	
		6	Buko Cahew nut factory				1,000				reffered to current existing old equipment *0.6~0.7	
		7	NHC Business complex				500				building	
		8	Estate houses in Lindi	500		1,000	1,000				Estate houses development will be done by NHC,LAPF,Watumishi Hoising Corporation,NSSF and Immigration	
		9	Proposed LNG & Industrial Park area in Lindi							100,000	Power will be used during construction of the plant.After construction of the plant they normally use own generated power for the plant.However still industrial park will use TANESCO's power.	
		10	AICC				1,200				Establishment of Arusha International Conference Centred in Lindi	
		11	Hotel Projects				5,000				10 Hotels plots to be developed in Lindi	
		12	Modern Marcket				200	Year of supply is undetermined.				
		13	Donkgyard fish prosessing & Packaging				200				smaller than Chasew nut	
		14	Cement Industry in Lindi			4,000					New cement Industry in Lindi Region	
		15	Ms Fraisal Enterprises Ltd in SIDO				224				Rehabilitation and expansion of power capacity	
	total			500	1,700	6,200	11,824	1,200	-	100,000	121,424	E
	IKWIRIRI	1	Kibiti water Pumping Station		59						Extension of the line and expansion of water pumps	
		2	Mtawanya Water Pumping station		80						Contractor is at the site building the line	
		3	Extension of 42km,33kV line to Nyamisati Village	340							Extension of 33kV line to add more customers	
		4	Korrean Irigation scheme at Ruwe (20 km from town)		2,500						New project	
		5	Ikwiriri Sugar factory			4,000					This power will be needed during construction	
		6	EUROVista Misimbo-Mchuku Farm	400							New project	
		7	Liku Timber Factory		160						The factory is under construction	
		8	Electrification of Kiwanga,Mkapa Bridge area, Kitembo, Mkupuka, Kinyanya and Pakaye areas		220						Electrification Projects	
		9	Electrification of Mloka and Jaribu areas	200							Extension of line	
		10	Electrification of Mpalange Village		160						Extension of line	
		11	Segeni water Project for Irrigation		80						Have not requested power officialy	

Table 2-22(3) Update Demand Verifications of Lindi and Mtwara - Year 2017

Red part are information from Planning Engineer of TANESCO Mtwara regional office.
Blue part are information from Mtwara regional council, Mtwara municipal council, and Mtwara district council.
Green part are information from Lindi TANESCO Lindi regional office, Lindi Regional secretary and Lindi District Maager

REGION	DISTRICT	S/N	INDUSTRY	Demand (kW)							REMARKS	
				2016	2017	2018	2019	2020	2021	2022 or later		
Lindi	KILWA	1	Establishment of kiwa Hotels	200							Estimeted from the expeted transformer size	
		2	Kilwa Chicken Poutry								Expansion	
		3	Extention of Line to Nangurukuru & Magogo	200							New extension	
		4	Extention of Singino - Magogo Line	80							New extension	
		5	Extention of line to Kingunge Ngombale Mwilu	120							New extension	
		6	Kilwa Sun flower oil factry				50	Year of supply is undetermined .			Lindi or Somanga	F
		7	Kilwa fertilizer factory				1,500				Lindi or Somanga (Refferd to Mtwara)	
	LINDI RURAL	1	Electrification of Ngongo Village to Milola Village , 33kV line,51KM (Ng'apa Mkupama, Ng'apa Mbuyuni, Narunyu, Tandangongoro, Rutamba, Nambawala, Chilala FDC, Kinyope, Legeza Mwendo & Milola					620			Electrification Projects	
		2	Electrification of Mchinga 1 to Mipingo village via Mkwajuni, 33kV OF about 40KM (Kilangala, Mvumbila, Kitomanga , Mkwajuni & Mipingo)					320			Electrification Projects	
		3	Electrification of Mchinga 2 to Mvuleni and Kijiweni village, 33kV of about 34KM					340			Electrification Projects	
		4	Electrification of Nyangao Village to Mahiwa, 33kV of about 3.7KM (Mahiwa Village)					80			Electrification Projects	
		5	Electrification of Nyangao Hospital to Namupa Village,33kV of about 11KM, (Mtakuja and Namupa Villages)					140			Electrification Projects	
		6	Electrification of Mtange Village to Nangaru Village, 33kV of about 41KM					400			Electrification Projects	
		7	Salt prosessing & Packaging				50				50-100	
		8	Mtama chasew nut factory				200		Year of supply is undetermined .			
		9	Mchingwa Gypsum Industry				1,000				(Kilwa) Graphite 500x2	
		10	Casava prosessing Industry				100					
		11	Lindi Graphite Factory				1,500				Graphite factory	
		12	REA phase III Lindi Rural		5,207	6,768	8,330				(little big?)	
	total			-	5,207	6,768	11,180	1,900	-	-	25,055	G
	LIWALE	1	Electrification of Liwale-Makonjiganga area to Kipule Village, 33kV line is about 10KM. (.Makonji, Mangirikiti, Ana Magoha Sec.School, & Kipule)					160			Electrification Projects	
		2	Electrification of Makonji at Tigo tower to Mihumo and Matarawe,33kV line of about 31KM (Kipule Kitamamui, Kipule Magereza, Likombola, Mihumo, & Matarawe(Turuki))					120			Electrification Projects	
		3	Electrification of Liwale B to Nangano, 33kV line of about 73KM (Mikunya, Kiangala, Kibutuka & Nangano)				240				Electrification Projects	
		4	REA phase III Liwale		1,906	2,478	3,050					
	total			-	1,906	2,478	3,290	280	-	-	7,954	H
	NACHINGWEA	1	Electrification of Ugogoni A(Anglican Church area) to Namatula A and B ,11kV line of about 6km (Ugogoni A, Namatula A, & Namatula B)		160						Electrification Projects	
		2	Electrification of Ugogoni A to Ugogoni B and Mianzini, 11kV line of about 0.6KM (Ugogoni B & **Mianzini)**		160						Electrification Projects	
		3	Electrification of Majengo L to Air port, 11kV line of about 1.2KM		160						Electrification Projects	
		4	Electrification of Kilimanihewa to Califonia(11KV,3KM)		80						Electrification Projects	
		5	Ngwena Nickel			15,000						
		6	Nachingewa cahew nut factory			300					Year of supply is undetermined .	
		7	REA phase III Nachingwea		8,073	10,494	12,916					
	total			-	8,633	25,794	12,916	-	-	-	47,343	I

Table 2-22(4) Update Demand Verifications of Lindi and Mtwara - Year 2017

Red part are information from Planning Engineer of TANESCO Mtwara regional office.
Blue part are information from Mtwara regional council, Mtwara municipal council, and Mtwara district council.
Green part are information from Lindi TANESCO Lindi regional office, Lindi Regional secretary and Lindi District Maager

REGION	DISTRICT	S/N	INDUSTRY	Demand (kW)							REMARKS	
				2016	2017	2018	2019	2020	2021	2022 or later		
Lindi	RUANGWA	1	Electrification of Mchangani to Mandawa, 33kVof about 38KM (Mbekenyera, Matumbu, Namichiga, Muhulu, Chikundi, & Mandawa)	800							Electrification Projects	
		2	Electrification of Naunambe village to Namungo, 33kV 8KM	200							Electrification Projects	
		3	Electrification of matumbu to chibula 33kV, 2.5KM	200							Electrification Projects	
		4	Electrification of Nkowe village to Nanganga , 51KM (Namahema, Nandagala, NchimbilaA, Nchimbila B, Michenga, Nangumbu, Nanganga)	250							Electrification Projects	
		5	M/s PACCO GERMS LTD		4,000						New Graphite Mine to be Located in Ruangwa	
		6	URANEX			30,000						
		7	REA Phase III Ruangwa		4,529	5,887	7,246					
	total			1,450	8,529	35,887	7,246	-	-	-	53,112	J
	KILWA	1	Electrification of Tingi(four ways) to Kipatimu Village 33kV line of about 51KM (Mingumbi, Namayuni, Chumo A, Chumo B, Nasaya, Darajani & Kipatimu)		500						Electrification Projects	
		2	Electrification of Nangurukuru village to Miguruwe village 33kV line, 73KM (Migeregere, Kipindimbi, Njinjo, Selou Camp & Miguruwe)		500						Electrification Projects	
		3	REA phase III Kilwa		2,496	3,244	3,993					
	Lindi S/S total										254,888	
	No Masasi S/S										281,728	
EXPORT TO MOZAMBICQUE		1	Supply of Power to North of Mozambicque				300,000				Supplying of North Mozambicque from Mtwara	
			SUB-TOTAL	-	-	-	300,000	-			300,000	

peak demand of Mahumbika S/S is 7.4MW
Transformer of Mahumbika is 20MVA
Many Industry who want to come Lindi and require more power in Linid. Reffered by regional secretary.

It can be concluded from the result of demand survey that various development projects are being planned for these regions. Following figures show the demand proportion of the planned projects for both the regions.

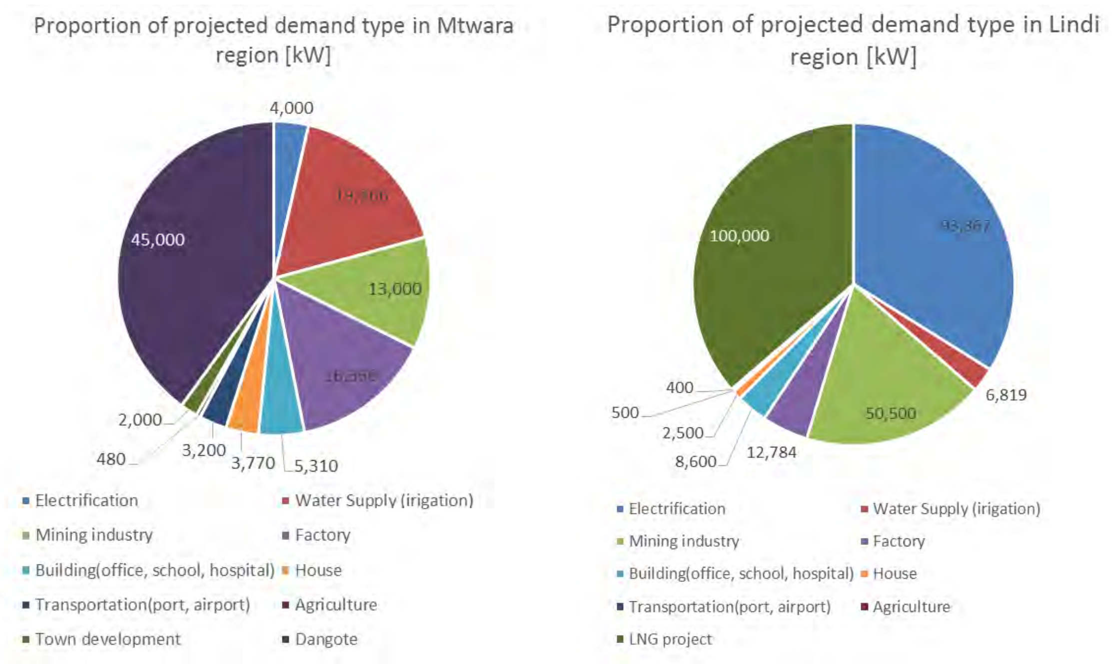


Figure 2-17 Proportion of the Demand of Planned Projects in Mtwara and Lindi Region

As for the Mtwara region, the demand of Dangote Cement is almost half of the entire demand of Mtwara region. Excluding the Dangote Cement, the water supply and the irrigation project attribute to the largest portion of the entire demand. The factories of produce such as fertilizers, cashew nuts, cassavas and other small factories have the second largest demand, and the mining industry of graphite has the third largest demand. As for the Lindi region, LNG project and industrial park are relatively big, but excluding this, the electrification project has the biggest demand, and the mining industries such as graphite, nickel, and uranium have the second largest demand.

The demands of Dangote Cement and LNG project are quite big when compared to other demands, therefore these two projects are considered separately from the other demand forecast.

The demand forecast of Mtwara and Lindi for the study of system planning and system analysis is conducted by the procedure described below.

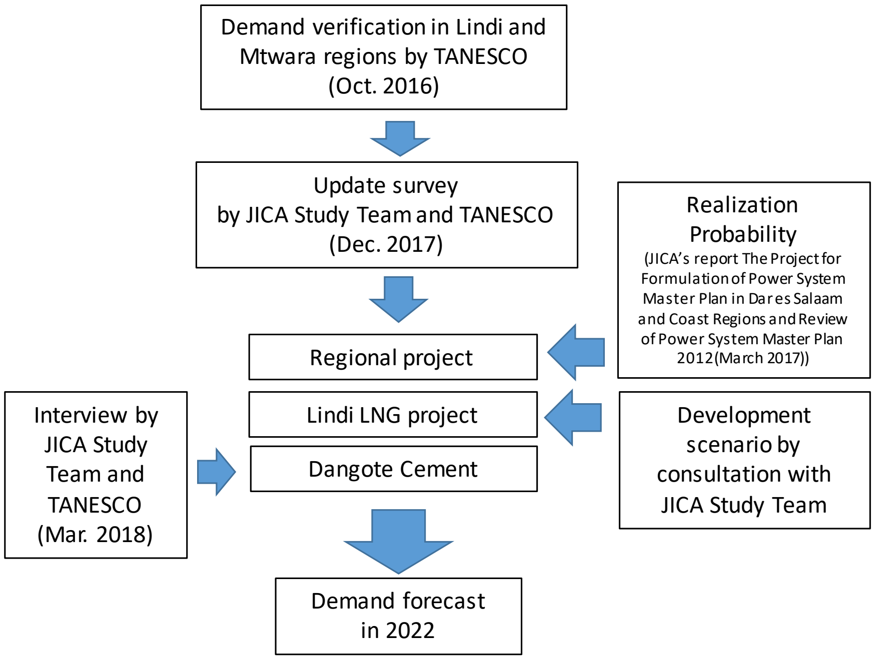


Figure 2-18 Demand Forecast Procedure for Update Previous Survey

After forecasting the demand of 2022, the demand growth trend is calculated from PSMP 2016 Update, and the demand growth scenario of the two large projects- LNG project and Dangote Cement is considered, with the information collected. The future demand estimation is calculated as shown in the following flowchart. The details are explained in this Section.

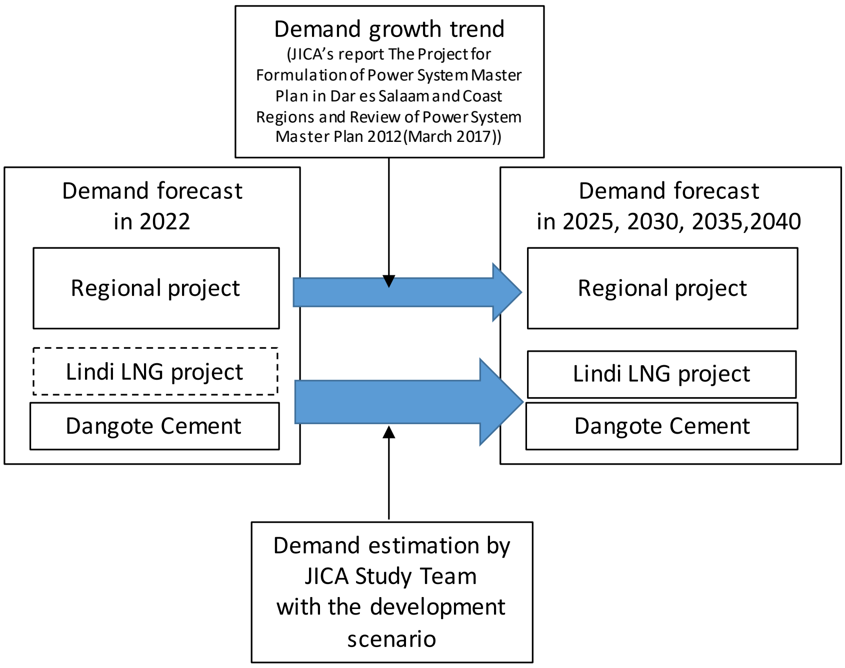


Figure 2-19 Future Demand Forecast Procedure

The demand of each district is the sum of demand listed in the survey data, shown in Table 2-22.

The total potential power demand of Lindi and Mtwara in 2022 is shown in Table 2-23.

Table 2-23 Total Potential Demand of Lindi and Mtwara in 2022

Region	District	Estimated demand in 2022 (kW)	Reference of Table 2-22
Lindi	Lindi Urban	121,424	E
	Lindi Rural	25,055	G
	Liwale	7,954	H
	Nachingwea	47,343	I
	Ruangwa	53,112	J
	Kilwa*	1,550	F
	Sub total	256,438	
Mtwara	Newala	9,640	B
	Masasi	16,980	C
	Tandahimba	220	D
	Mtwara	85,646	A
	Sub total	112,486	
Total		368,924	

* Kilwa district and Ikwiriri district will be supplied from 400kV Somanga substation. Only two factories-Sun flower factory and Fertilizer factory, will be distributed from the New Lindi substation.

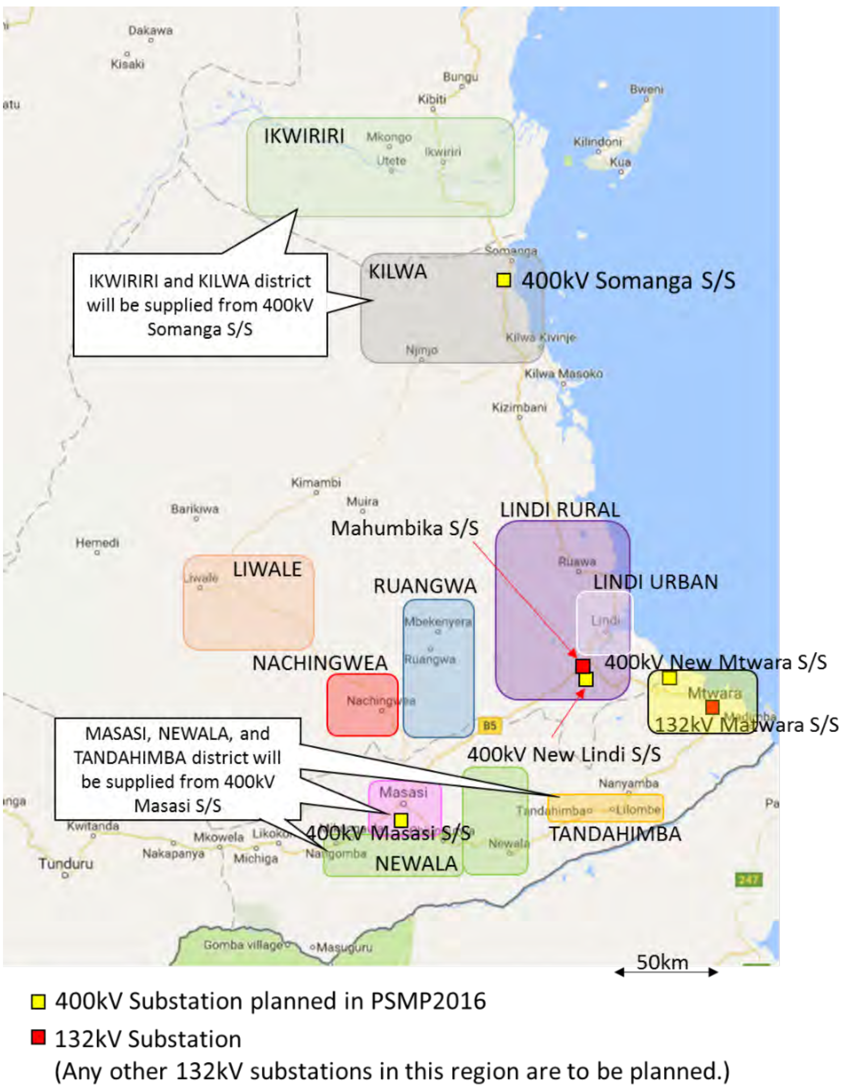
2.5.2 Distribution Area

Total potential demand displayed in Table 2-23, shows the demand of each district, and it does not match the demand of substation. This is because, Newala, Masasi, and Tandahimba districts belong to Mtwara region, but these districts will be supplied from the 132kV Mahumbika substation. It means the demand of these three districts will be included in the New Lindi substation until the completion of 400kV Masasi substation. Only the Mtwara district will be supplied from the 132kV Mtwara (400kV New Mtwara) substation. Figure 2-20 shows the location of districts in Lindi region and Mtwara region, and the future distribution area of each distribution substation.

Ikwiriri and Kilwa are districts of the Lindi region, and these districts are located in the northern region of Lindi. The other new 400kV substation called the 400kV Somanga substation will be constructed in that area, therefore these two districts will be supplied electricity from 400kV Somanga substation. Only the small sunflower factory and fertilizer factory will be supplied from the New Lindi substation.

Table 2-24 Estimated Future Demand for Each Substation by Survey Result

Region	District	Estimated demand in 2022 (kW)	Substation	Total demand of substation
Lindi	Lindi Urban	121,424	Mahumbika (400kV New Lindi)	283MW
	Lindi Rural	25,055		
	Liwale	7,954		
	Nachingwea	47,343		
	Ruangwa	53,112		
	Kilwa	1,550		
Mtwara	Newala	9,640		
	Masasi	16,980		
	Tandahimba	220		
	Mtwara	85,646	132kV Mtwara (400kV New Mtwara)	86MW



Source: JICA Study Team. Based on PSMP 2016 Update and information from TANESCO

Figure 2-20 Demand Distribution Map of Lindi and Mtwara Region

2.5.3 Demand Forecast of Lindi and Mtwara in 2022

All projects will not be developed as planned. The projects listed in the demand survey, such as the mining development, industrial parks, commercial malls, airport and harbor expansion and other development projects should be considered with the realization probabilities mentioned in JICA's report "the Project for Formulation of Power System Master Plan in Dar es Salaam and Coast Regions and Review of Power System Master Plan 2012" (March 2017).

The LNG and industrial park area, proposed in the Lindi project seem to have higher probability of being implemented. This project is managed by the government of Tanzania, through Tanzania Petroleum Development Corporation (TPDC) in partnership with six international major oil companies. On the other hand, Dangote Cement is the biggest industry in Mtwara region, and they have a future expansion plan for their factory. These two big projects should be considered separately from the other forecast in the future demand due to their magnitude.

LNG project, planned for Lindi, needs huge investment and development period. JICA's survey regarding the development and utilization of natural gas in Tanzania is now in progress. The latest information from this gas survey suggest that the Lindi LNG plant will start operation in the late 2020s at the earliest.

The forecasted demand should be considered in deciding the components of the LNG plant and the related potential industries. The energy source for the LNG plant is generally supplied by the gas turbine. The main components needed by the energy in the LNG plant are the compressors for the liquefaction process. The proposed LNG plant in Lindi will have two trains of 5 million tonnes to begin with, and two more trains of 5 million tonnes will be added after five years. The potential power demand of first two trains is estimated to be 20MW for emergency backup. When the gas turbine is selected as the power source of LNG plants, the total demand of plant is estimated to be 100MW, and it will not be supplied by the grid power but by the gas turbine. Therefore the forecasted power demand for grid supply is 20MW in the latter half of the 2020s and 40MW in the first half of the 2030s. As for the demand of industrial park, the industries expected to be related to the LNG process are fertilizer (ammonia & urea), methanol, GTL (Gas to Liquid), DME (Di-Methyl Ether), MTG (Methanol to Gasoline), and CNG (Compressed Natural Gas). These industries will be in operation long after the construction of LNG plant, because the development of these industries require a demand for their products. However, it will a take long time to start these related industries, considering the current demand condition of these products.

If LNG plant employs the electric motor for the compression process, due to its easy maintenance and quick start-up, the estimated electric demand is 200MW for one train of 5 million tonne plant. At the beginning of the LNG project, the high voltage power grid may not have enough reliability, because, Tanzania does not have long experience in high voltage power grid. Therefore this first LNG project will adopt the gas turbine as its power source, and an all-electric-motored LNG plant may be implemented in case of high demand.

As the result of this consideration, the demand of the Proposed LNG and industrial park area in Lindi is estimated to be 20MW with a backup of two trains for the LNG plant in 2030, and the demand is expected to grow to 42MW (40MW for the backup of four trains and 2MW for the related industry) in 2035, and 44MW (40MW for the backup of four trains and 4MW for the industrial park) in 2040.

As for the future demand of Mtwara district, Dangote Cement is the biggest industry in this area but the electricity for this big factory is supplied by the Cement factory itself. When they started their industry in Mtwara, the utility did not have enough power supply. Therefore they had to generate electricity using their own diesel generators. Dangote Cement in Mtwara has a new expansion plan for their factory, and they have already started to construct additional generators for electricity. Unfortunately, the Mtwara GTCC power plant will not be ready in time, for this expansion. The survey team had an interview with them and confirmed that they don't have any intention to receive electricity from the grid this time, as they don't have additional expansion plan from the view point of uncertain future demand growth for cement in Tanzania, but there is a possibility of receiving electricity in the future from the grid if the supply cost is cheaper than their own supply, or the supply reliability is higher than their self-supply. Regional survey conducted for PSMP 2016 Update shows that the demand forecast of Dangote cement is 45MW in 2020 and 90MW in 2025. The demand of Dangote Cement from the grid is set as backup, the amount of backup capacity is estimated to be 20% of the total demand. Hence, the demand of Dangote Cement is estimated to be 10MW in 2022 and 20MW in 2025, in this study.

Table 2-25 Forecasted Demand of LNG Project and Dangote Cement (MW)

Project	2022	2025	2030	2035	2040
Lindi LNG project	-	-	20	42	44
Mtwara Dangote Cement	10	20	20	20	20

Source: JICA Study Team. Made from the information obtained through interview with Dangote Cement

As for middle voltage expansion program by TANESCO, this program also has high possibility of being implemented. The TANESCO's expansion program has been going on as a part of rural electrification project.

On the other hand, there is another electrification program, REA Phase III. TANESCO's demand survey in 2016 included REA Phase III. REA Phase III is counted as one of the big projects, which has to be considered with realization probabilities.

Based on the above situation, in this study, TANESCO's middle voltage expansion project is assumed to be a high realization project that will use 100% of the planned demand. Other demands including REA Phase III should be considered with realization probabilities. Realization probabilities is the probability that is used for consideration of uncertainty of the big project plans in the JICA's report 'the Project for Formulation of Power System Master Plan in Dar es Salaam and Coast Regions and Review of Power System Master Plan 2012 (March 2017)'. The big projects are- mining development, industrial parks, commercial malls, and airport and harbor expansion project.

Realization probabilities from JICA's report are shown in Table 2-26;

Table 2-26 Realization Probabilities of Big Project (Lindi and Mtwara Region)

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Lindi	80.0%	77.6%	75.3%	73.0%	70.8%	68.7%	66.6%	64.6%	62.7%	60.8%	59.0%
Mtwara	100%	97.0%	94.1%	91.3%	88.5%	85.9%	83.3%	80.8%	78.4%	76.0%	73.7%

Source: JICA's report "The Project for Formulation of Power System Master Plan in Dar es Salaam and Coast Regions and Review of Power System Master Plan 2012" (March 2017).

The estimated future demand in 2022 for the study of this project is calculated in Table 2-27 keeping in view the above conditions.

Table 2-27 Demand Estimation of Lindi and Mtwara in Consideration of Realization Probabilities

Region	District	Estimated demand at 2022 (kW)						Substation	Demand of substation
		Survey result	Consideration of realization probabilities			Demand estimation A + (B × C%)			
			Demand of high probabilities A*	Demand to be considered with realization probabilities B**	Realization probabilities in 2022 C (%)	District	Subtotal		
Lindi	Lindi Urban	21,424	0	21,424	64.6%	13,840	102,627	400kV New Lindi	124.5MW (102.6+21.9)
	Lindi Rural	25,055	1,900	23,155		16,858			
	Liwale	7,954	520	7,434		5,322			
	Nachingwea	47,343	560	46,783		30,782			
	Ruangwa	53,112	1,450	51,662		34,824			
	Kilwa	1,550	-	1,550		1,001			
Mtwara	Newala	9,640	640	9,000	80.8%	7,912	21,883		
	Masasi	16,980	240	16,740		13,766			
	Tandahimba	220	140	80		205			
	Mtwara	85,646	10,000 (Dangote)	40,646		42,842	42,842	400kV New Mtwara	42.8MW (10.0+32.8)

*: A means the high probability projects such as Proposed LNG & Industrial park area in Lindi, Dangote Cement in Mtwara, and TANESCO's extension and electrification projects listed in Table 2-22

**: B is the demand to be considered with realization probabilities. This demand is listed in Table 2-22 exception of high probabilities.

Estimated demand of 400kV New Lindi substation is approximately 124.5MW and the estimated demand of 400kV New Mtwara substation is about 42.8MW in 2022. (Some big demand such as LNG project in Lindi and Dangote Cement in Mtwara should be distributed by the 132kV transmission line directly from the new 400kV substation.)

The potential demand of 400kV Lindi substation and 400kV Mtwara substation in 2022 is summarized as follows;

Table 2-28 Potential Demand of 400kV Lindi Substation and 400kV Mtwara Substation in 2022

Substation	Demand (MW)
400kV Lindi	125
400kV Mtwara	43

2.5.4 Demand Forecast of Lindi and Mtwara after 2025

PSMP 2016 Update shows future grid plan until 2040, the grid around Mtwara will change with the construction of other new power plants and new transmission lines. In this study, the reliability of Mtwara power system will be confirmed for the period shown in PSMP 2016 Update.

Further demand estimation is calculated with the basic forecast for 2025, 2030, 2035, and 2040.

As per the PSMP 2016 Update, the demand of 400kV Mtwara substation in 2030 is lesser than the demand in 2025, as some of the demand will be supplied from the Masasi substation on its completion. Therefore, in this study, the demand growth trend of Mtwara is not calculated solely from the demand of 400kV Mtwara substation, but the total demand data of the Mtwara region, which includes both 400kV Mtwara substation and 400kV Masasi substation is considered.

Figure 2-21 and Figure 2-22 show the trend of demand growth and the linearization of the future demand of 400kV Lindi substation and Mtwara region until 2040.

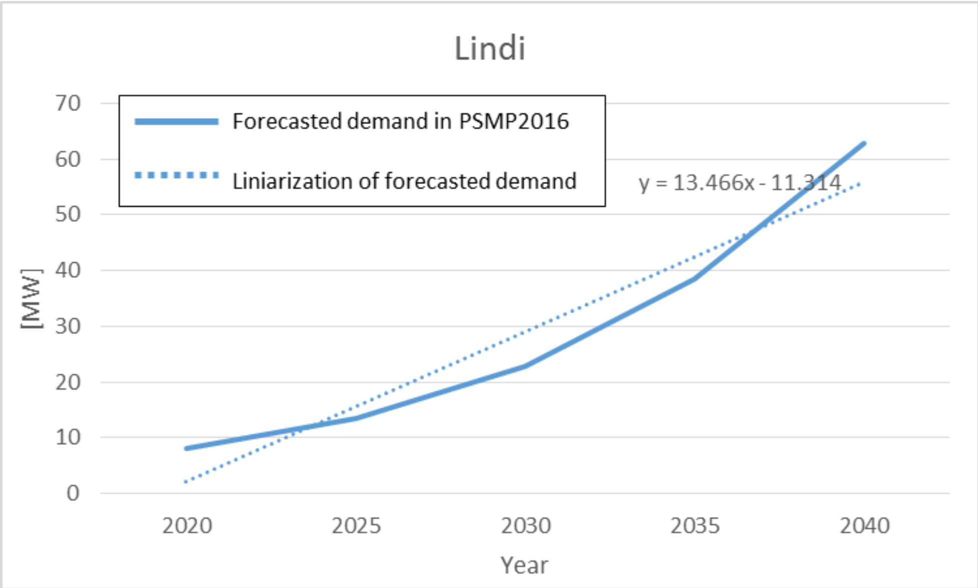


Figure 2-21 Demand Growth Trend and Linearization of the 400kV Lindi Substation as per PSMP 2016 Update

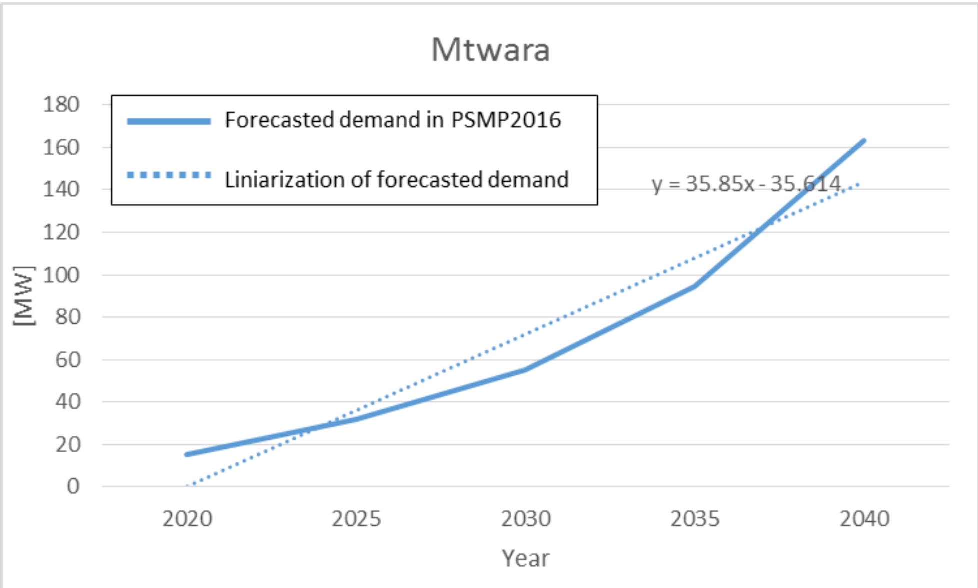


Figure 2-22 Demand Growth Trend and Linearization of Mtwara Region as per PSMP 2016 Update

The solid line represents the trend of forecasted demand, as mentioned in PSMP 2016 Update. The dotted line represents the linearization of the forecasted demand line.

According to the above linearization, the demand of the New Lindi substation and the New Mtwara substation are as follows;

X represents pass of years and Y represents demand;
The demand of the New Lindi substation : Y=13.466X-11.314
The demand of Mtwara region : Y=35.85X-35.614

The demand of the New Mtwara substation is half of the demand of Mtwara region,

The demand of the New Mtwara substation: Y=17.924X-18.307
X=1 stands for Year 2020, also X=2,3,4,5 stands for 2025,2030,2035,2040 respectively.

The demand in 2022, as calculated by the above formula is 7.5MW for the New Lindi substation and 6.8MW for the New Mtwara substation. X is set as 1.4 for 2022.

7.5MW and 6.8MW are much lesser than 102.6MW and 42.8MW, which are calculated by the latest survey results.

Therefore, JICA Study Team set 102.6MW and 42.8MW as the starting point to estimate the demand after 2022, and tried to employ only inclinations of these linear approximate equation.

Newala, Masasi, and Tandahimba district will be supplied electricity from the Mahumbika substation until the completion of Masasi substation, the Mahumbika substation will be supplied from the New Lindi substation.

The demand of Masasi district in 2022 is estimated to be 21.8MW and the demand of Lindi region supplied from the New Lindi substation in 2022 is estimated to be 102.6MW, these are shown in Table 2-27.

The forecasted demand of each area after 2025 are calculated as follows;

1. Lindi ; <u>Y=13.5X+102.6</u> (not including LNG Project)
2. Mtwara ; <u>Y=17.9X+32.8</u> (not including Dangote Cement)
3. Masasi ; <u>Y=17.9X+21.8</u>

X is set as 2, 3, 4, and 5, representing the years 2025, 2030, 2035, and 2040 respectively.

The result of calculation is as follows;

Table 2-29 Forecasted Demand by Area (not including Lindi LNG and Dangote Cement) (MW)

Supply Area	Inclination of approximate equation.	Year	2022	2025	2030	2035	2040
		X	(Base)	2	3	4	5
Lindi	13.5	-	102.6	129.6	143.1	156.6	170.1
Masasi	17.9	-	21.8	57.6	75.5	93.4	111.3
Mtwara		-	32.8	68.6	86.5	104.4	122.3

The demand of Masasi area is included in the Lindi area until the completion of 400kV Masasi substation. 400kV Masasi substation is planned for construction in 2023 as per PSMP 2016 Update, but there is no concrete plan for construction at the time of this study.

As a result of the discussion between JICA Study Team and TANESCO, it is decided to set the timing of construction of Masasi substation to 2030 in this study considering the delay in development of Ngaka power plant and the construction of related transmission line.

The estimated demand for the New Lindi substation considering the timing of construction of Masasi substation is as follows;

Table 2-30 Forecasted Demand of Lindi, Masasi, and Mtwara (MW)

	Area/ Big demand	2022	2025	2030	2035	2040
Area and Big demand	Lindi	103	130	143	157	170
	Lindi LNG	-	-	20	42	44
	Masasi	22	58	76	93	111
	(Lindi + Masasi)*	125	188	-	-	-
	Mtwara	33	69	87	104	122
	Dangote Cement	10	20	20	20	20

*The demand of the New Lindi substation at 2022 and 2025 includes Newala, Masasi, and Tandahimba district.

The demand components of each 400kV substation is as follows;

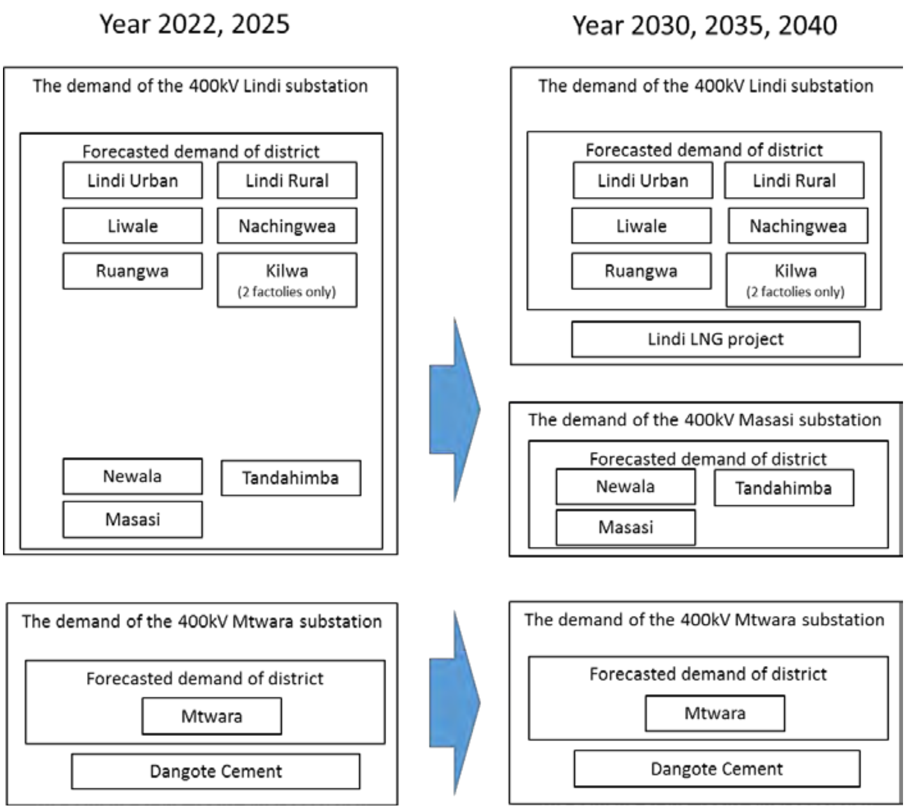


Figure 2-23 Components of 400kV Substation Demand

Forecasted demand for each 400kV substation is as follows;

Table 2-31 Forecasted Demand for Each 400kV Substation (MW)

Area	400kV Substation	2022	2025	2030	2035	2040
Lindi	Lindi	125*	188*	163	199	214
Masasi	Masasi	-	-	76	93	111
Mtwara	Mtwara	43	89	107	124	142

*The demand of the New Lindi substation at 2022 and 2025 includes Newala, Masasi, and Tandahimba.

The substations will be designed with this estimation.

These forecasted demands are more than those forecasted in PSMP 2016 Update. The demand forecast of PSMP 2016 Update was calculated by macro analysis, and the demand of each substation was calculated from the distributed regional demand of the national demand taking into consideration the regional index such as population and big projects of the region. The demand of the New Lindi substation is half of Lindi region demand, and the demand of Masasi substation and the New Mtwara substation is half of Mtwara region demand. The demand forecast of this study was calculated by micro analysis with the updated survey data. This survey data includes some new information regarding the projects developing in Lindi and Mtwara area, which were not included in the previous regional survey conducted for PSMP 2016 Update study. This latest survey found additional demand from the new development projects, and it is more detailed than the previous survey.

Table 2-32 Forecasted Demand compared with PSMP 2016 Update (MW)

Area	400kV Substation	2022	2025	2030	2035	2040
Lindi	Lindi	125*	188*	163	179	214
Masasi	Masasi	-	-	76	93	111
Mtwara	Mtwara	43	89	107	124	142
(Ref.) PSMP 2016 Update	Lindi	-	13.73	22.84	38.39	62.82
	Masasi	-	-	27.5	47.31	81.49
	Mtwara	-	32.08	27.5	47.31	81.49

*The demand of the New Lindi substation at 2022 and 2025 includes Newala, Masasi, and Tandahimba.

The demand of Lindi area and Mtwara area are expected to increase substantially in the future if sufficient and stable power supply are realized. The total demand of Lindi area will reach 200MW and the demand of Mtwara area will become more than 140MW in 2040.

2.6 POWER SYSTEM PLANNING

2.6.1 Proposed 400kV System and Grid Configuration

The result of demand estimation shows that the capacity necessary to supply Lindi area is 214MW, and Mtwara area is 142MW by 2040. Memorandum of Understanding (MOU) between TANESCO and EDM, Electric Utility of Mozambique, says that "Mtwara" is the point at which 400kV international transmission line is connected with Mozambique. It has to be determined whether a substation or a switching station is better for Lindi.

(1) Comparison of 132 kV Transmission Line and 400kV Substation for Lindi

There are two methods to supply electricity to Lindi. One is using the 132kV transmission line from the 400kV New Mtwara substation, and another is to construct a 400kV substation in Lindi. The reliability and construction cost of both the systems should be considered. The existing system is currently composed of - 1cct. (circuit) 132kV transmission line between Lindi area and Mtwara area, the 132kV Mahumbika substation and the 132kV Mtwara substation. The grid plan should be studied considering the existing system.

The transformer requires a capacity of 320MVA. On the other hand, high voltage backbone systems, such as a 400kV substation, need high reliability. Therefore, a 400kV substation should have more than two transformers generally.

The system configuration for the substation should be considered keeping in view both the reliability and cost, this includes not only the initial cost but also the long-term operation and maintenance cost.

Table 2-33 Required Transformer Capacity (Power factor: 0.85)

Substation	Max demand until 2040	Capacity required
New Lindi	214MW (2040)	320MVA
New Mtwara	142MW (2040)	212MVA

Case A: New Lindi Substation

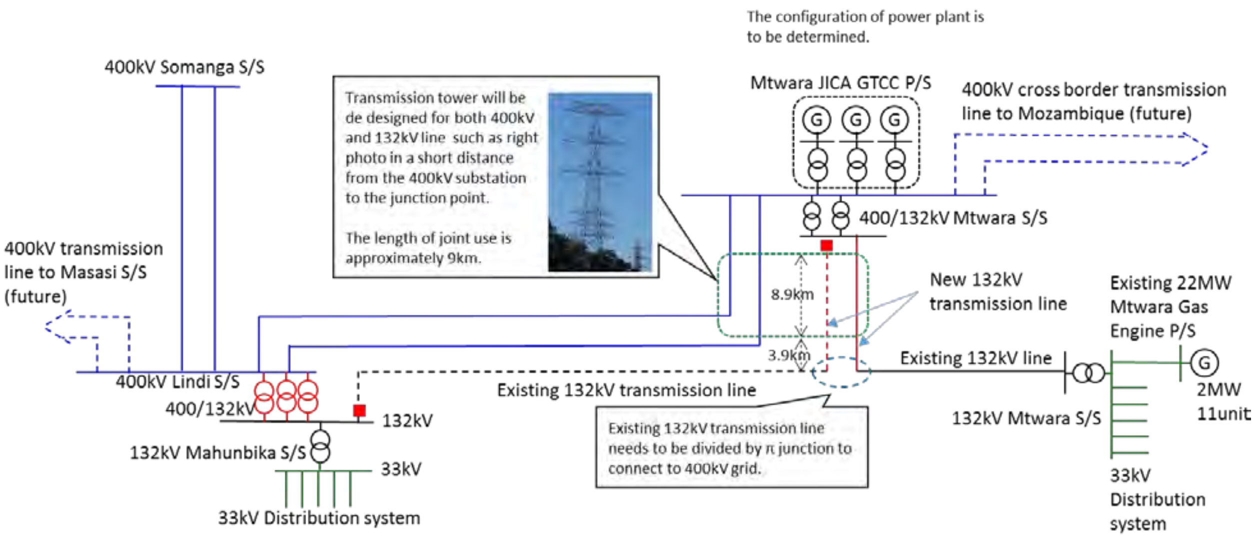


Figure 2-24 System Configuration – Lindi Substation Case

If Lindi has a 400/132kV transformer, the demand of Lindi, Mahumbika substation and LNG project will be supplied from the 132kV bus of the New Lindi substation. The power source is sent by a 400kV transmission line from the New Mtwara substation - 400kV bus.

The Mtwara area will be distributed electricity by the 132kV Mtwara existing substation through the 132kV transmission line and the 400/132kV transformer at the New Mtwara substation. In this case, there is a possibility that the New Mtwara substation may need only a single transformer, because the 132kV transmission line from New Lindi can distribute electricity up to 121MW. If this is possible, it would be economically advantageous, but it has to be studied in detail.

Case B. Lindi Switching station and new 132 kV transmission line

Another method to supply 214MW to Lindi is by the 132kV transmission line from the New Mtwara substation, but it needs two new 132kV transmission lines, because the maximum capacity of a single 132kV transmission line is only 121MW. The proposed system configuration is as follows;

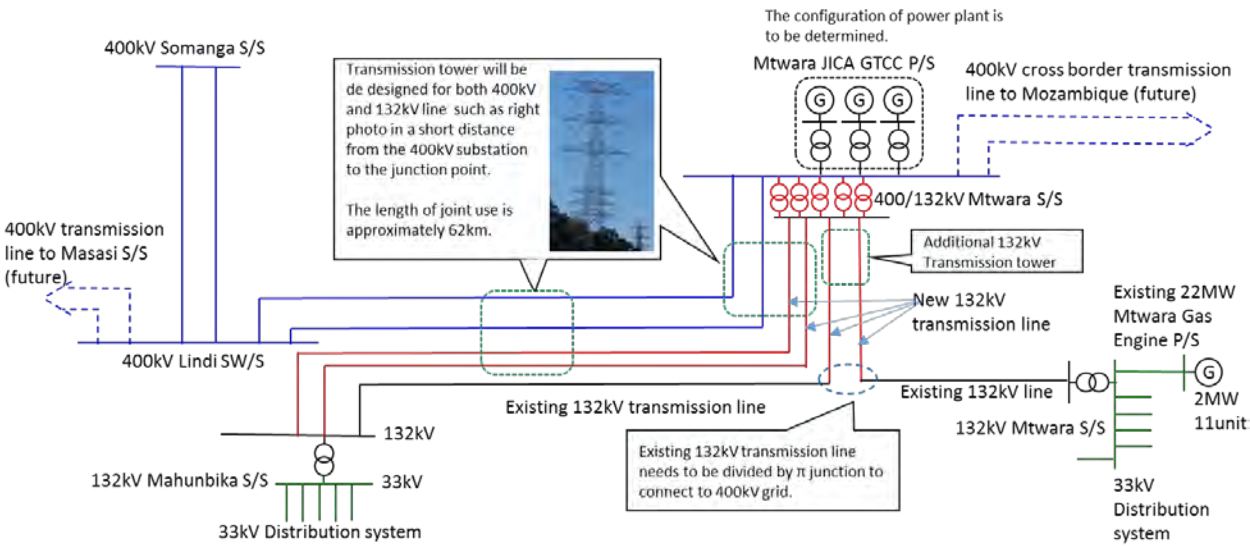


Figure 2-25 System Configuration – Lindi Switching Station Case

If Lindi does not have transformers, Lindi can be treated as a switching station. In this case, the New Mtwara substation must have more than two transformers, and there should be two new circuits of 132kV transmission line from the New Mtwara substation to the Lindi switching station.

The results on comparing these two cases are as follows;

The switching station case (case B) needs two additional transmission lines in comparison with the substation case (case A), in order to supply to the 132kV Mahumbika substation. Moreover, case A has advantages from the view point of not only the system reliability but also the system loss. The detailed comparison is shown in the following table.

Table 2-34 Comparison of Substation and Switching Station for New Lindi

Item		Case	
		Substation (Case A)	Switching Station (Case B)
Transformer Switching Bay	Specification	New Lindi S/S 110MVA x 3 New Mtwara S/S 110MVA x 2	New Mtwara S/S 110MVA x 5 132kV Switching Bay x 6
	Cost	Base	Base + 20.94USD Million
132kV Transmission Line	Specification	9km x 2cct of joint use** 4km new 2cct tower	62km x 2cct of joint use** 13km of new 2cct tower
	Cost	0.34~0.77 (400kV joint tower 9km) + 0.8~1.28 (new 2cct 132kV tower 4km) = 1.14~2.05 USD Million	2.365~5.27 (400kV joint tower 62km) + 2.6~4.16 (new 2cct 132kV tower 13km) = 4.965~9.43 USD Million
Total cost		Base	Base + 28 USD Million (21+7)
System reliability		High	Base
Transmission loss*		Low: 0.7GWh/year	High: 42.2GWh/year
Voltage compensation		Base	Additional compensation devices, such as capacitor are needed for 132kV transmission line.

* Transmission Loss is calculated under the condition: Power flow=214MW, Load factor = 70%

** The cost of 400/132kV joint use transmission line is estimated as 10% of 400kV transmission lines.
Unit Cost source; PSMP 2016 Update
400kV 2cct transmission lines 0.38-0.85 USD Million/km
132kV 2cct transmission lines 0.2-0.32 USD Million/km
132kV Switching Bay 3.49 USD Million/Bay

Based on the above study, the 400kV substation case (case A) is recommended for the power system configuration and to supply electricity to Lindi area.

2.7 SYSTEM RELIABILITY STUDY

In this report, power system study is conducted by using PSSE. PSSE is a tool, which calculates basic factors of power system such as power flow, voltage, short circuit current, and transient stability to evaluate system reliability. The power system is studied for the year 2025, as the Mtwara GTCC power plant will start its operation in 2025. Then, the system is also studied for 2030, 2035, and 2040.

All substations discussed in this Section are 400kV substations, therefore the New Mtwara substation and the New Lindi substation are represented as the Mtwara substation and the Lindi substation respectively.

2.7.1 Preset Condition

The preset condition of this study is as follows;

Transmission line and Transformer:

Although most of the data for system study are based on the PSMP 2016 update, some of the 'transmission line' specifications have been changed according to the results of survey and the discussions with TANESCO. Especially regarding the bundles of conductors, 8 bundles had been applied for the lines: Lindi - Somanga, Somanga - Kinyerezi, Kinyerezi - Mkuranga, Mkuranga - Somanga, Somanga - Chalinze, and Chalinze - Stiegler's Gorge in the PSMP 2016, they have been changed to 4 bundles.

The reason for this change is because the line between Lindi – Somanga has to be completed earlier, so that the new power plants can supply power using this line. And the specification of the other lines mentioned above have also been changed together with the Lindi – Somanga line. These changes are based on the requirements of TANESCO. As a result, the specification of 400kV transmission line is set as follows.

Table 2-35 Transmission Line Models in this Study

No.	From	to	cct	Length (km)	Bundles
1	Mtwara	Lindi	2	59	4
2	Lindi	Somanga	2	209	4*
3-1~4	Somanga	Kinyerezi	2	49.5 x 4	4*
4	Kinyerezi	Chalinze	2	93	4
5	Chalinze	Stiegler's Gorge	2	161	4*
6	Kinyerezi	Mkuraga	2	70	4*
7**	Somanga	Somanga Fungu	1	1	4
8	Mtwara	Mozambique	2	300	2
9	Masasi	Lindi	2	141	4
10	Tunduru	Masasi	2	194	4
11	Songea	Tunduru	2	230	4
12	Ngaka	Songea	2	37	4
13-1~2	Future CGT3-1~2	Songea	2	20	4
14	Chalinze	Somanga	2	284	4*
15-1~3	Somanga	Mkuraga	2	61 x 3	4*

*: 8 bundles in PSMP 2016 Update.
**: The model of the transmission line between Somanga Fungu power plant and Somanga substation is very short, therefore this line model is omitted in the future models.

The system model is created for 2025, as the Mtwara GTCC power plant will start its operation in 2025. And the models of 2030, 2035, and 2040 are for future study. The models are show below.

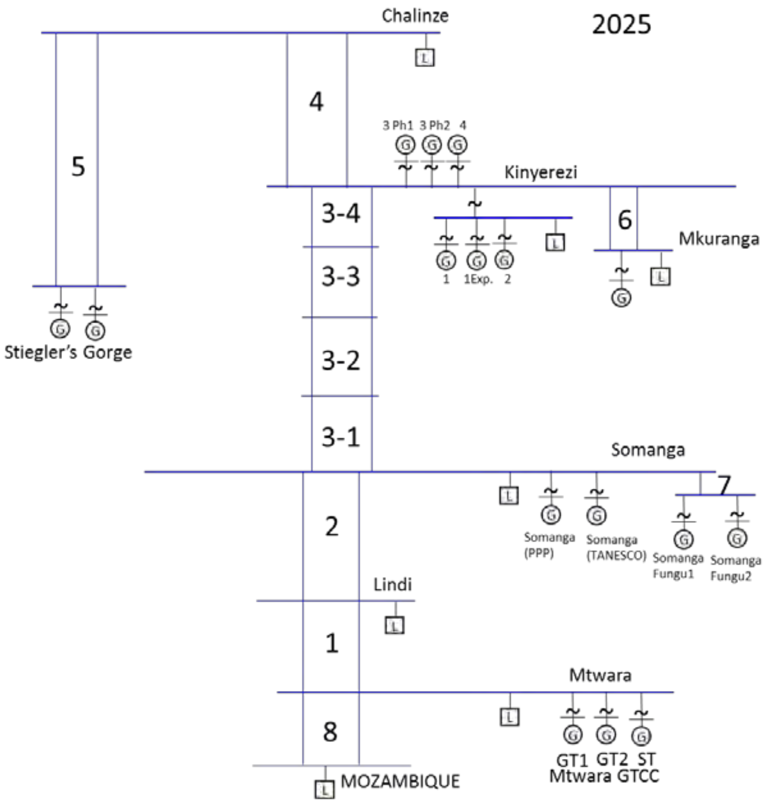


Figure 2-26 System Study Model for 2025

In the models for future system, some simplifications have been applied for efficient simulation.

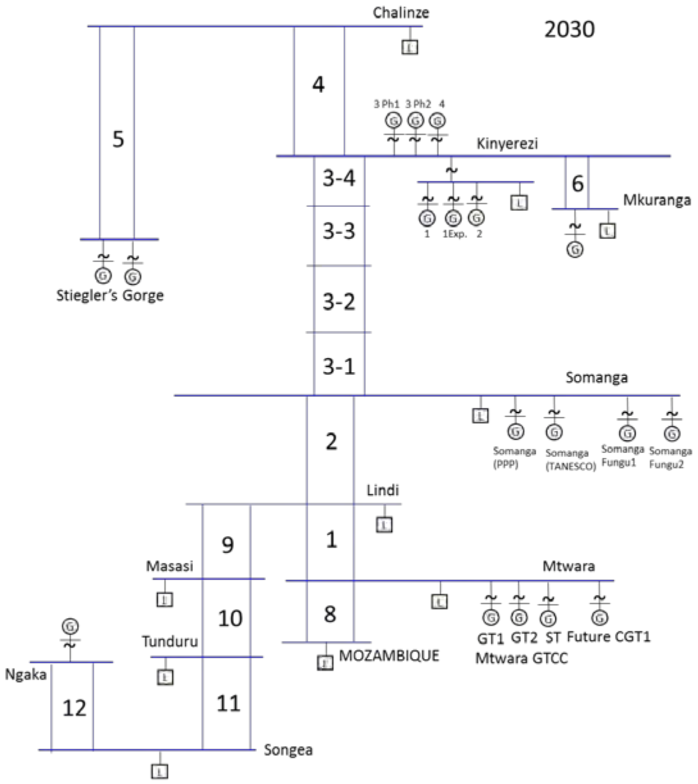


Figure 2-27 System Study Model for 2030

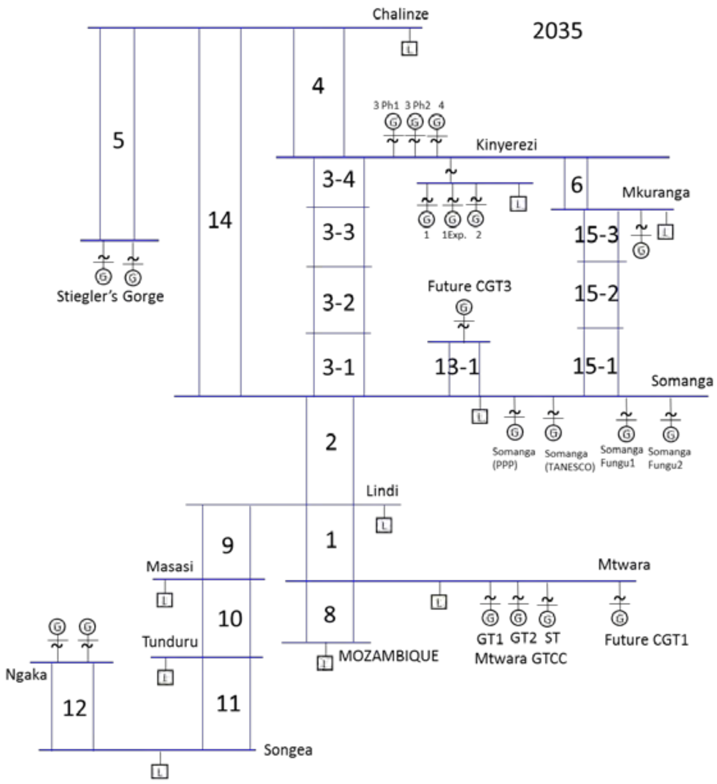


Figure 2-28 System Study Model for 2035

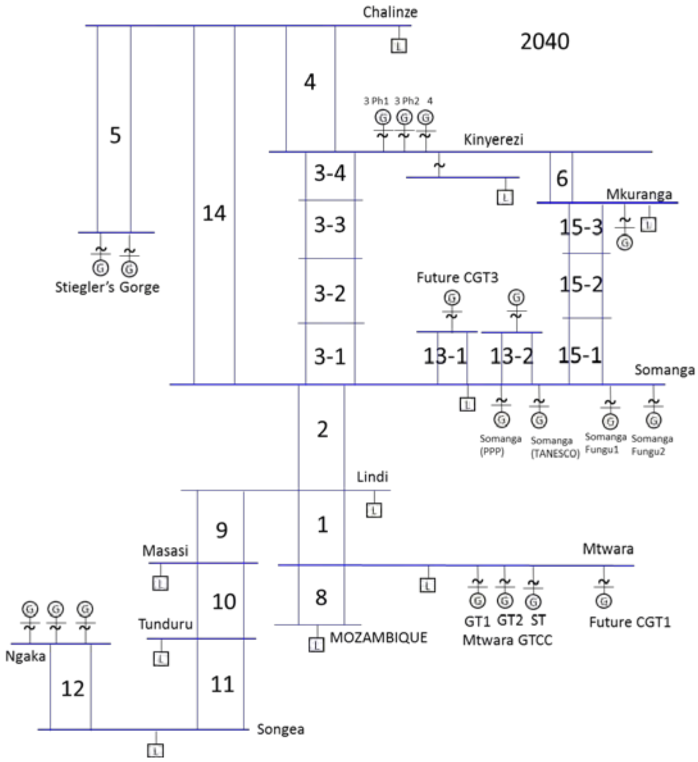


Figure 2-29 System Study Model for 2040

Generator:

Base data from PSMP 2016 Update and some generator data have been updated with the latest information as indicated in Section 2.3, on discussion with TANESCO.

The three candidates of plant model for the Mtwara GTCC power plant are: H-100, SGT-800, and LM-6000PF+. They are all gas turbines. The gross output of GTCC, used for H-100, in this study, is 300.3MW, and this is the largest among all the candidates of this study. The type of GT will be determined in this study, therefore the system reliability study should be conducted for the largest type from the view point of system stability. The bigger the power output of generator, the more severe is the stability. Therefore H-100 model is applied in this system study.

H-100 model: Turbine configuration: 2 set of 100 MW GT and 1 set of 100.3MW ST, total power output is 300.3MW[2]with net output at the site condition.

The configuration and unit capacity of generators should be considered from the view point of system reliability. The maximum capable capacity should be considered from the view point of the system frequency drop when the generators disconnect from the grid, due to a single fault. The consideration of the generator feeder configuration, based on the unit capacity, is explained in Section 4.1.7.

Demand:

Demand data is also set based on the data from Power System Master Plan of Dar es Salaam, and PSMP 2016 Update. Only the demand of Lindi, Mtwara, and Masasi are updated in this study. In order to simplify this Study, the demand of Chalinze, Kinyerezi, Mkuranga, Songea are put together as a load model.

[2] H-100 model is based on 2018 GTW Handbook.

2.7.2 Power Flow Study

The result of power flow calculation for the grid at peak demand in 2025 is shown Figure 2-30. It shows that the power flow on the transmission line between Somanga and Lindi is towards the direction of Lindi, because the total demand of Lindi, Mtwara, and the export to Mozambique is larger than the output of the Mtwara GTCC power plant.

From the view point of the system stability of the Mtwara GTCC power plant, a bigger power flow on the transmission line between Mtwara and Somanga, causes the system to be more severe. The worst condition for system stability will be supposed as the following condition;

- No export to Mozambique
- Demand of Mtwara and Lindi is set as their minimum demand.
- Power output of the Mtwara GTCC power plant is full.

Above conditions makes heavy power flow on the transmission line between Mtwara and Kinyerezi, it represents the severest condition for the generator of the Mtwara GTCC power plant from the view point of internal power angle. Therefore this condition is applied for the study.

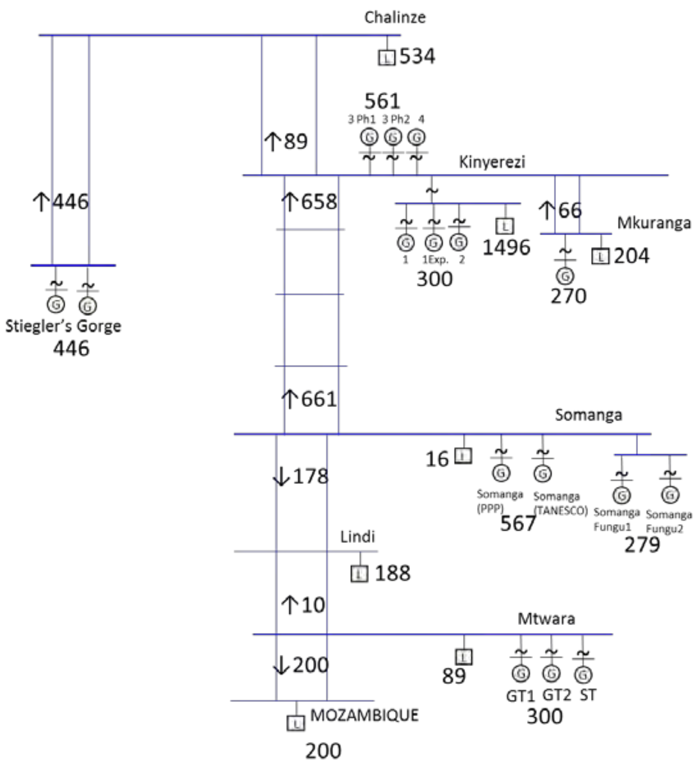
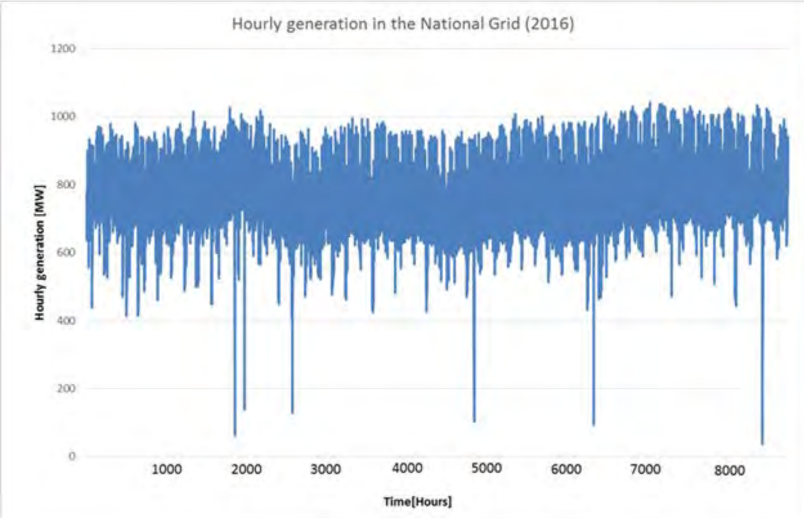


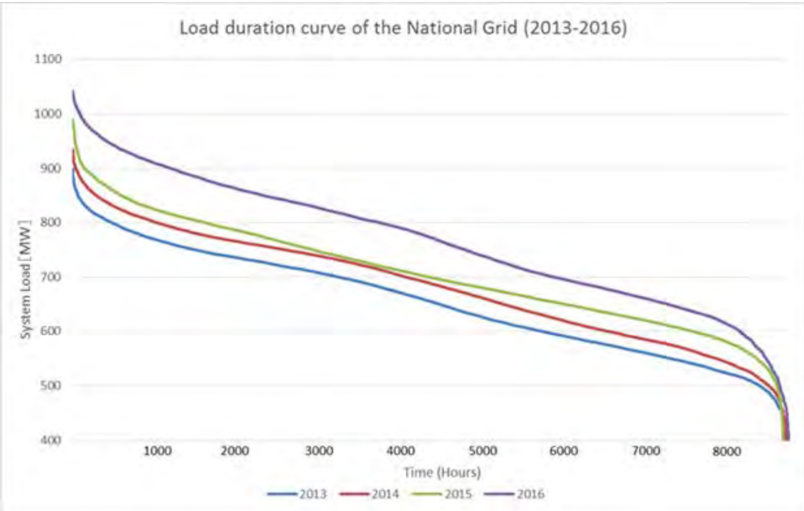
Figure 2-30 Power Flow Calculation for 2025 Grid (Peak Demand)

Figure 2-31 shows the hourly generation of Tanzania's national grid in 2016 and Figure 2-32 shows the load duration curve of Tanzania's national grid in 2013, 2014, 2015, and 2016.



Source: TANESCO

Figure 2-31   Hourly Generation of Tanzania's National Grid (2016)



Source: TANESCO

Figure 2-32   Load Duration Curve of Tanzania's National Grid (2013-2016)

The minimum demand is estimated to be at least 400MW approximately from these data.

On the other hand, the peak demand of 2016 is 1041.63MW, therefore the minimum demand will be set as 38.4% of the peak demand. The forecasted peak demand for the Lindi substation in 2025 is 188MW, therefore the forecasted minimum demand is calculated as 72.19MW. Similarly, the minimum demand of the Mtwara substation in 2025 is calculated as 34.17MW from its forecasted peak demand of 89MW.

Table 2-36 Forecasted Minimum Demand of Substations

Substation	Peak demand in 2025	Minimum/peak	Minimum demand in 2025
Lindi	188MW	400/1041.63 = 0.384	72.19MW
Mtwara	89MW		34.17MW

Power flow calculated with the above conditions is shown in Figure 2-33.

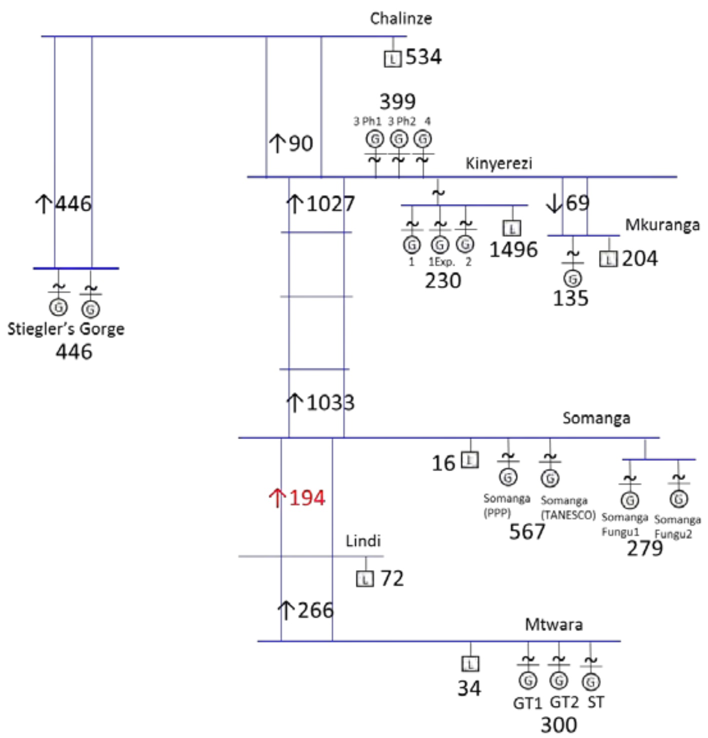


Figure 2-33 Power Flow Calculation for 2025 (Minimum Demand of Lindi and Mtwara)

In this case, the power flow of the transmission line between Lindi and Somanga is 194MW and the power flow is towards the direction of Somanga.

There are no over load transmission lines in this power flow calculation.

The power flow study for the future grid is conducted for the years 2030, 2035, and 2040. Each phase is calculated for base case (peak demand) and severe case, and the severe case is set as the calculated minimum demand of Mtwara, Lindi, Masasi, and Tunduru to maximize the power flow on the transmission line from Lindi to Somanga.

The result of this study is as follows;

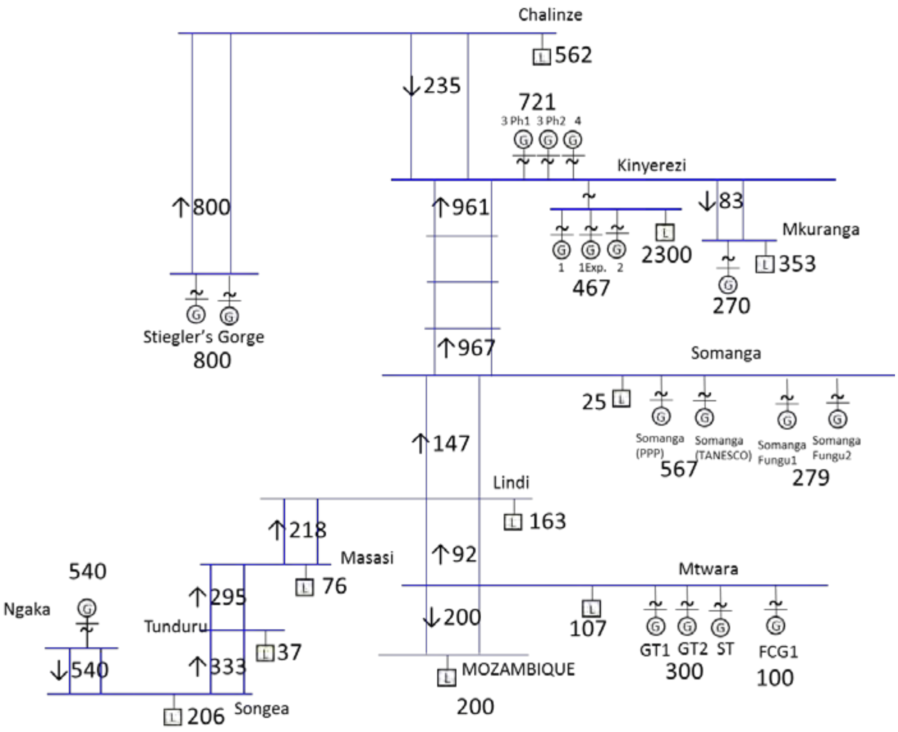


Figure 2-34 Power Flow Calculation for 2030 Grid (Peak Demand)

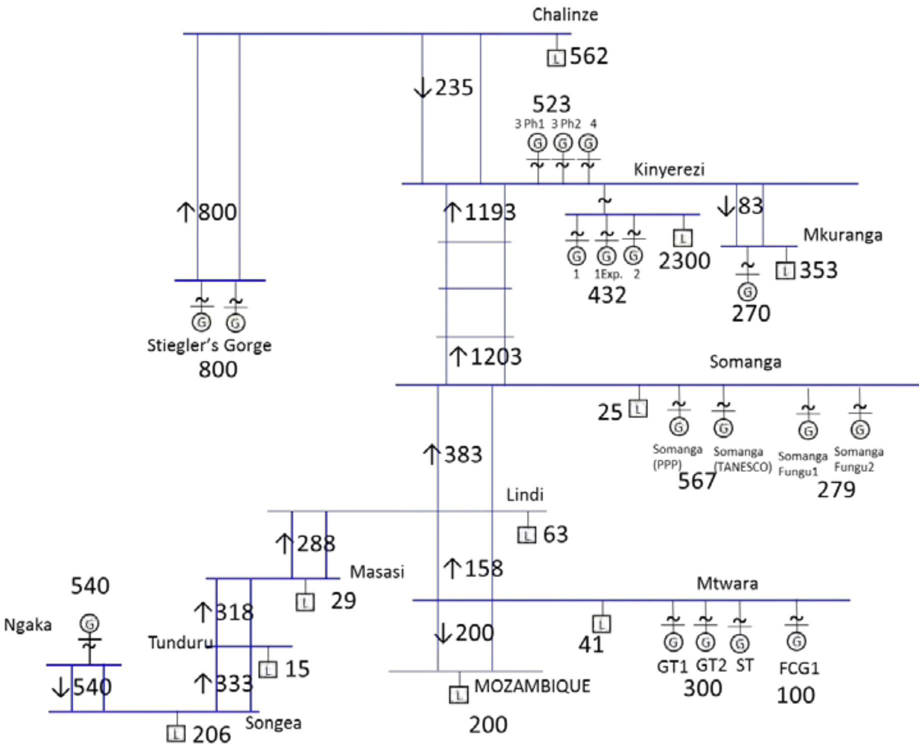


Figure 2-35 Power Flow Calculation for 2030
(Minimum Demand of Lindi, Mtwara, Masasi, and Tunduru)

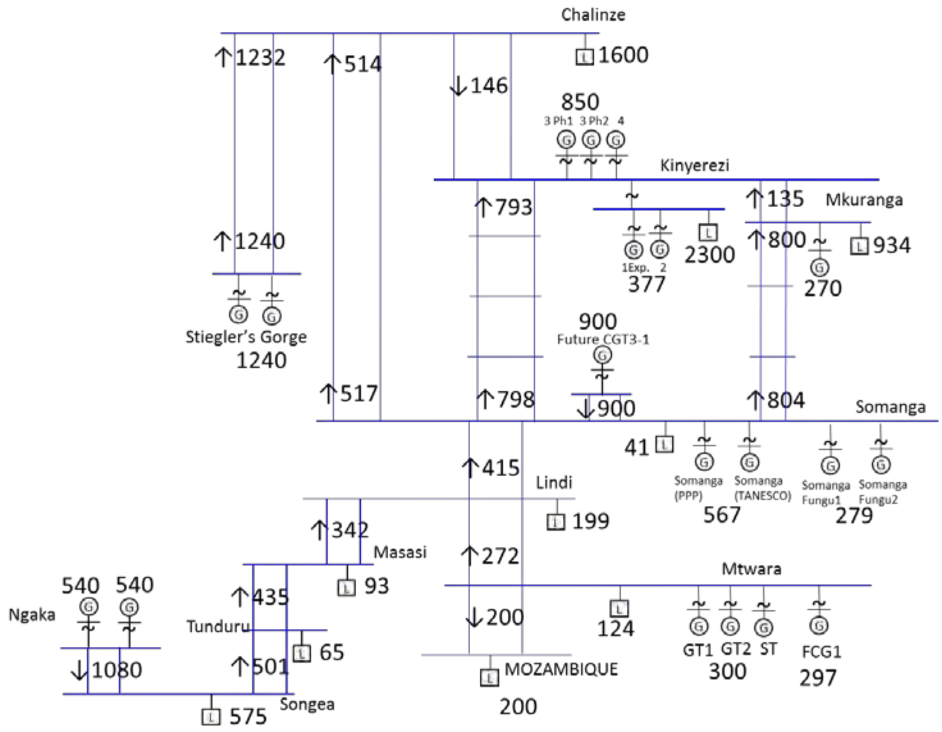


Figure 2-36 Power Flow Calculation for 2035 Grid (Peak Demand)

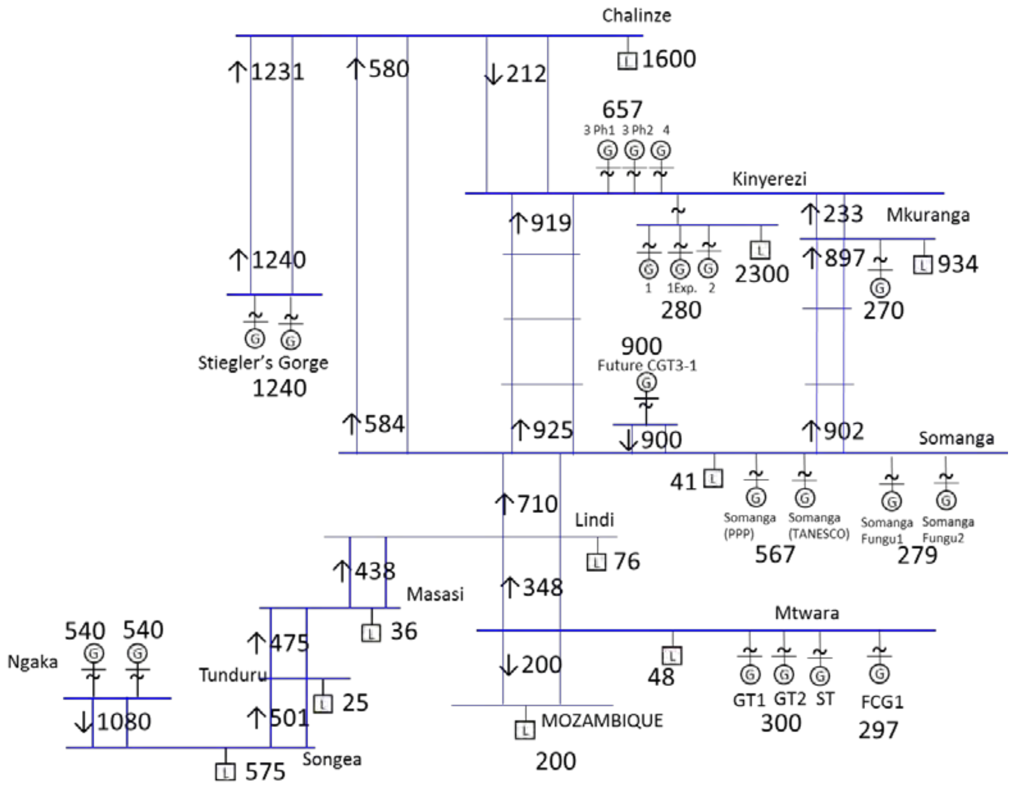


Figure 2-37 Power Flow Calculation for 2035
(Minimum Demand of Lindi, Mtwara, Masasi, and Tunduru)

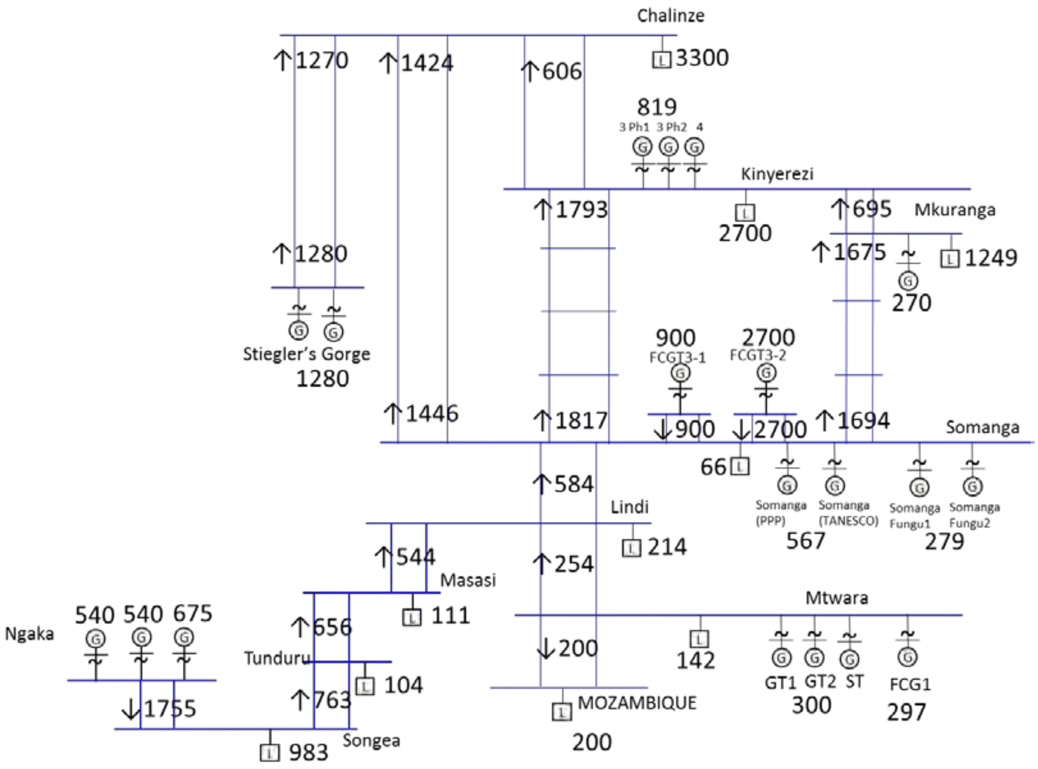


Figure 2-38 Power Flow Calculation for 2040 Grid (Peak Demand)

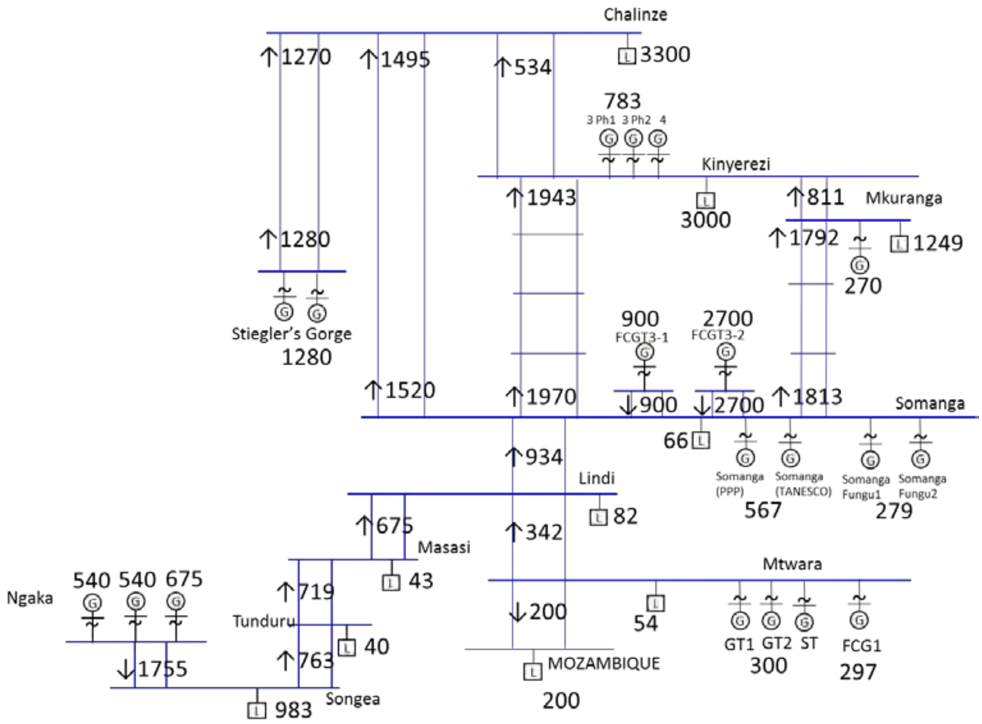


Figure 2-39 Power Flow Calculation for 2040
(Minimum Demand of Lindi, Mtwara, Masasi, and Tunduru)

2.7.3 Voltage Study

The voltage of 400kV bus, used in this model, is calculated for power flow calculation. The voltage profile of 400kV bus for both the cases (base and severe case) of 2025 are shown below;

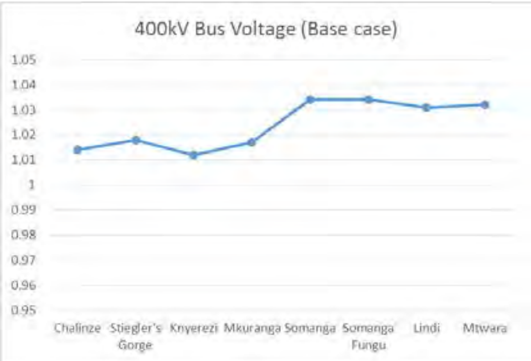


Figure 2-40 Voltage Profile of 400kV Bus of 2025 System (Base case)

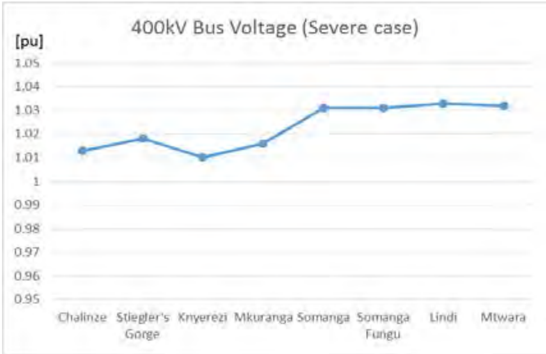


Figure 2-41 Voltage Profile of 400kV Bus of 2025 System (Severe case)

The voltage of 400kV bus stays within the range of 0.95 pu to 1.05 pu for the models of base case and severe case in 2025.

The voltage of all of these substation's 400kV bus stay within the range of 0.95pu to 1.05pu for the future grid model.

In this Study, the voltage of another substation, which is located far away, is adjusted with some reactive power compensation to calculate the transient stability of the future grid. However, the values of Somanga, Lindi, Mtwara, and Masasi substation are not adjusted, which means, the voltage of these substations can be considered reasonable.

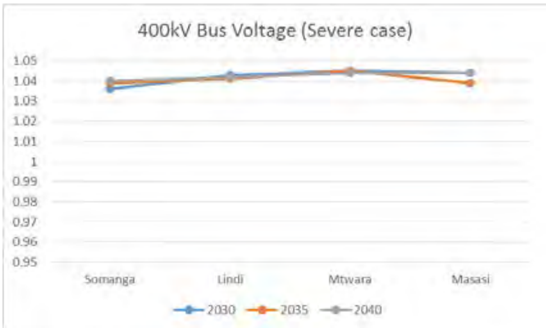


Figure 2-42 400kV Bus Voltage in the Future Grid Model

2.7.4 Short Circuit Current

According to the PSMP 2016 Update, the entire 400/220kV transmission system does not experience any switchgear short circuit rating problems until 2040.

In this study, some modifications have been applied to the PSMP's model of 2040. The changes added are as follows;

- The generator model for Mtwara : 400MW*1 → 100MW*2+100.3MW*1
- The generator model for Somanga (TANESCO) : New 330MW is added

In terms of transmission line length and number of bundles, the below items have been modified.

- Mtwara – Lindi (length)
- Lindi – Somanga (length, bundles)
- Somanga - 3 SW/Ss – Kinyerezi (bundles)
- Kinyerezi – Chalinze (length)
- Chalinze – Stiegler's Gorge (length, bundles)

- Somanga – Mkuranga (bundles)
- Somanga – Chalinze (bundles)
- Kinyerezi – 2 SW/Ss – Mkuranga (bundles)

The result of short circuit current analysis of some major bus around Mtwara is as follows;

Table 2-37 Short Circuit Current in 2040

Bus	kV	Short circuit current (kA)	
		This study	Ref. PSMP 2016 study
Chalinze	400	21.59	24.49
	220	10.85	11.54
Kinyerezi	400	24.16	28.68
	220	33.00	37.59
Mkuranga	400	17.75	23.36
Somanga	400	47.89	50.54
Lindi	400	11.13	14.34
Mtwara	400	9.85	11.03
Masasi	400	7.19	7.93
Tunduru	400	6.89	7.13
Songea	400	15.67	15.78
Ngaka	400	17.12	17.18

Note: FCGT3-3 is included in this system model in order to check the most severe condition

In this study, the number of conductors for some transmission lines have been reduced to 4 bundles from 8 bundles, in order to realize earlier development. If 8 bundles are adopted for the transmission line between Lindi and Somanga, it will take more years for design and construction, when compared with the 4 bundles. JICA Study Team discussed this issue with TANESCO and they stated that they want to have an early launch of the power plant. An early launch is their first priority. Therefore, the usage of 4 bundles is selected for this Project. This is one of the reasons for the difference in short circuit current of the above studies. As a result, it is necessary to apply 63kA rating only for 400kV Somanga, and 40kA rating for other system.

2.7.5 Steady State Analysis

The power system should maintain its stability in both the steady state and the transient state. Steady state stability is confirmed by the stability calculation with the simulation of a normal system operation such as a system switching, or with the simulation of a very light fault such as a very short and natural extinction bus fault.

The fault which is considered for steady state analysis is a bus ground fault on the 400kV Mtwara substation bus, and this fault is cleared within 0.01seconds after its occurrence. This disturbance simulation is generally used for this kind of steady state stability study.

The result of 2025 system model study is as follows;

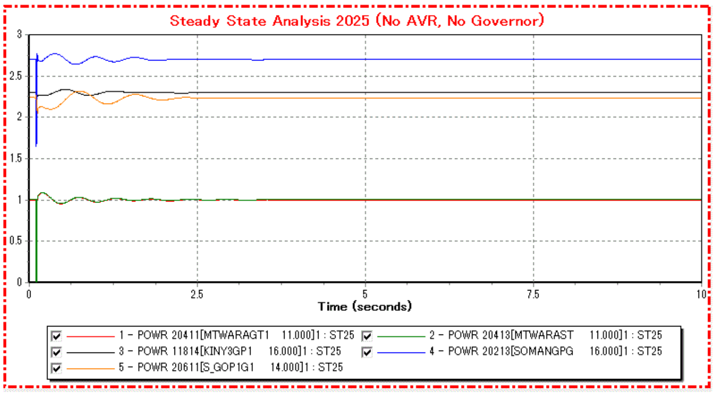


Figure 2-43 Steady State Analysis for 2025 System

The same simulation is conducted with the 2040 model as shown in Figure 2-44.

These calculation results show that there is no problem in the steady state stability of 2025 model and 2040 model, as the study result shows stable condition after the small disturbance.

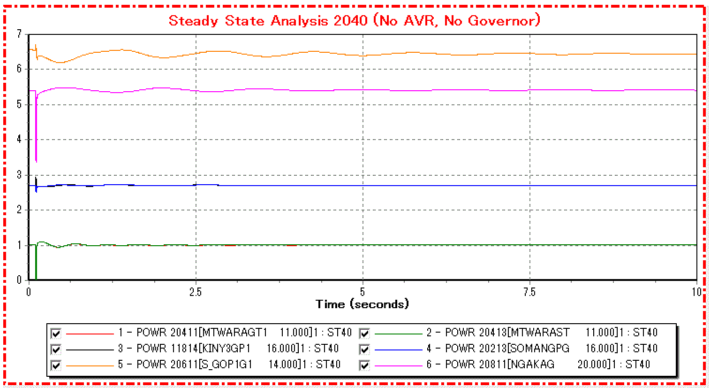


Figure 2-44 Steady State Analysis for 2040 System

2.7.6 Transient Stability Analysis

For the studied power flow condition, the transient stability analysis of the system is conducted. The calculation in the study is done using PSSE with the simulation of system disturbance. In the system planning, the standard fault case for N-1 contingency is 3LG-O, three line ground fault and open. In this Study, 3LG-O simulated sequence is set on several points of the model grid. The procedure of this simulation is shown in Figure 2-45.

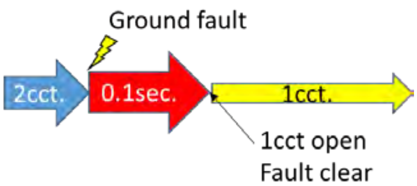


Figure 2-45 3LG-O Sequence

The model image under this simulation is shown in Figure 2-46.

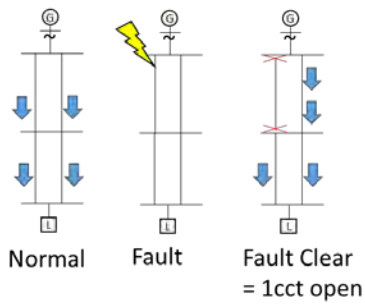


Figure 2-46 Model of 3LG-O Simulation

The fault sequence is as follows; the ground fault is cleared at 0.1 seconds after the fault occurrence, and the transmission line on which the fault occurred is opened for clearing the fault. The clearing time of the fault is set to 0.1 seconds for this study, according to the previous feasibility study. This setting is reasonable and in-line with the Japanese standard of four cycle, 0.08 seconds. 0.1 seconds is greater than 0.08 seconds, which means that this condition has some safety margin.

Figure 2-47 shows the active power output of the major generators. When the three phase ground fault occurs on the transmission line, the active power output of generator has a power swing, but this swing gets converged in a short time. It means this system is stable in terms of transient stability for N-1 criteria.

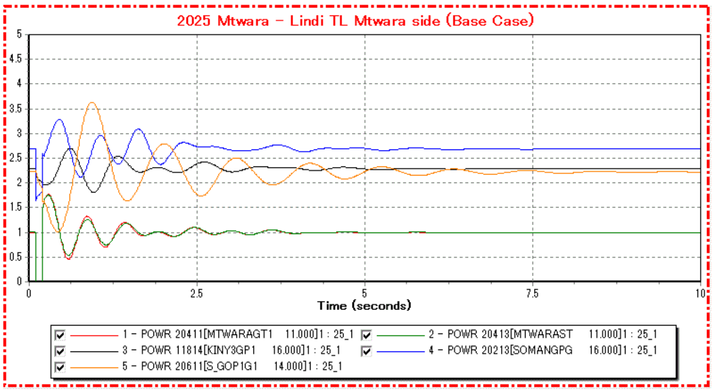


Figure 2-47 Result of Transient Stability Analysis, 3LG-O Simulation

Figure 2-48 shows the fault setting point for each case of this study. Four points are selected as fault points. Case one- the fault point is in Mtwara on the transmission line between Mtwara and Lindi, and this is the point closest to the Mtwara GTCC power plant. Case two- the fault point is in Lindi on the transmission line between Lindi and Somanga. Case three- the fault point is in Somanga on the transmission line between Somanga and Kinyerezi, and case four- the fault point is in Kinyerezi on the transmission line between Somanga and Kinyerezi.

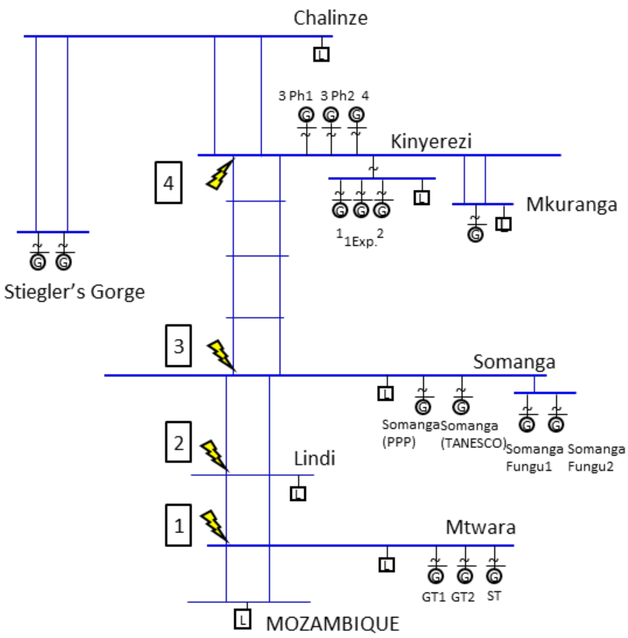


Figure 2-48 Fault Point of 3LG-O in the Transient Stability Analysis

Table 2-38 Summary of Transient Stability Analysis for 2025

Case	Fault transmission line	Fault	Fault point	Result	
				Base case	Severe case
1	Mtwara – Lindi	3LG-O	Mtwara	Stable	Stable
2	Lindi – Somanga	3LG-O	Lindi	Stable	Stable
3	Somanga - Kinyerezi (SW/S 3)	3LG-O	Somanga	Stable	Stable
4	Somanga (SW/S1) – Kinyerezi	3LG-O	Kinyerezi	Stable	Stable

All cases of 2025 model show stable results for 3 phase ground fault and open. Power swings appear in generators, but they converge in a short time. It means this grid has a transient stability for system planning.

Table 2-39 shows the active power output of the respective generators and the calculation results of the four cases for 2025 model using 3LG-O analysis, and Table 2-40 shows the calculation results of severe case for 2025. Table 2-41 shows the substation bus voltage of Mtwara, Lindi, Somanga, and Masasi substations and the generator terminal voltage of Mtwara power plant.

Table 2-39 Results of Calculation by 3LG-O Simulation on 2025 System (Base case)

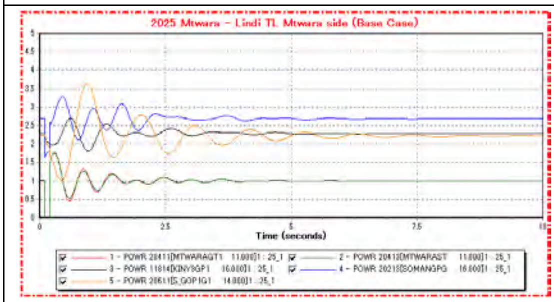
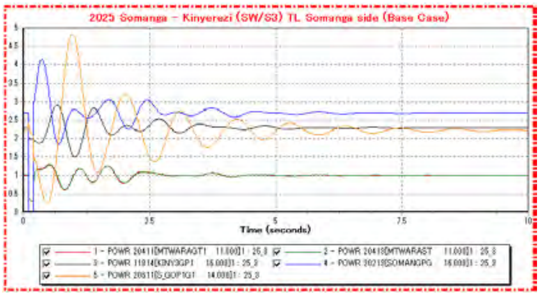
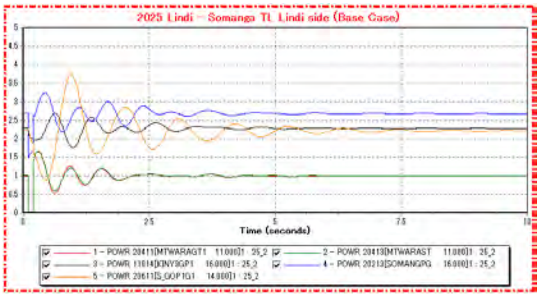
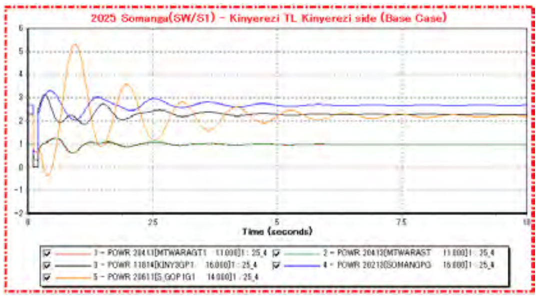
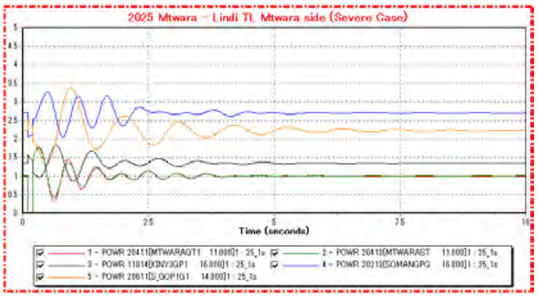
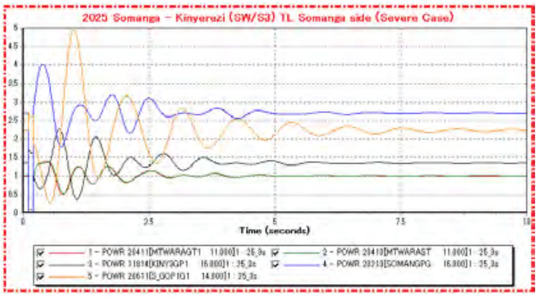
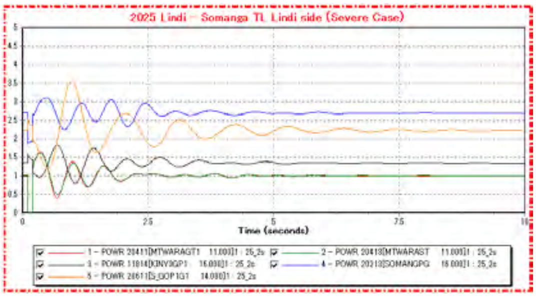
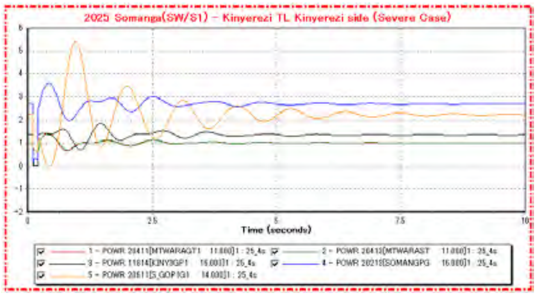
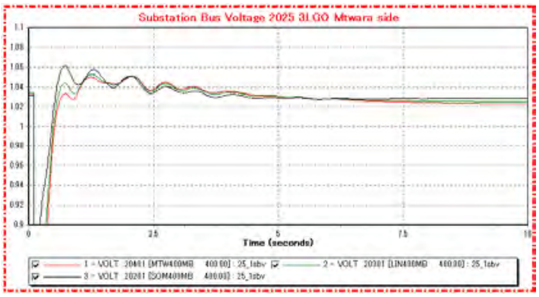
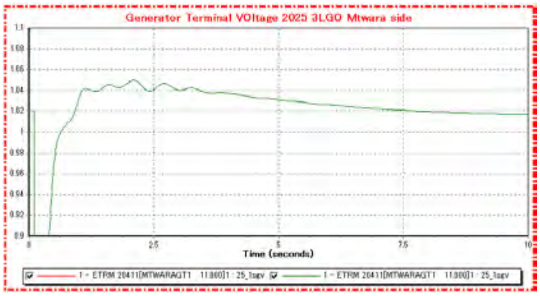
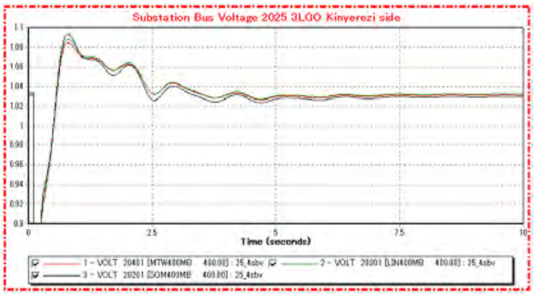
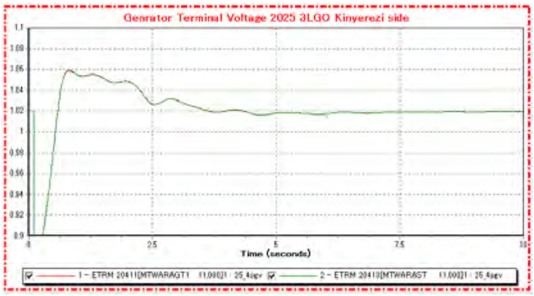
<table>
<tr><th>No.</th><th>Transient Stability Analysis</th><th>No.</th><th>Transient Stability Analysis</th></tr>
<tr><td rowspan="2">1</td><td>3LG-O Mtwara – Lindi T/L Mtwara side</td><td rowspan="2">3</td><td>3LG-O Somanga – SW/S3 T/L Somanga side</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td rowspan="2">2</td><td>3LG-O Lindi – Somanga T/L Lindi side</td><td rowspan="2">4</td><td>3LG-O Kinyerezi – SW1 T/L Kinyerezi side</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 2-40 Results of Calculation by 3LG-O Simulation on 2025 System (Severe case)

No.	Transient Stability Analysis	No.	Transient Stability Analysis
1	3LG-O Mtwara – Lindi T/L Mtwara side 	3	3LG-O Somanga – SW/S3 T/L Somanga side 
2	3LG-O Lindi – Somanga T/L Lindi side 	4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side 

The power swing of Stiegler's Gorge seems big, but this happens because the output of the Stiegler's is the biggest in this model. The power swing convergence could be realized with help of an optimized controller. The fault points of case 3 and 4 are closer to Stiegler's Gorge than that of case 1 and 2. The power swing of the Stiegler's Gorge is bigger for case 3 and 4 than that of case 1 and 2. As for the Mtwara GTCC power plant, the fault point of case 1 is the closest, i.e. the fault point is located on Mtwara side of the transmission line between Mtwara and Lindi. The biggest power swing is observed in the Mtwara GTCC power plant for case 1. However, all cases seem to have no serious problem as per these results.

Table 2-41 Voltage Results of Calculation by 3LG-O Simulation on 2025 (Severe Case)

No.	Substation Bus Voltage	No.	Generator Terminal Voltage
1	3LG-O Mtwara – Lindi T/L Mtwara side 	1	3LG-O Somanga – SW/S3 T/L Somanga side 
4	3LG-O Lindi – Somanga T/L Lindi side 	4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side 

The voltage of the substations and the generator terminal are fluctuating after the fault, but the swing has converged in a short time, and the voltage has returned close to its original value. The voltage after contingency, converged between 90% and 105% which is the standard voltage level during emergency operation condition.

To confirm the stability of the future grid model, the transient stability analysis is conducted for 2030, 2035, and 2040 grid models. The summary of this transient stability study is shown in Table 2-42.

Table 2-42 Summary of Transient Stability Analysis for 2030, 2035, and 2040

Case	Fault transmission line	Fault	Fault point	Result					
				2030		2035		2040	
				Base	Severe	Base	Severe	Base	Severe
1	Mtwara – Lindi	3LG-O	Mtwara	Stable	Stable	Stable	Stable	Stable	Stable
2	Lindi – Somanga	3LG-O	Lindi	Stable	Stable	Stable	Stable	Stable	Stable
3	Somanga - Kinyerezi (SW/S 3)	3LG-O	Somanga	Stable	Stable	Stable	Stable	Stable	Stable
4	Somanga (SW/S1) – Kinyerezi	3LG-O	Kinyerezi	Stable	Stable	Stable	Stable	Stable	Stable

The result of transient stability calculation shows that there are no problems in transient stability.

Table 2-43 and Table 2-44 show the active power output of the generators and some results of transient stability study and Table 2-25 shows the voltage of the substation bus and the generator terminal.

Table 2-43 Some Results of Calculation by 3LG-O Simulation on 2030 and 2035 System (Severe case)

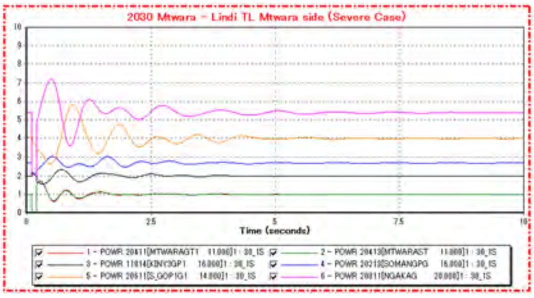
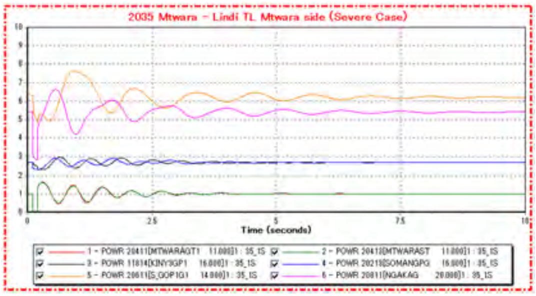
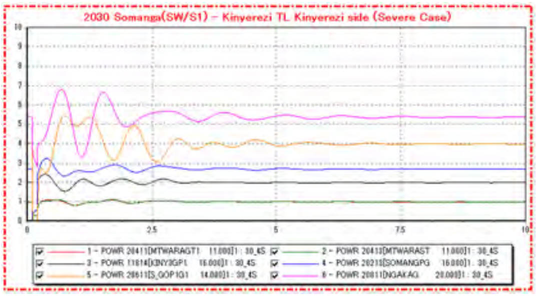
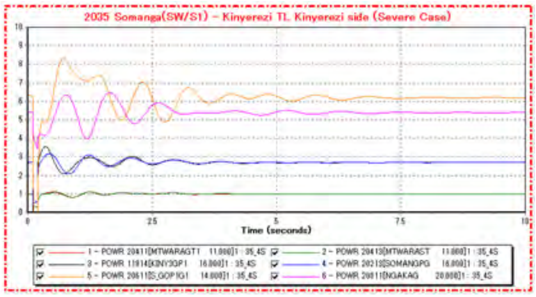
No.	2030 severe case	No.	2035 severe case
1	3LG-O Mtwara – Lindi T/L Mtwara side	1	3LG-O Mtwara – Lindi T/L Mtwara side
			
4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side	4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side
			

Table 2-44 Some Results of Calculation by 3LG-O Simulation on 2040 System

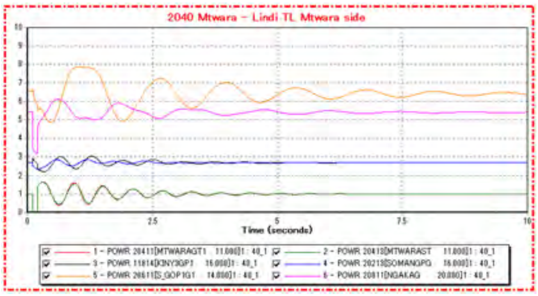
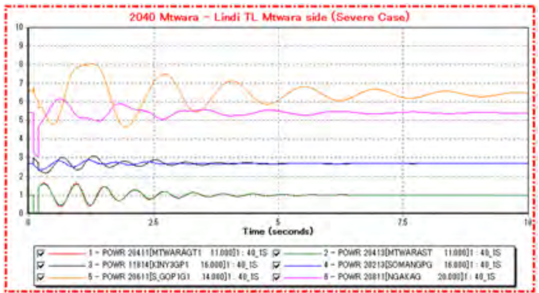
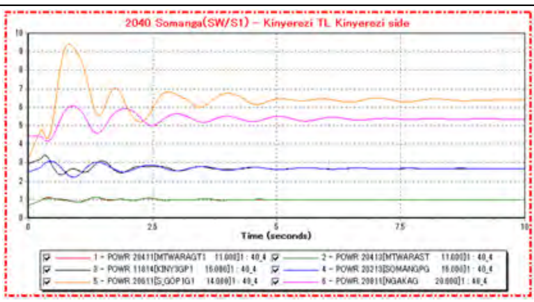
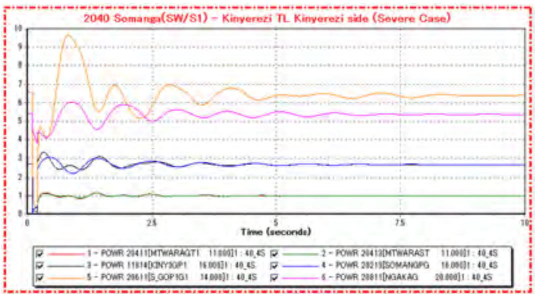
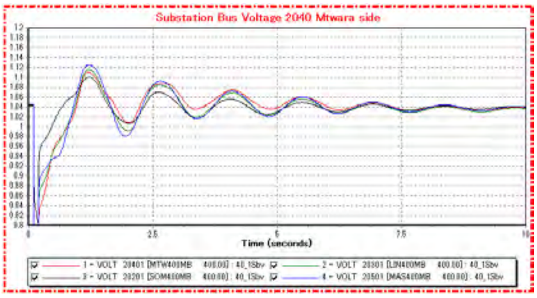
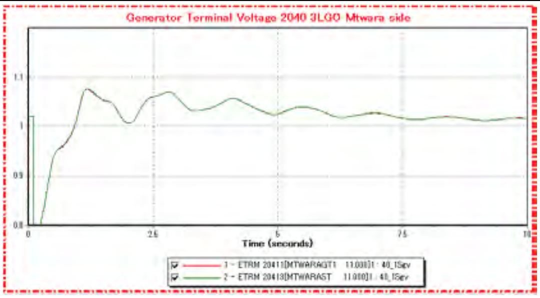
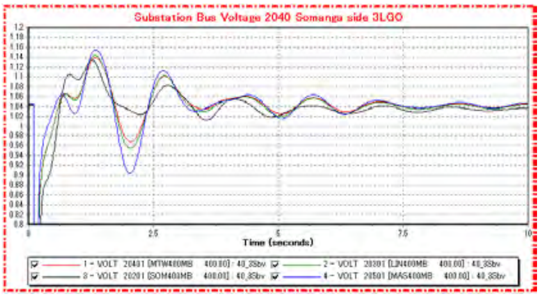
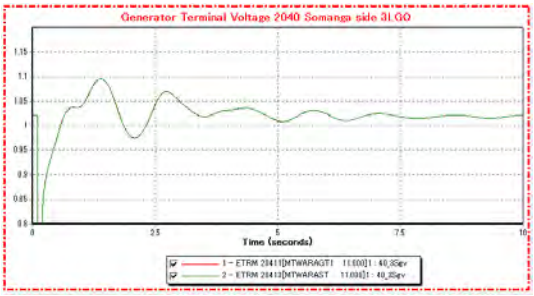
No.	2040 base case	No.	2040 severe case
1	3LG-O Mtwara – Lindi T/L Mtwara side	1	3LG-O Mtwara – Lindi T/L Mtwara side
			
4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side	4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side
			

Table 2-45 Voltage Results of Calculation by 3LG-O Simulation on 2040 Severe Case

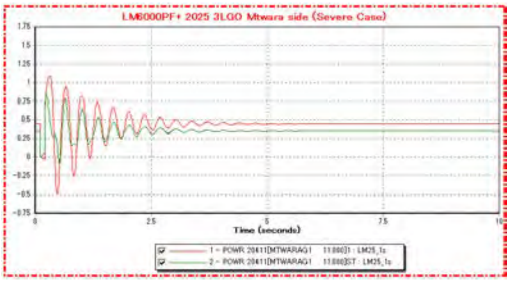
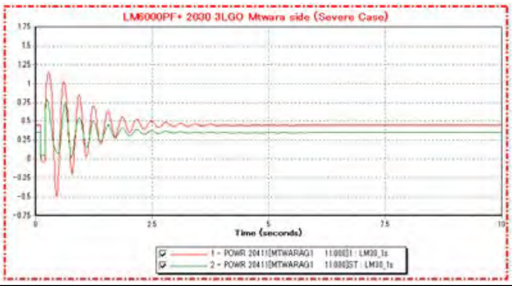
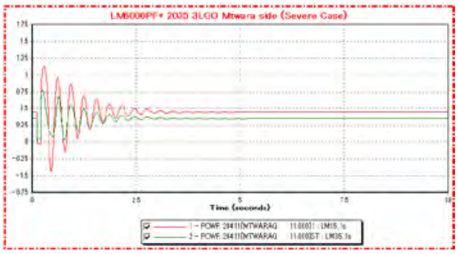
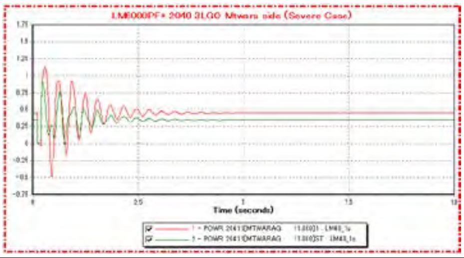
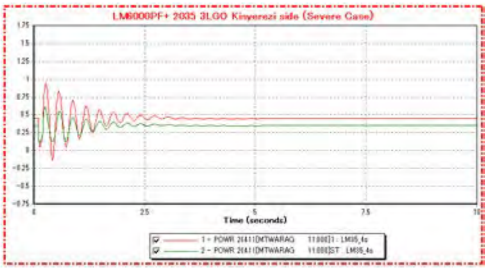
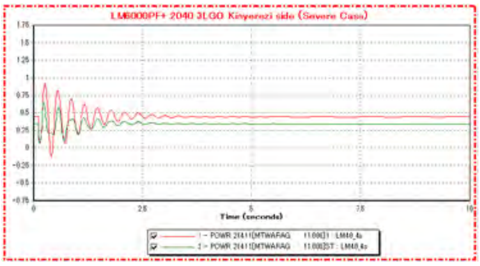
No.	Substation Bus Voltage	No.	Generator Terminal Voltage
1	3LG-O Mtwara – Lindi T/L Mtwara side 	1	3LG-O Somanga – SW/S3 T/L Somanga side 
3	3LG-O Somanga – SW/S3 T/L Somanga side 	3	3LG-O Somanga – SW/S3 T/L Somanga side 

The power swing of the Mtwara GTCC power plant reached close to double of its output in 2040 severe case, but this swing has converged in a short time.

The voltage of the substation bus and the generator terminal have fluctuated, but the swings have converged and returned close to their original value, within the standard emergency operation condition of 90% to 105%.

As for the other generator models, LM6000PF+ is also a candidate for Mtwara power plant. The power flow by this model is smaller than H-100 model, but LM6000PF+ is an aero derivative type turbine that has smaller inertia than H-100, a heavy duty type. This means the transient stability of this type may be more vulnerable than others. The transient study of this is confirmed. The result of calculation is as follows;

Table 2-46 Transient Stability Calculation Results of LM6000PF+

No.	2025 Severe case	No.	2030 severe case
1	3LG-O Mtwara – Lindi T/L Mtwara side	1	3LG-O Mtwara – Lindi T/L Mtwara side
			
4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side	4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side
			
No.	2035 Severe case	No.	2040 severe case
1	3LG-O Mtwara – Lindi T/L Mtwara side	1	3LG-O Mtwara – Lindi T/L Mtwara side
			
4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side	4	3LG-O Kinyerezi – SW1 T/L Kinyerezi side
			

An aero derivative model is lighter than a heavy duty model, therefore swing cycle is faster than H-100. However the power swings have converged in a short time in all cases, this indicates that it is also stable.

The result of study shows no significant problem in the future grid.

2.8 RELEVANCE OF THE MTWARA PROJECT

According to PSMP 2016 Update, Tanzania will need a power capacity of 4,915MW in 2020, more than 10,000MW in 2030, and more than 20,000MW in 2040. Power development is needed to meet these targets for stable supply and for national development. The total amount of power generation development is around 4,000MW until 2020, around 5,000MW between 2020 and 2030, and more than 10,000MW between 2030 and 2040. PSMP 2016 Update outlines the development plan, but there has been a delay in the development of many thermal power projects, which were originally planned to be completed in 2010s and early 2020s. Moreover, the coal-fired power plant needs mine development and careful environmental survey, which means that it may take a long time to realize it. The gas-fired power plant is the most suitable power source in the situation, where a certain amount of capacity is required in a short period. JICA conducted data collection survey of gas thermal power generation in the United Republic of Tanzania in 2016 (Basic Survey (2016)) to select a proper site for the new generation plant, in order to meet the growing power demand of Tanzania in a short term. A secure finance is important to promote the power plant project in such a situation. Recently, it appears that the EPC plus finance scheme is preferred over the IPP scheme for its financial certainty to carry out the projects in Tanzania.

In this Section, the relevance of the Mtwara GTCC power plant and 400kV transmission line project is explained from the view point of power demand, power system, and location.

2.8.1 Relevance from the Viewpoint of Demand

(1) Probable Energy Source for both the Southern region and Economic center

The Mtwara GTCC power plant and 400kV transmission line project is expected to advance the reliably under the current situation of Tanzania, and it is expected to have a positive impact on the projects related to the future development of the bulk power system of the national grid from the view point of not only the power supply, but also the reinforcement of Southern grid. Southern grid is a part of the national grid and it will connect to Mozambique and southwestern regions such as Ruvuma and Njombe. Southern grid will play an important role as the connecting point for Dar es Salaam, Mozambique, and southwestern region to transport electricity.

The development of Lindi region and Mtwara region faces some challenges in terms of energy supply and the prospect of infrastructure development, in spite of the existence of mineral resource in these regions. Therefore, a positive development has still not happened. There are a dilemmas as the industries have not developed due to underdevelopment of infrastructure, and the development of infrastructure has not happened due to the underdevelopment of industries.

The development of the Mtwara GTCC power plant may have the potential to enable power supply, in order to develop regional industries such as agricultural industry and mineral industry, which are expected in Lindi and Mtwara region. In this regard, the project of the Mtwara GTCC power plant and 400kV transmission line is expected to be the key project to not only provide power supply to the entire national grid, but also to contribute to the economic development of southern region.

(2) Contribution towards Local Electrification

It is necessary to supply to the new power demand which is resulted according to the progress of REA program in the Mtwara and Lindi regions. Considering the forecasted power demand in Table 2-28 including REA program, the implementation of Mtwara GTCC project will cover the amount of demand and contribute to the electrification in the regions.

2.8.2 Relevance from the Viewpoint of Power System

(1) As a part of the National Grid

As of now, Mtwara and Lindi region are supplied from an isolated grid, and not from the national grid, hence the current capacity of power is insufficient to supply for the future development, projected in these regions. A serious black out occurred in this region due to the troubles caused by generators in 2017. People living there didn't have electricity for ten days until the repair parts of generators arrived. One of the reasons for this accident may be the isolated grid situation. If the grid was connected to the national grid, they would receive reserve electricity from the grid. From the view point of the supply reliability, the grid connection is one of the answers to solve such troubles. This Mtwara GTCC power plant and the transmission line project can become the best answer not only from the view point of sufficient power capacity, but also from the view point of power supply from a stable grid.

Moreover, Mtwara is an important point, connecting to Mozambique. The MOU of electricity trade was concluded between TANESCO and EDM (Electricidade de Mozambique) in 2014 and it was updated in June 2018. The MOU between the government of Tanzania and the government of Mozambique is now in its final stages. When the interconnection between Tanzania and Mozambique is completed, the transmission line between Mtwara and Somanga will become more important. Lindi is proposed as a connecting point to southwestern region in PSMP 2016 Update. Based on this plan, the transmission line from Mtwara- Lindi- Somanga is one of the most important parts in the future national trunk line of Tanzania.

(2) Energy Security

There are long gas pipe lines between Mtwara region and Dar es Salaam, but the capacity to send gas is limited. Sending energy from Mtwara to Dar es Salaam in the form of electricity will contribute to securing energy in Dar es Salaam, because the capacity of gas pipe line can be saved, in case of alternative energy transport by gas and electricity. Therefore, it is preferable to have a new power plant in Mtwara for energy security.

2.8.3 Relevance from the Viewpoint of Location

A 36 inch gas pipeline from Mnazi Bay gas field (Mtwara) to Dar es Salaam, along the east coast of Tanzania, has been in operation since 2015. Therefore, new gas turbine power plants are planned to be installed along the gas pipeline.

TANESCO plans to develop two (2) GTCC power complexes (PCs) and two (2) GTCC power plants (PPs) by utilizing the gas pipeline. The two (2) GTCC power complexes (PCs) are: the Kinyerezi Power Complex and the Mtwara Power Complex, and the two (2) GTCC power plants (PPs) are: the Somanga (TANESCO) and Somanga (PPP) as shown in Figure 2-49.

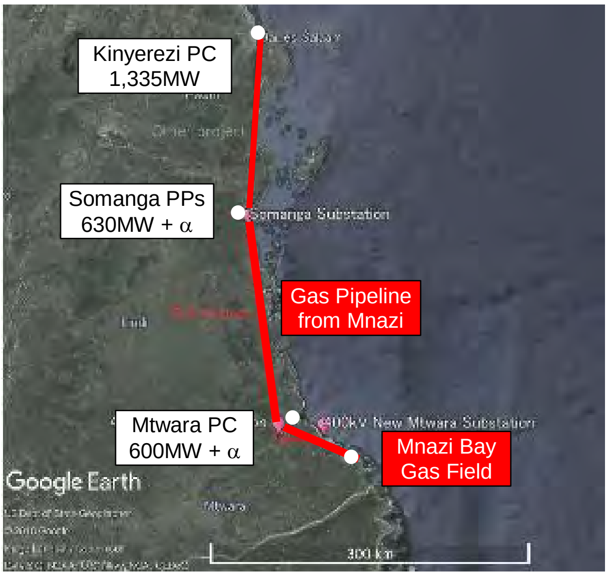


Figure 2-49 Locations of Planned Power Complex and Power Plants

Figure 2-50 Green Color Belt of the Seashore Line

The 400kV transmission line for these PCs and PPs is planned to be installed along the east coast of Tanzania. Therefore, the following points are recommended for the site location of this Project;

1) A location, along the east coast of Tanzania, which is near the gas pipeline and the 400kV transmission line.

2) A location, close to the sea to adopt seawater cooling system that provides the highest efficiency of GTCC among the condenser cooling system of steam turbine.

The Kinyerezi Power Complex is located in Dar es Salaam, and Kinyerezi I has already been put into operation, Kinyerezi II is now under commercial operation and Kinyerezi III and IV are being planned. Although this complex is suitable to supply power to Dar es Salaam, there is no room to install the new GTCC power plant in the premises of the complex, because the complex is surrounded by households and cannot be expanded.

Such being the case, in 2014, TANESCO investigated the Mkuranga sites, which are around 50km away in a linear distance from Dar es Salaam. TANESCO intended to apply the seawater cooling system for the Project, however, the sea is shallow and seashore line is covered by thick mangrove trees. As a result, TANESCO gave up on the adoption of seawater cooling system, and the sites, which were 1.7~4.6km away from the seashore line were selected as candidate sites, to avoid the villages and/or households along the seashore line.

Through the screening works of the Basic Survey (2016), the JICA Study Team excluded the 3 sites of Mkuranga, as it is not only difficult to adopt the seawater cooling system, but also it is far away from the planned 400kV transmission line and the gas pipeline.

JICA Study Team checked the area through Google Earth and found that the seashore line from Dar es Salaam till the Mkuranga site is covered by green color belt as shown in Figure 2-50. The belt seems to indicate a shallow sea and the existence of thick mangrove trees.

The Somanga Power plants are located in the extensive wetland area, nominated as the sanctuary by Ramsar Convention. Therefore, the site is recommended to avoid as much as possible.

Therefore, JICA Study Team focused on Mtwara and Lindi areas for the candidate sites of the Project. Although the seashore lines of Mtwara and Lindi areas are also covered by green color belt, the Kisiwa Bay in Mtwara area and a part of the Mikindani Bay are not covered by the green belt. JICA Study Team confirmed by site reconnaissance that both sites have the possibility of adopting seawater cooling system.

The rise in efficiency of GTCC, caused by adopting the seawater cooling system instead of the air cooling system, is higher than the transmission loss expected between Mtwara to Dar es Salaam. The location in Mtwara is advantageous than the location around Dar es Salaam, as TANESCO must adopt the air cooling system if the GTCC is constructed in Dar es Salaam.

Adoption of the sea water cooling system for the Mikindai site seemed to have no problem, because the site faces outer sea. On the other hand, the Kisiwa site is located inside the Kisiwa Bay, therefore, the possibility of adopting seawater cooling system needed to be determined by the hot seawater simulation.

The best candidate site is determined through the Study based on the environmental conditions of the sites and the hot seawater simulation results, etc.

The details are explained in Chapter 3 Site Selection.

CHAPTER 3

SITE SELECTION

CHAPTER 3 SITE SELECTION

3.1 PREHISTORY

3.1.1 Basic Survey (2016)

The Basic Survey (2016) was carried out during July ~ December 2016. TANESCO proposed 9 candidate sites for the construction of the new 300MW class GTCC to JICA based on "Site Earmarking Report for the Proposed Mkuranga 250MW GTCC Power Plant Project" by TANESCO and USAID, conducted in 2014.

(1) Screening of the candidate sites

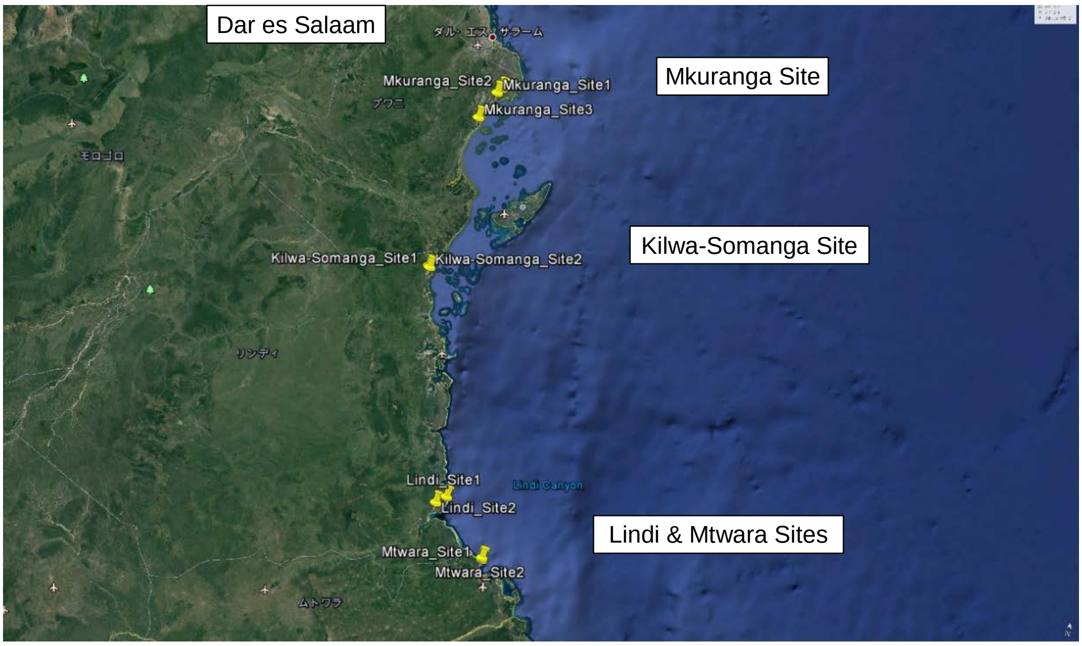
Due to the restriction in site survey period (1 week), JICA Study Team narrowed 9 candidate sites down to 4 sites by screening the candidate sites for the 15 checklist items with TANESCO.

Locations of candidate sites are indicated in Figure 3-1, and the screening results are shown in Table 3-1.

As a result of the screening, 3 sites of Mkuranga were excluded. Because the sites were not close to the seashore, which meant that the sea water cooling of ST was difficult. On top of that, according to TANESCO's information, these 3 sites were far from the main road and the planned 400 kV transmission lines (refer to Table 3-1).

With regard to the 2 sites of Kilwa-Somanga, these sites were also excluded. Because the sites were located in the vast wetland designated as sanctuary by Ramsar Convention although the distance from the gas valve station to the sites was the shortest.

As a result, 2 sites of Lindi and 2 sites of Mtwara were selected for investigation.



Sources: JICA Study Team

Figure 3-1 Candidate Sites for Screening

Table 3-1 Screening of Candidate Sites

Good Bad Worst

No.	Check Item	Mkuranga			Kilwa-Somanga		Lindi		Mtwara	
		Site 1	Site 2	Site 3	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
1	Power Demand	We assume that there is a strong power demand								
2	Transmission Line	400kV transmission lines will be constructed in 2019. But Mkuranga sites are apart 40km from the transmission lines,					Request to construction a new gas-fired power plant with 400kV transmission lines is issued by Tanzania Government.			
3	Gas Supply Capability	It is confirmed that gas supply to a new gas-fired power plant (300MW class) is capable by the gas supply and demand balance of PSMP.								
4	Gas Pipeline Length	Distant (18~25 km)			Very short (0.4~1.2 km)		Distant (27~35 km)		Short (13)	Distant (20)
5	Power demand near Site	Dar es Salaam			-		LNG terminal (future)		Cement, Nickels, Graphite factories	
6	Cooling Water System for Steam Turbine	It seems to be air cooling due to long distance from the sea (1.7~4.6 km)					Possibility of sea water cooling (0.4~0.6km)		Same as Lindi (0.8km)	Same as Mkuranga (4)
7	Raw Water Supply	Raw water supply is crucial. Desalination plant (for whole area) or Town water (possibility only for Mtwara and Kilwa)								
8	Unloading/Transportation of Heavy Equipment	Dar es Salaam Port, then land transportation. But sites are apart from 45km from main road.			There is a port in Kilwa. (Reinforcement be required)		Jetty at the site seems to be required.		Same as Kilwa-Somanga site	
9	Land Space	By the site inspection								
10	Easiness of Land Acquisition	In general, land acquisition is not difficult in Tanzania.								
11	Site Conditions (Topography, Geology, Fault Zone)	Topography, Geology: By the site inspection Fault Zone: No fault zone in these area								
12	Oceanography (Sea level, Tidal wave, Tidal flow)	In general, sallow sea in these area, but deep sea are expected in Kilwa and Mtwara port sites (confirmed by the site inspection).								
13	Environmental Issue (Protected Area, etc.)	Mangrove forest. (cutting it needs permission from Authority)			Extensive wetland designated as the sanctuary by Ramsar Convention		Mangrove forest. (cutting it needs permission from Authority)			
14	Site Population	Unpopulated area								
15	Fishery Activity	Exclusive use of sea in front of a new gas-fired power plant is possible due to minor fishery activity.								
Overall Evaluation		Rank 3			Rank 4		Rank 2		Rank 1	

Note: Rank 1: Best, Rank 2: Better. Rank 3: Worse, Rank 4: Worst

Source: JICA Study Team

(2) Evaluation of Investigation Results

The site reconnaissance was implemented during August 29 ~ September 2, 2016. In the course of site reconnaissance, 1 site of Lindi and 2 sites of Mtwara were additionally investigated, therefore, totally 7 sites were investigated. Table 3-2 shows the reasons for selecting the investigation sites.

Table 3-2 Reasons for Selecting the Investigation Sites

	Name of Site	Reason
Mtwara	Mtwara Site 1	The site selected by TANESCO's investigation in 2014.
	Mtwara Site 2	Ditto
	Mtwara TANESCO Site	The site that TANESCO plans to obtain (**Kisiwa Site** in the Preparatory Survey)
	Mtwara New Site	The site that is found in the course of discussion with Mtwara Local Government (**Mikindani Site** in the Preparatory Survey)
Lindi	Lindi Site 1	The site selected by TANESCO's investigation in 2014.
	Lindi Site 2	Ditto, and the site is former/old TANESCO's DG P/S
	Lindi New Site	The site proposed by TANESCO

Sources: JICA Study Team

Figure 3-2 shows the location of reconnaissance sites along with the gas pipeline and its valve stations, water pipeline from the Ruvuma River and its intake point and water storage tanks.

Sources: JICA Study Team

Figure 3-2 Location Map of Reconnaissance Sites and Relevant Facilities

During the site reconnaissance, topography/ geology/ oceanography of sites, water supply prospect, length and condition of access roads, distance from gas valve stations, heavy equipment unloading capacities of ports, the inhabitants around the sites, local power demand and environmental issues were investigated. As for the distance from the future 400kV transmission lines, it was excluded because its route was unclear at that time.

The site reconnaissance's results of Mtwara and Lindi are summarized in Table 3-3 and Table 3-4 respectively. The last row of these 2 tables shows the overall ranking of the investigated sites. JICA Study Team, a JICA expert and TANESCO engineers, agreed that the Mtwara new site (Mikindani site in the preparatory survey) is the most feasible site to construct the new power plant (300MW class GTCC).

Table 3-3 Site Reconnaissance Results (Mtwara)

No	Item	Candidate Sites			
		Mtwara Site 1	Mtwara Site 2	Mtwara TANESCO Site	Mtwara New Site
1.	Topography	Coastal flat low land with about 1 m - 2 m above sea level. Empty land with bush and many Baobab trees, without agriculture. Enough space for a 300MW class GTCC.	Coastal flat land with about 4 m above sea level. Empty land with bush and only a few Baobab trees, without agriculture. Enough space for a 300MW class GTCC.	Flat high land with 40 ~ 50 m above sea level. Empty land with bush without agriculture. Enough space for the gas-fired power plant complex (1 km x 1 km).	The site is located at the edge of small peninsular. Coastal flat land with about 4 ~ 5 m above sea level. Empty land with bush and only a few Baobab trees (5 trees), without agriculture. Space seems to be enough for a 300MW class GTCC.
2.	Geology	Silty sand with outcrop of rock and coral rock. No fault Zone.	Silty sand with outcrop of rock and coral rock. No fault Zone.	Silty cray with outcrop of rock. No fault Zone.	Silty sand with outcrop of rock and coral rock. No fault Zone.
3.	Oceanography	Shallow sea with beach and lagoon, without mangrove trees. Deep water is expected more than 2 km form shore.	Shallow sea with beach and lagoon, with only a few mangrove trees. Deep water is expected at 1 ~ 2 km form shore.	The site is about 300 m away from the edge of narrow bay.	Deep sea with narrow beach, with only a few mangrove trees. Deep water is expected at about 0.6 km form shore.
4.	Raw Water Supply	There is the Mtwara Ruvuma River Supply Project. The design has finished and MOF is now reviewing the financial items. After approval by MOF, it takes about 2.5 years to complete the project. Supply capacity in 2022 is about 50, 000 m^3/day. Although water supply area is south region from the airport, it is possible to supply water to the 300MW class GTCC (water demand is about 300 m^3/day). Water will be supplied from 1,000 m^3 water storage tank at Mikindani by water piping. The distance between the Ruvuma River and the water storage tank in Mikindani is about 60 km.			
5.	Road	The distance of access road from main road is about 5 km with 3 ~ 5 m width and unpaved.	The distance of access road from main road is about 6.5 km with 3 ~ 5 m width and unpaved.	The distance of access road from main road is about 7 km.	The distance of access road from main road is about 8 km with 4 ~ 6 m width and unpaved.
6.	Length of Gas Pipeline	Distance from BVS 01 is about 13 km.	Distance from BVS 01 is about 20 km.	Distance from BVS 01 is about 9 km.	Distance from BVS 01 is about 13 km.
7.	Distance to 400kV T/L	Later	Later	Later	Later
8.	Mtwara Port	1 x 100 ton mobile crane, 1x 120 ton mobile crane (adjacent oil company's property). Wharf length is 385 m and its depth is 9.5 m at normal sea water level. New port is planned to be constructed of which wharf length is 300 m and its depth is 13 ~ 14 m.			
9	Human Elements around Plant	Almost no household in the plant site. Nearby village is located about 1 km from the plant site with 260 households (853 people). Small fishing activities.	Almost no household in the plant site. Nearby village is adjacent to the plant site with 200 households (800 people). Small fishing activities. Small cattle raising activity	Almost no household in the plant site. Nearby village is located about 2 km from the plant site with small number of households.	3 households in the plant site. Nearby village is adjacent to the plant site with 162 households (593 people). Small fishing activities.
10	Local Power Demand	Cement, Graphite, Nickel, Gold (small), Fertilizer, Gas treatment plant, Water supply			
11	Environmental Issues*	Air pollution source nearby plant site is Dangote (cement company) industry about 10 km away from the plant site.	Same as Mtwara Site 1	Air pollution source nearby plant site is Dangote (cement company) industry about 7 km away from the plant site.	Air pollution source nearby plant site is Dangote (cement company) industry about 13 km away from the plant site.
12	Conclusion of the Site	(1) Backfill of the plant site with 2 ~ 3m is required. (2) Geological conditions seem to be good (3) Sea water cooling cannot be adopted due to shallow sea. Air cooled condenser is sole solution. (4) Heavy equipment can be unloaded at Mtwara port and transported by the main road, but 5 km access road has to be widened and paved.	(1) Backfill of the plant site on large scale is not expected. (2) Geological conditions seem to be good (3) There is a possibility of sea water cooling, if the distance of deep sea is around 1 km (measurement is required). (4) Heavy equipment can be unloaded at Mtwara port and transported by the main road, but 6.5 km access road has to be widened and paved. (5) Environmental measures for nearby village is required during construction stage and operation stage of the plant. (6) Job opportunity for resident is positive impact.	(1) Backfill or excavation of the plant site is not required. (2) Geological conditions seem to be good (3) Air cooled condenser due to high land. (4) Heavy equipment can be unloaded at Mtwara port and transported by the main road, but 7 km access road has to be widened and paved. (5) Length of the gas pipeline is the shortest among candidates.	(1) Backfill of the plant site is not expected. (2) Geological conditions seem to be good (3) Sea water cooling (once-through type) is adoptable due to suitable land height and deep sea. (4) Heavy equipment can be unloaded at the unloading jetty by utilizing the intake channel (no need to widen and pave the access road). (5) Environmental measures for nearby village is required during construction stage and operation stage of the plant. (6) Job opportunity for resident is positive impact.
Overall Ranking		**5**	**3**	**2**	**1**

*Environmental issues do not mean the impact during the constructionand operation periods of GTCC. They mean the present site conditions.

Source: JICA Study Team

Table 3-4 Site Reconnaissance Results (Lindi)

No	Item	Candidate Sites		
		Lindi Site 1	Lindi Site 2	Lindi New Site
1.	Topography	Coastal flat low land with about 3 m above sea level. Empty land with bush and only a few Baobab trees, without agriculture. Enough space for a 300MW class GTCC.	Slightly hilly high land with about 35 ~ 40 m above sea level. TANESCO former/old DG power station. Enough space for a 300MW class GTCC.	Slightly hilly high land with 7 ~ 8 m above sea level. Empty land with bush without agriculture. Enough space for a 300MW class GTCC.
2.	Geology	Silty sand with outcrop of rock and coral rock. No fault Zone.	Silt and cray with outcrop of rock. No fault Zone.	Silty cray with outcrop of rock. No fault Zone.
3.	Oceanography	Shallow sea with beach and lagoon, with only a few mangrove trees. Deep water is expected more than 2 km form shore.	The site is about 400 m away from seashore. Seashore is shallow and covered by mangrove forest.	Shallow sea with cliff, and big mangrove forest, without beach
4.	Raw Water Supply	Lindi water supply project is in progress. 7,500 m^3/day will be supplied from deep wells to Lindi area. The project is expected to be completed in December 2016. The water source is abundant and capable to install another train. It is possible to supply water to the 300MW class GTCC (water demand is about 300 m^3/day).		
5.	Road	The distance of access road from main road is about 6 km with 2 ~ 4 m width and unpaved.	The distance of access road from main road is about 300 m with about 3 m width and unpaved.	The distance of access road from main road is 1.5 km.
6.	Length of Gas Pipeline	Distance from BVS 03 is about 35 km.	Distance from BVS 03 is about 27 km.	Distance from BVS 03 is about 31 km.
7.	Distance to 400kV T/L	Later	Later	Later
8.	Lindi Port	No unlading equipment. Depth of wharf is at present 4m at high tide (2m at normal tide). After dredging (September 2016), wharf depth will be 7 ~ 8 m at high tide		
9	Human Elements around Plant	1 household in the plant site. Nearby village is located about 200 m from the plant site with 3 households (3 people). Small fishing activities.	No household in the plant site. No village due to industrial area around the plant site	Almost no household in the plant site. Nearby village is located about 1.5 km from the plant site with big households. Small fishing activities.
10	Local Power Demand	Graphite, Nickel, Gold (small), Future LNG,		
11	Environmental Issues*	Nothing	Nothing	Nothing
12	Conclusion of the Site	(1) Backfill of the plant site with 1 ~ 2 m is required. (2) Geological conditions seem to be good (3) Sea water cooling cannot be adopted due to shallow sea. Air cooled condenser is sole solution. (4) Heavy equipment must be unloaded at Mtwara port and transported by the main road with long distance, and farther 6 km access road has to be widened and paved.	(1) Excavation and backfill of the plant site seem to be required to level the ground of the plant site. (2) Geological conditions seem to be good (3) Air cooled condenser due to high land and mangrove forest. (4) No need to acquire land due to TANESCO's property. (5) Heavy equipment must be unloaded at Mtwara port and transported by the main road with long distance. (6) For altitude optimization, it may require land extension towards Lindi-Mtwara main road.	(1) Excavation and backfill of the plant site seem to be required to level the ground of the plant site. (2) Geological conditions seem to be good (3) Air cooled condenser due to shallow sea and big mangrove forest. (4) Heavy equipment must be unloaded at Mtwara port and transported by the main road with long distance, and farther 1.5 km access road has to be widened and paved
Overall Ranking		**7**	**4**	**6**

* Environmental issues do not mean the impact during the construction and operation periods of GTCC. They mean the present site conditions. Nothing means that the site is inhabited or small village is nearby without large scale building, etc.

Source: JICA Study Team

(3) Advantages of the New Mtwara site

The major reasons, as to why the New Mtwara Site (**Mikindani site** in the preparatory survey) is selected as the most feasible site, are as follows;

1) The site is at an ideal height above sea level, therefore civil works on a large scale are not expected at the site.

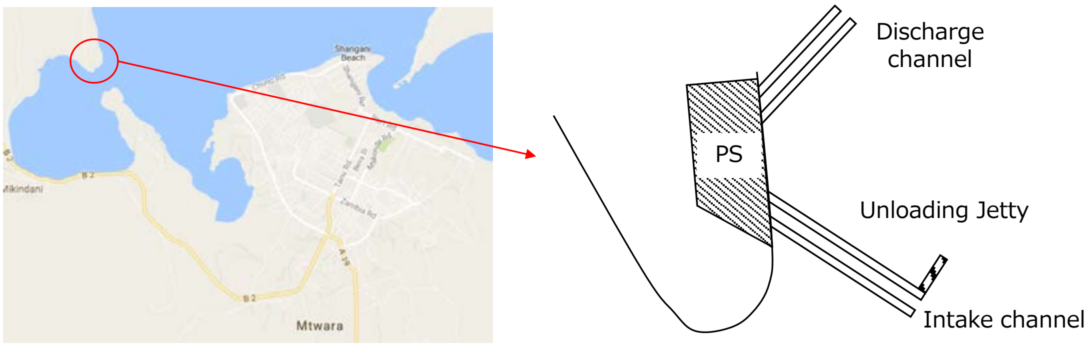
2) The site is located at the edge of a small peninsula surrounded by deep sea, therefore sea water cooling (once-through type) can be adopted for the ST cooling, and it has the highest plant efficiency among all ST cooling systems. (Figure 3-3 shows the comparison among all ST cooling systems).

3) The intake channel for the ST can be utilized to unload the jetty, therefore the heavy equipment can be directly transported to the site from the sea without land transportation. The widening/pavement of the access road and relocation of villagers along the access road are not required. Recently, heavy equipment have been transported by cargo ships with unloading cranes, therefore, it is not necessary to install any unloading facility for the jetty. (Figure 3-3 shows the conceptual idea of the unloading jetty).

4) It is necessary to carry out environmental measures for the nearby village during the construction stage and the operation stage of the plant. However, the plant is a gas-fired power plant, which is an environmental friendly plant compared to the coal-fired power plant. Environmental impacts of coal and ash are not present. Expected impacts seem to be NOx, noise and vibration, but they can be solved by setting the plant boundary at an appropriate level during the plant design stage.

5) The power plant will provide job opportunity/ business chance for residents in the nearby village during the construction stage and the operation stage of the power plant. This is one of positive impacts.

Item	Seawater cooling	Cooling tower	Air-cooled condenser
Installation cost	High	Low	High
Efficiency of S/T	High	Medium	Low
Fresh water consumption	Little	Large	Little
Space of land	Base	Almost same as seawater cooling	More vast
Land height above NSWL	4 ~ 5m	No limitation	No limitation
Possibility of unloading Jetty	High	No	No
Remark 1	Hot water recirculation and heat accumulation have to be avoided	N/A	N/A
Remark 2	Mangrove forest area has to be avoided	N/A	N/A



Sources: JICA Study Team

Figure 3-3 Comparison of ST Cooling Systems and the Conceptual Drawing of the Unloading Jetty

3.1.2 Discussions between TANESCO and JICA in July 2017 about the Issues of Site Selection after the Screening based on the Basic Survey (2016)

JICA had planned to proceed with the preparatory survey of Mikindani site that was ranked top in the Basic Survey (2016). However, TANESCO stated that they want to utilize the Kisiwa site that was ranked 2 in the Basic Survey (2016), where 150ha of huge area has already been purchased by TANESCO for the future power complex. TANESCO proposed to carry out further investigation of both sites before the final decision.
TANESCO gave the following reasons;

(1) After the Basic Survey (2016), TANESCO communicated with Mtwara Regional Administrative Secretary (RAS) office and Municipality and was informed that the Mikindani site is designated as a residential area and has land use restriction. Mtwara RAS wouldn't allow the Mikindani site to be used for power plant, while the Kisiwa site, which TANESCO has already acquired, is designated as a power plant area and is suitable from the viewpoint of land use.

(2) TANESCO scrutinized the conditions of Mikindani site for further action. TANESCO found some concerns in terms of environmental and social considerations as described below;

a) High cost of compensation for land acquisition.
b) Necessity to consider navigation route for the daily transportation of local people.
c) Compensation for local fishery activity.

(3) TANESCO has been planning to develop a power complex at the Kisiwa site, so as to optimize the cost of infrastructure development and operation by having all functions at one site.

JICA and JICA Study Team responded;

(1) JICA understood the situation and agreed to conduct further comparative study before the final decision, because TANESCO's concerns would become critical issues.

(2) JICA explained that the Basic Survey (2016) was carried out by screening the potential sites with the assumption that the seawater cooling system would be adopted for steam turbine condenser in order to improve plant efficiency. It was estimated that adoption of seawater cooling system would result in around 2.7% higher plant efficiency compared to the air cooling system, which would provide 8MW additional capacity or save ca. 2.2 million

USD/year of fuel cost in the case of 300MW GTCC.

Due to the altitude of the Kisiwa site, which is 40 ~ 50m above sea level, the adoption of seawater cooling system seemed to be not feasible from the technical and economical perspectives.

TANESCO commented that although the Basic Survey described that the altitude of Kisiwa site is 40 ~ 50m above sea level, there are both highland and lowland areas near the sea in the Kisiwa site.

On discussion, both parties agreed to conduct further comparative study for both the sites through field survey and by collecting additional data and information.

Figure 3-4 Site Locations, Existing Gas Pipeline & Future Water Supply Pipeline

3.2 OVERALL STUDY ON ALTERNATIVE SITES

The field survey and the collection of additional data and information were carried out during July 17 ~ 29, 2017. During this period, the transportation route survey for the Kisiwa site and the Mikindani site was also conducted.

(1) Information from Mtwara RAS (Regional Administrative Secretary)

a) The Kisiwa site was designated as a power plant area, while the Mikindani site was designated as a residential area by the Master Plan of Mtwara RAS (hereinafter referred to as "MP"). Figure 3-5 shows the land utilization map of the MP.

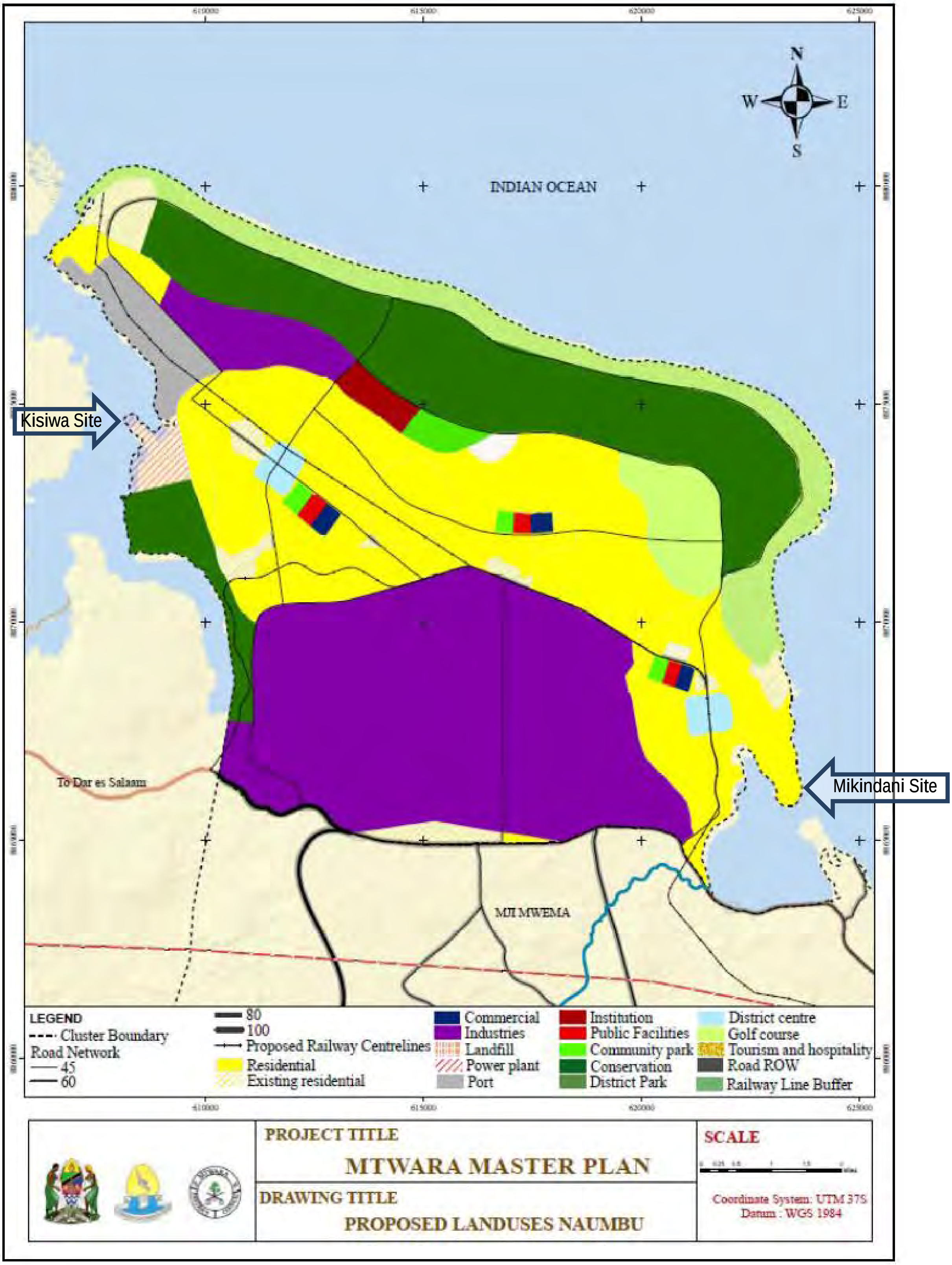
b) The MP was approved by the government in March 2017 based on the Urban Planning Act No.8 of 2017 through a process stretched over a few years. Therefore, the process for changing the status of the Mikindani site from residential area to power plant area will take a long time. A high ranking official of Mtwara RAS stated that the change is not acceptable as it will raise significant troubles, because, the compensation plan of Kisiwa site has already been assessed.

c) If the power plant is constructed in the residential area, resettlement or a huge compensation for the nearby village is required due to strict noise limitations for the residential area[1]. On the other hand, noise limitations for the power plant area is moderate[2].

d) Although RAS doesn't have any data on the number of fishermen, fishing is actively carried out, both inside and outside the Mikindani Bay.

e) RAS has concerns about the heat accumulation caused by hot water discharge from the power plant in the Mikindani Bay.

1 Daytime: 50dB, Night time: 35dB
2 Daytime: 70dB, Night time: 60dB



Sources: Mtwara RAS

Figure 3-5 Land Utilization Plan of the Master Plan

(2) Field investigation of Kisiwa site

a) Both parties confirmed that the Kisiwa site extends to the seashore. Only a small area of the Kisiwa site faces the seashore line, such as the nose. The other areas are covered by thick mangrove trees along seashore lines. Therefore, the nose area is being utilized as the mooring point of fishing boats. On the other hand, the nose area is covered by sand and the height of the nose area is almost 0m above sea level. Therefore, the nose area is preferred for beaching and transportation of heavy equipment.

The area within 60m distance from the seashore cannot be developed as it is an environmental buffer zone in Tanzania. However, an officer of Mtwara RAS informed that the temporary use of this area is acceptable during the construction of power plant, provided this area is returned to its original state after the construction.

Nose area at the low land

Mangrove forest at the low land[3]

b) There is an open area behind the nose area. The area is a flat- low land, and can be utilized as the power plant area with banking. As the Kisiwa site also has high land, the necessary soil can be obtained from the high land.

c) There are pastures, salt fields, houses and fishermen. However, the number of houses and fishermen is limited. No protective fauna and flora are observed in sight.

Open area behind the nose

Salt field in the low land (the green backyard is mangrove forest)

d) Although the information from Mtwara port authority stated that the sea depth in front of the nose area is shallow, the temporary measurements by JICA Study Team and TANESCO on July 25, 2017 show that it is deep enough for the adoption of the seawater cooling. The seawater depth will be investigated accurately afterwards, in front of the nose area.

3 In the mangrove forest, there is a way from sea to salt field. In case of seawater cooling system, the way will be able to utilize as the route of hot water discharge.

Another issue in the adoption of seawater cooling is the heat accumulation in the narrow bay. The heat accumulation degree (negligible or significant) will be confirmed by simulation during the Preparatory Survey period.

	
High land (sea area in the background)	Foot pass in the high land

(3) Field investigation of the Mikindani site

The reasons why the Mikindani site was chosen in the Basic Survey (2016), conducted in 2016 are;

1) The site faces outer sea, and the sea water cooling system can be adopted.
2) The site is flat with height of 4 ~ 5m, therefore it is not necessary to carry out large-scale civil work.
3) Although there is a village near the site, it was determined that it is possible to mitigate the environmental and social impacts.

Point 3) has been evaluated based on Engineers' experience, mainly in South-east Asia. However, during investigation, the JICA Study Team was informed that the Mikindani site has been designated as a residential area by MP in March 2017, after the Basic Survey (2016). It seems to be difficult to construct a power plant in the Mikindani site because a resettlement or a huge compensation for the nearby village is envisaged, as Tanzania has strict noise limitations for a residential area.

	
Flat land	Nearby village

The Mikindani site seems to have little chance as a power plant site. A quick site investigation was carried out in July 18, 2017 and the findings are as follows;

1) Fishery activities have become popular.
2) The sea in front of the expected power plant site (300MW class GTCC) seems to be shallower than what was expected by the JICA Study Team.
3) One endangered species (fish coral eagle) is found.

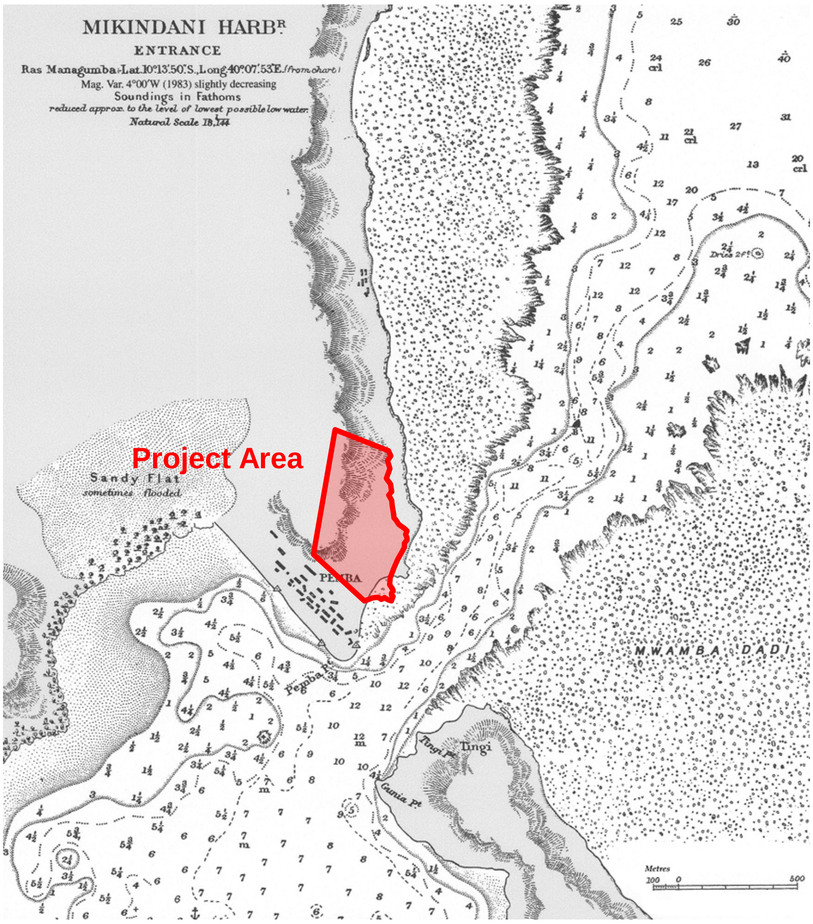
	
The site in 2016	The site in 2017

In 2016, the survey was conducted in the afternoon. On the other hand, in 2017, the survey was conducted in the evening and it matched with the timing of low tide[4]. Compared with survey of 2016, although several minus factors are found, seawater cooling system is still adoptable by extending the sea bottom intake/discharge pipelines to the off-shore.

Figure 3-6 shows the sea chart at the Mikindani area.

Expected length of the intake pipeline is around 600 m and the expected length of discharge pipeline is around 400 m. The routes of these pipelines must be determined in such a way that they don’t interfere with the navigation routes.

4 According to data of Mtwara port, the ebb tide occurred at 17:43 on July 18.



Sources: JICA Study Team

Figure 3-6 Sea Chart of Mikindani Area

(4) Method for Transporting the Equipment to the Sites

Although the details are explained in Section 3.3 Heavy Cargo Transportation Route Survey, the outline is as follow;

1) As land transportation weight is limited to 56 ton GVM (gross vehicle mass), the maximum payload seems to be around 30 ton. In case of a payload over 30 ton, penalty charges will be imposed. Therefore, a heavy equipment weighing more than 30 ton must be transported to the site by means of beaching.

2) There are no obstacles for beaching at the Kisiwa site, because the nose area is covered by sand and the height of the nose area is almost 0m above sea level, which are ideal conditions for beaching. However, due to the distance between outer sea and the site, quick maneuver of the barge to access/retreat the site during a high tide and quick unloading during a low tide are required.

3) Beaching at the Mikindani site is also possible, however, special care such as laying of sandbags and iron plates should be taken, before the beaching. Such special care are indispensable due to the hard coral rock.

4) The distance from the Mtwara port to the Kisiwa site is around 40km. Land transportation

involves several obstacles such as bridges and culverts, etc. However, these issues can be solved through special care before transportation.

5) The distance from the Mtwara port to the Mikindani site is around 20km. Land transportation involves several obstacles such as bridges and culverts, etc.

(5) Survey on environmental and social considerations

Although the details are explained in Chapter 12 Environmental and Social Considerations, the outline is as follow;

a) Resettlement

There are only a few household inside the Mikindani site, but 164 household (around 900 people) in the nearby village may require relocation.

On the other hand, there are 2 household inside the Kisiwa site, but it may be necessary to relocate 5 household (around 20 people) and one grave from the nearby village.

The details of the assets lost by the inhabitants will be confirmed through Resettlement Action Plan (RAP), which will be investigated by the local consultant.

b) Compensation

Both sites will require compensations for lost crops and land. For the Mikindani site, even if there is no relocation, compensation for noise will be needed.

c) Ecosystem

The Kisiwa site has coral reefs and mangrove forest. On the other hand, the Mikindani site has significant coral reef but only a few mangrove trees. Both sites will have to be checked for the impact caused by hot water discharge on the coral reef, in case the sea water cooling system is adopted.

d) Fishery

There are about 150 fishermen in the Kisiwa site and about 300 fishermen in the Mikindani site. In the Kisiwa site, the nose area is utilized as the mooring point by the fishing boats, therefore, if TANESCO wants exclusive use of nose area, TANESCO needs to study an alternative mooring point for the fishermen.

e) Navigation route

At the Mikindani site, there is a navigation route, to travel to and fro the Mikindani Bay and the outer sea. Therefore, if sea water cooling system is applied, the sea bottom intake/discharge pipelines have to be arranged in such a way that they don’t interfere with the navigation. There is no navigation route at the Kisiwa site.

f) Land price

According to the Maura District Council, the land price of the Mikindani site is almost double of amount of Kisiwa site.

3.3 HEAVY CARGO TRANSPORTATION ROUTE STUDY

During the site survey period, transportation feasibility study for heavy cargo was carried out for both the Mikindani and Kisiwa sites.

The heavy cargo transportation route survey items are as follows.

① Ocean transportation from load port to destination
② Utilization of the Mtwara public port, which is the nearest port from the site
③ Transportation route from Mtwara port to the destination site (Both land and sea)

3.3.1 Transportation Route

(1) Long distance ocean transportation (to Tanzania)

Here, the information regarding the transportation of main equipment from Japan to Tanzania, which is available at this moment, is introduced as a case study, due to the time limitation of this survey. However, the contract for this project has not yet been signed.

There are 3 basic patterns of cargo ship route, which is westbound, from the Far East (ex. Japan) to East Africa.

① Re-routing: East China Sea – Malacca – Indian Ocean – Persian Gulf
② Re-routing: East China Sea – Malacca – Indian Ocean – Red Sea – Suez Canal – Mediterranean
③ Re-routing: East China Sea – Malacca – Indian Ocean – East Africa, Cape of Good Hope

The Major gate port in Tanzania is the Dar es Salaam port. Large size vessels such as container vessels, RoRo vessels have regular liner service from Japan to Dar es Salaam.

- The direct distance from Japan (Yokohama) to Tanzania (Dar es Salaam):
  When calculated based on Yokohama as the base point, the distance to Tanzania is about 6,916 miles. In case of non-stop transportation at the speed of 14.3 knots, it will take about 20 days to cover the distance. But taking into consideration the transportation route and re-fueling, etc., total navigation days will be about 1 month.

- The distance, when travelling from Japan to Tanzania, avoiding the pirate area:
  Yokohama to Dar es Salaam is about 8,166 miles. As a heavy cargo ship has deck at a low height, there is a risk of being attacked by pirates. If the pirate area is avoided, it will take about 24 days. Total navigation days will be about 1 month 1 week.

- In Figure 3-7, the pirate area is indicated by blue lines in the open sea.

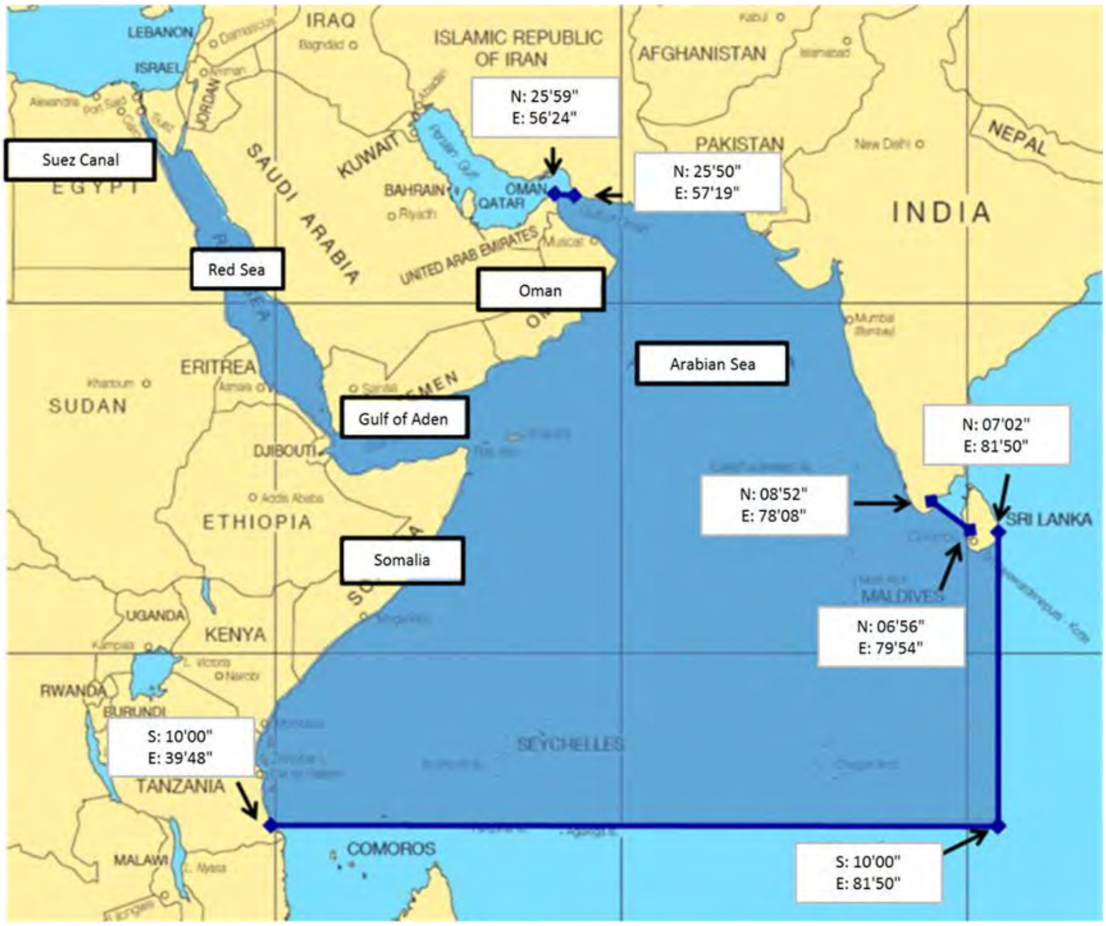


Figure 3-7 Pirate Area

The size of a typical heavy cargo ship engaged in service from the Far East (Including Japan) to the Middle East, Africa, and Europe is basically 20,000ton to 30,000ton in dead weight size. The major gate port in Tanzania is the Dar es Salaam port.

For example, the specification of a heavy cargo ship is shown below,

Dead weight	:	19,950 ton
Gross ton	:	13,694 ton
LOA (Length)	:	149.53 m
Draft (Depth)	:	9.63 m
Breath (Width)	:	24 m
Capacity of Crane	:	150ton × 2 (300 ton)
Class	:	Class NK
Speed	:	around 14.3 knot (26.5km/h)
Hold, Hatch	:	3 Hold, 3Hatch
Deck	:	Twin Deck (Twin deck + Weather deck)

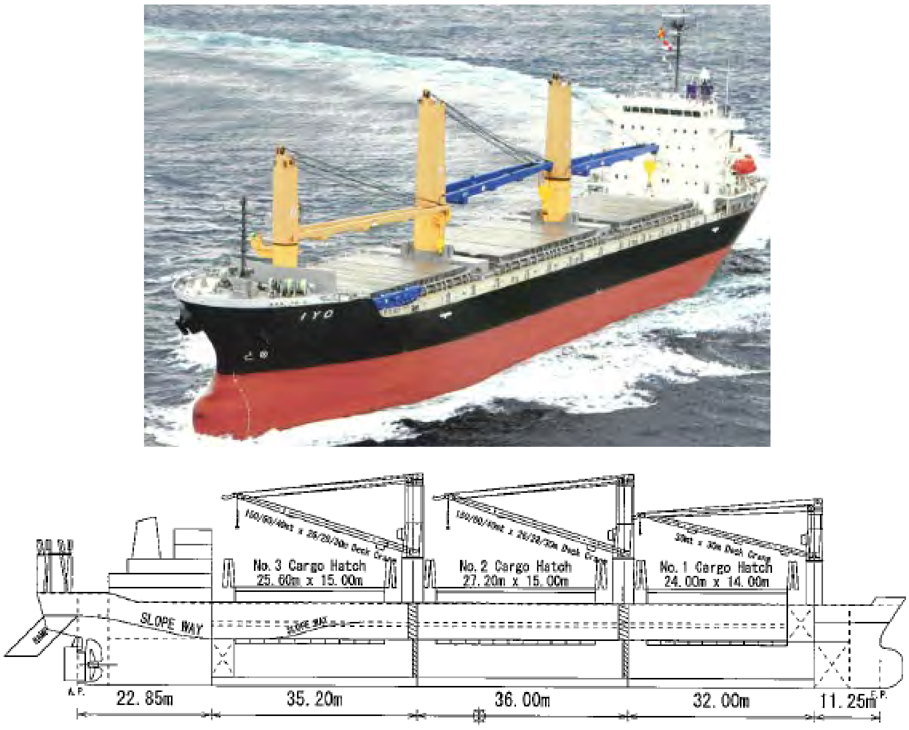


Figure 3-8 Heavy Cargo Ship of Dead Weight 19,950ton (Sample)

(2) Major specifications of Mtwara port (Interview with Mtwara Port Authority)

The nearest port to the candidate construction power plant site is the Mtwara port. The Mtwara port is also feasible as it has wharf for heavy cargo ships from Japan. However, the sea water at the Mtwara port does not seem to have enough depth, needed for the heavy cargo ship. JICA Study Team has investigated the Mtwara port and interviewed the port authority.

Specifications of Mtwara port,

Terminal operation	:	Joint operation with Tanzania military organization.
Major export commodity	:	Agricultural products (Especially cashew nuts) September to January is high season.
Draft (Water depth)	:	Low tide 9m, high tide 12.5m
Wharf length	:	216m (To be expected to expand 385m)
Terminal crane	:	100ton × 1 (Drivable)
Spreader beam	:	L=6m 28ton, L=12m, 37ton

Since the large and heavy cargo ships require a greater water depth, it may not be possible to moor a ship with a dead weight of 20,000 ton to 30,000 ton at the wharf of the Mtwara port.

For this reason, the JICA Study Team have enquired with the Mtwara port authority and the port master, if it is possible to arrange an anchorage cargo discharge for the Project instead of a discharge operation at the wharf along with the ship. When the JICA Study Team had a discussion with the Mtwara port master on the application procedure for using the Mtwara port, it was brought to notice that it is necessary to confirm again at the time of Project commencement.

As a result, the JICA Study Team has received advice from the port master of Mtwara and noted that they can arrange discharge operation at the anchorage.

However, in case such a vessel discharge operation is not allowed, heavy cargo ships with smaller dead weights such as an 11,000 ton dead weight with a shallow draft have to be considered and arranged for the Project.

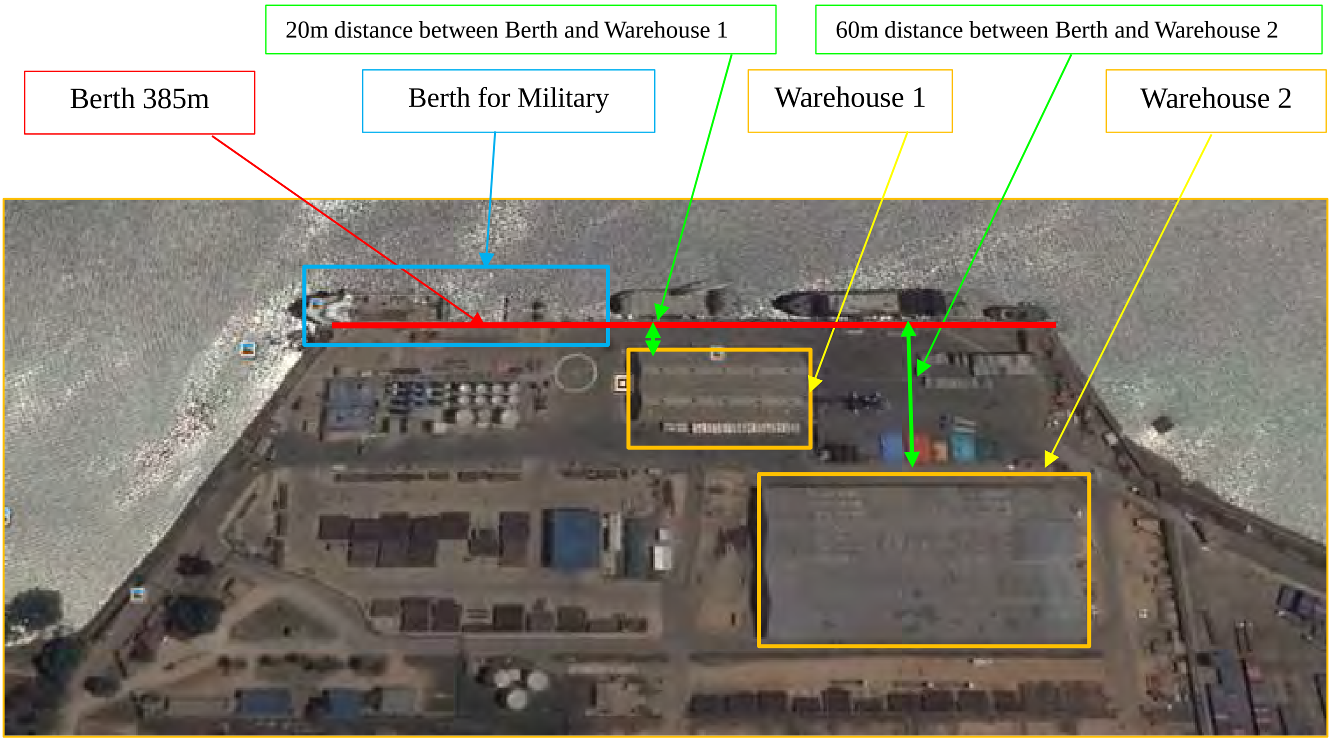


Figure 3-9 Mtwara Port

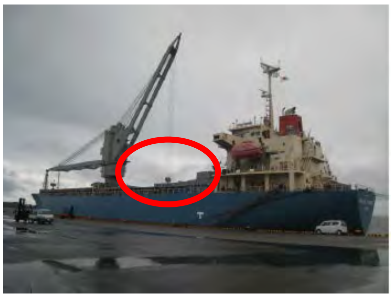
Overall view of Mtwara port

Anchorage discharge operation (Sample)

(3) Precaution and Procedures for Discharging at Mtwara Port

After the heavy lift conventional vessel arrives at the Mtwara port, sea water transportation barge for heavy cargoes such as main equipment should be arranged, in order to avoid penalty payment for over size cargoes and land transportation risks caused by trucks or trailers. Heavy cargo ships are equipped with a crane for lifting a heavy cargo, which can be lifted from the hatch and loaded. If a vessel is delayed due to shipper or consignee’s responsibility, shipping lines may charge detention cost. This detention sometimes amounts to about a few hundred thousand dollars per day, thus it is necessary for the shipper or consignee to prepare in advance for a smooth discharging operation. On the other hand, the EPC contractor should arrange for the land transportation of ordinal cargoes by means of trucks or trailers.

Sample of Discharging Operation for Power Plant Tanks


1. Discharging


2. Heavy Lift of a vessel


3. Hatch


4. In Hold


5. Lifting up from the lower deck


6. Lifting through the hatch


7. Discharge on land side


8. Loading on Trailer


9. Depart for delivery

Figure 3-10 Discharge Operation at Port

(4) Transportation from port to Mikindani, Kisiwa sites by land and water re-routing

a) Transportation after discharging from the heavy cargo ship at Mtwara port ~ Final destination at sites

After the arrival of heavy cargo ship at the Mtwara port, there is a concern about safe transportation of heavy loads, due to the quality of the land transportation. If the weight exceeds the limit, the Project may be charged with a high penalty. So, instead of land transportation by truck, it is best to use waterway transport. On the other hand, with regard to equipment, which are not heavy cargoes, in principle, road transportation by truck and trailers is ideal. However, the route to be used is the national road (under TANROADS). Although it is paved with a road width of about 9 m, the access road branches from the national road. The local road (under TARURA) is a dirt road with a road width of about 5 m. Therefore, advance survey and paving work are necessary.

b) Regulation for land transportation (Interview with TANROADS Mtwara regional office)

Maximum weight limit	:	56ton (Include vehicle weight) If it exceeds the weight limit, penalty charges will have to be incurred such as US$140,000/shipment.
Bridges max load bearing capacity	:	78ton
Maximum weight record in Mtwara region	:	@60ton cargo to Dangote cement factory

Land transportation requires permission from TANROADS. Basically, JICA Study Team needs to plan for transporting lesser than the regulated road weight limit (56 ton) of the TANROADS. There are many bridges and culverts on the way from the Mtwara port to the final destination sites.

The Project has to check the actual strength of those bridges and culverts in advance, before the submission of actual transportation plan and application to the government offices (such as TANROADS).

In addition, there are many unpaved roads in the transportation route. The Project should be careful about the bad road condition during rainy season, and also should either avoid transportation or be careful about the increase in the number of trucks during the high crop season of cashew nuts. (Especially between September to January)

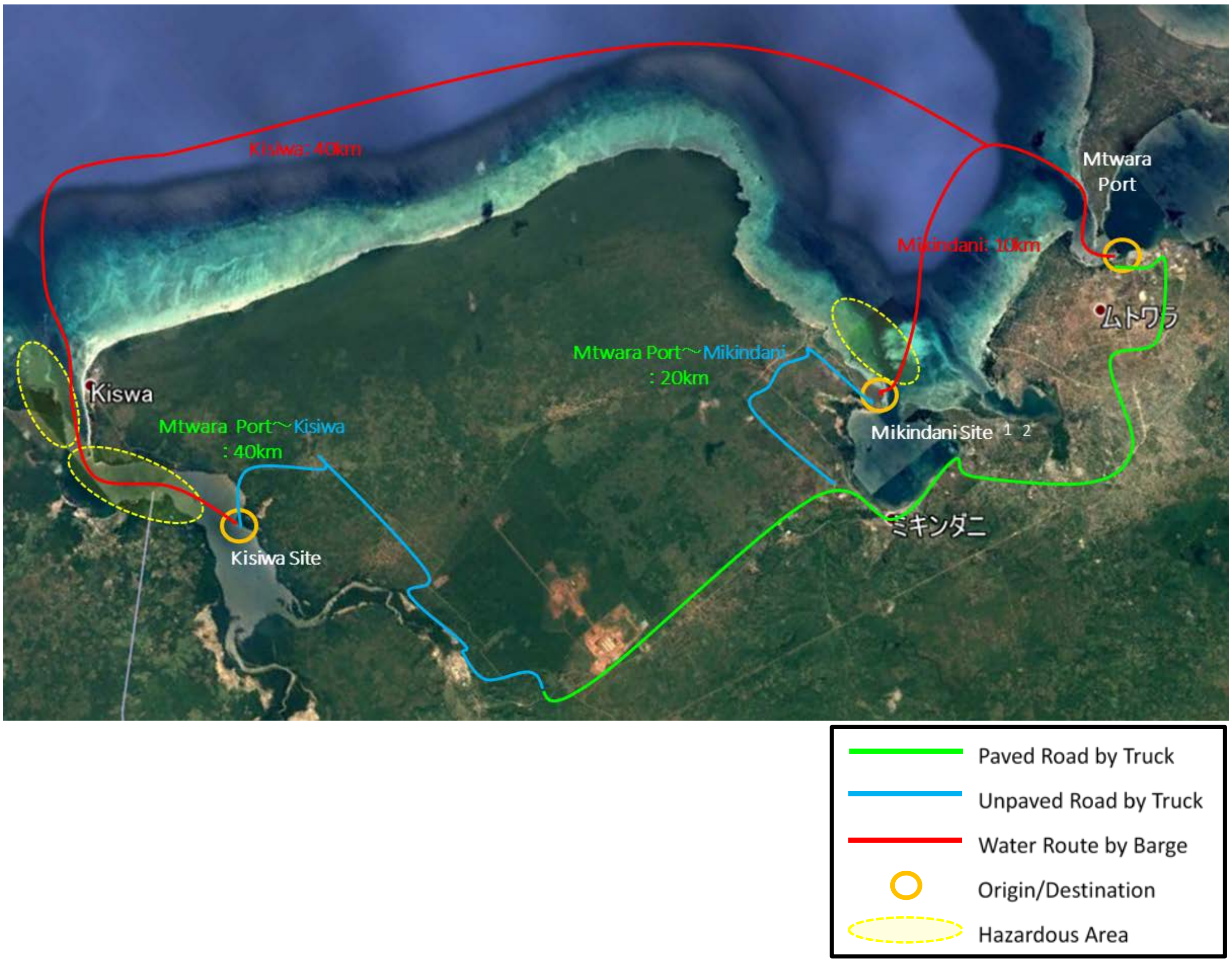


Figure 3-11 Mikindani/Kisiwa - 2 Points Transportation Route


Culvert


Culvert


Mikindani Bridge 1


Mikindani Bridge 2


Culvert


Exposed Water pipe

c) Sea water transportation by barge and beach landing

In a country, which is well developed with enough local port infrastructure, the domestic sea transportation is done by domestic cargo ships after the heavy cargo ships arrive at the major gate port.

However, in case the local port facility is not well developed, the barge transportation with beach landing can be carried out.

① Preparation before operation

Before the ocean transport from Japan by heavy cargo ship is commenced, the JICA Study Team needs to confirm the following conditions,

- The nearest discharging place from the construction site
- A place where physical safety conditions are met
- A place where the operation can be conducted in a reasonably economical way

② Routing confirmation

It is necessary to confirm in advance, the route for water transportation by means of barge from the Mtwara port to the candidate beach landing point. It is possible for the barge to transport through the water route, which is not usually used, however, it is inevitable to check the draft and the tide conditions before the operation. In addition, when carrying out the actual transportation work, it is requested that the local residents (including fishermen) in the vicinity of the Mikindani or Kisiwa site are informed in advance, and a guarding ship is arranged at the Mikindani or Kisiwa Bay at the time of the transportation work, in order to ensure safety.

③ Equipment: Special trailer (SPMT), Barge (Roll on, Roll off load / discharge type)

The method for beach landing is same as the landing operation of a vehicle in a military landing operation. This operation requires an equipment, which enables to load/discharge cargo to the barge by Roll on, Roll off work.

The heavy equipment of power plant are not designed for self-drive, so they need equipment such as a special self-running trailer called Self-Propelled Modular Transporter (SPMT).

A special trailer, with multiple axes and many tires, disperses the load on the ground surface

Due to the above reason, SPMT have to be loaded in the barge in advance, to discharge cargo from the heavy lift ship at the Mtwara port.

Barge and SPMT must be secured in one piece, before receiving the cargo at Mtwara port, for safe operation.

Barges for Beach Landing

The shape of Roll on-Roll off barge is similar to the normal barge, however, there are ramp gates at the foreside of the barge and the bottom of the barge is flat in order to reach the bottom of the sea bed safely.


Figure 3-12 Barge for Beach Landing

Special trailer (SPMT)

SPMT flexibly accommodates the length, width and weight of the equipment to be loaded by linking multiple modules, and it can move freely in all directions such as rotation on the spot, back and forth, movement to the left and right etc. Therefore, it is suitable for the cargo handling work of super heavy items, which are difficult to handle.

Figure 3-13 SPMT Trailer Sample

④ **Beach landing Operation**

As a preliminary work, JICA Study Team has to prepare for beach landing, by arranging for barge's safe grounding at the sea bed and by placing sand bags, steel plates, and carrying out the necessary civil work to make the SPMT's approaching angle shallow.

Before the heavy cargo ship arrives at the Mtwara port, the barge along with SPMT has to be kept on standby near the Mtwara port, for the Project. Once the heavy cargo ship arrives, the heavy cargo will be lifted from the cargo hold by the ship's own crane, and discharged to the SPMT on the barge.

After that the heavy cargo, SPMT and the barge must be connected and secured by materials such as lashing chain.

The departure time from the Mtwara port and the arrival time at the beach landing place has to be coordinated in the Project, to make the operation safe with best tide conditions, water depth and a suitable horizontal angle approach of the SPMT from the barge to the beach.

The SPMT has to be discharged when the approach angle is almost horizontal, and the final angle adjustments will be done by sand bags, steel plates and wooden materials.

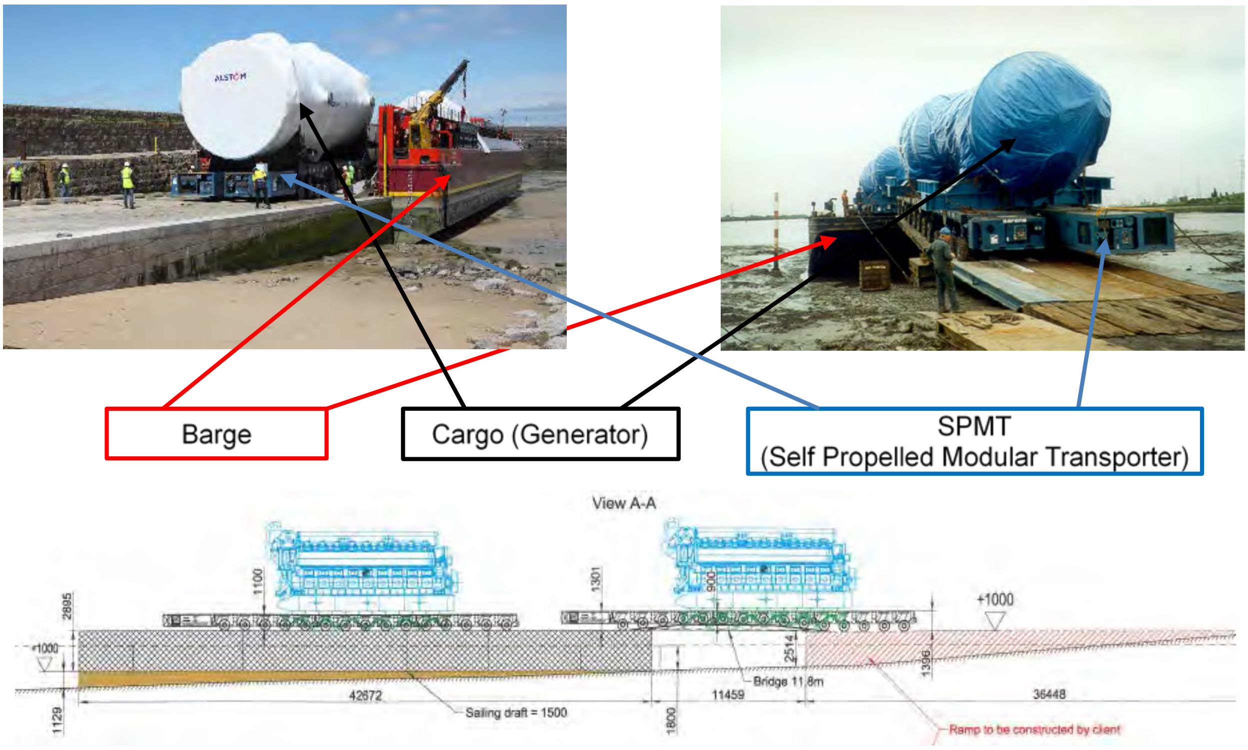


Figure 3-14 Beach Landing Sample Picture

⑤ **Beach landing location at site**

After unloading the SPMT from the barge at the nearest beach from the power plant construction site, use the shortest and the most flat passage to move to the site by SPMT.

Transportation route to the site should have no obstacles, so that, the route for the transportation of heavy cargo after its arrival is as short as possible. The SPMT carrying the heavy cargo must be driven with sufficient clearance, in some cases, a route that enables a turnaround has to be secured.

Proposed transportation plan from beach to Kisiwa site is shown in Figure 3-15.

Kisiwa site beaching point

①

②

③

Figure 3-15　Beach Landing Location

⑥ Unloading at the construction site

Unloading heavy cargo from SPMT is usually done by lifting using a crane, arranged at the construction site.

Or, after fixing the height of the cargo with the support materials installed under the heavy object, jack down the SPMT, self-propel it and extract it to complete the work.

When unloading from SPMT at the site, it is necessary to pay attention to the following points.

- Select a large crane that matches the weight and size of the major equipment (GT, ST, generator, etc.) and procure it.
- Secure an assembly space for the crane to be installed at the site.
- Space for turning the crane and securing the outrigger overhang.
- Cargo must be stored with enough space so that the necessary cargo can be pulled out and new cargo can be put in during the installation work of the Project.
- When removing storage equipment along with the equipment, ensure that there is sufficient storage space including sufficient passage and clearance so that the cargoes

do not interfere with each other.

- Securing space to store all cargoes including equipment transported by land transport.

⑦ **Number of barge, conditions for determining the number of SPMT**

The number of barges and SPMT to be procured will be adjusted mainly according to the following conditions.

- Equipment unit weight · Dimensions
- Equipment freight volume
- Maximum loading capacity of barge · Allowable dimension
- Construction site side acceptance passage · storage space
- Manufacturer's production · Shipment frequency · Timing of Japan

(5) Comparison of Logistics between Mikindani / Kisiwa sites

Both, the Mikindani site and the Kisiwa site, require sea transportation /shipping for heavy cargo transportation. For the non-heavy equipment, land transportation from the Mtwara port will be applied. There is a difference in cost due to the distance, but the difference is not huge. On the other hand, at the Mikindani and Kisiwa sites, the coastal geology is different, so there is a difference in the civil works.

The particulars and comparison of both the sites are as below;

a) Mikindani site

Mikindani site is about 20km away from the Mtwara port by land, it is nearer to Mtwara port than the Kisiwa site. Land transport to Mikindani site can save time when compared to the water transport, but the difference is not much considering the waiting time of trucks for unloading at site. On the contrary, water route is about 10km away from the port, but there are problems in beach landing, as mentioned before, the water depth is shallow and there are hard coral rocks of about 500 m length. Therefore, in order to protect the bottom of the barge, large-scale guarding by laying sandbags and iron plates is required beforehand. In addition, the site has hard coral rocks with a height of about 6 m. It is necessary to construct a large-scale transportation access road (runway).

Moreover, marine creatures such as wild crabs inhabit around the beach, and there are plenty of baobab trees around the site. Thus, it is necessary to consider ecology.

b) Kisiwa site

Kisiwa site is 40km away from the Mtwara port by land. In case of water transport, the route length is 40km, and the proposed beach landing point is a gently sloping sand beach at the fishermen’s village. For the Project, it is necessary to secure the access route to the site, to avoid the houses.

It is more convenient to carry out beach landing, and the gently sloping sand beach can be used as a transportation access road. Though the beach is surrounded by mangrove forest, there is enough space for landing.

Mikindani site is a shallow but has hard coral reef. In addition, the construction site is a hard coral rock of about 6m above sea level. Therefore, construction of gentle slope road is necessary for beaching transport. On the other hand, Kisiwa site has flat sandy beach and the front of the site at

0m above sea level, and it is easy to carry out beaching transportation, so it is superior in terms of construction period and cost. From the above, it can be concluded that, Kisiwa site has advantages in terms of heavy cargo transportation.

Table 3-5 Mikindani / Kisiwa Comparison for Logistics between 2 Sites

		Site 1 Mikindani	Site 2 Kisiwa	Remark
Transportation Route	Distance by Land	Mtwara port ~ Approx. 20 km	Mtwara port ~ Approx. 40 km	
	Sea Transportation	Mtwara port ~ Approx. 10 km	Mtwara port ~ Approx. 40 km	Additional survey required
	Heavy Cargoes	Beaching by Barge + Truck (SPMT)	Beaching by Barge + Truck (SPMT)	※
	General Cargo	by Truck	by Truck	
	Number of Bridges	Approx. 10	Approx. 10	
	Number of Culverts	Approx. 20	Approx. 30	
	Cross Roads, Sharp curves, Others	Many	Many	Widening of Roads
Topics (Potential Risk)	Sea shore condition	Hard Coral Rock (Potential risk for damage Barge)	Sand Beach near Salt fields (Easy access by barge)	
		500 m length coral rock	Distance between sand Beach shore side and village: Approx. 100m	
	Civil work	Required to make 500m length "RUNWAY on sea"	Temporary works only	
	Impact to environment by civil work	Habitat zone for rare species (Fish Eagle) and Marine living in Coral Reef	Mangrove woods exists	Must verify
	Transportation cost (Sea / Land)	If the site has been accepted as private area, penalty fee will be waived	If the site has been accepted as private area, penalty fee will be waived	
		Over 56 ton cargo will be fined	Over 56 ton cargo will be fined	
		Barge costs required	Barge costs required	
		Civil work in order to get rid of coral rock to make "low angle Runway" required	Civil work for access roads will be required	
Others	Rainy season	Field survey was conducted in the rainy season (March, 2018). It was confirmed through the survey that heavy weight equipment is not affected by beaching transport. For equipment below 56 tons, land transport from Mtwara port to the site is possible. Regarding the roads used in transportation, the national highway is paved and there are no problems such as a flood. Access road from the national highway to the site is currently unpaved, so it is difficult to drive the trailer in the rainy season. But this problem can be solved by widening the pavement in the project.		
	Cashew nuts harvest season	Traffic congestion risk during Cashew nuts harvest season, during September to January.		
	Tax, Penalty, etc. potential risk	Advance check regarding Tax on high value equipment, penalties for over size cargo transportation will be required.		
Transportation cost		Base	Cost increases due to the long transport distance	
Assessment		2	1	

※) Need to consider time limit of Tide table for beaching/ discharging operation from the Barge

3.3.2 Required Days for Transportation

Marine transport (50days ~) ⇒ Customs clearance (18days)
⇒ Unloading & Barge transport (14days) ⇒ Beach landing & delivery (13days)
＝ Total 95days ~

* Direct delivery to the site with partial truckload shipping after unloading at the Mtwara port / in parallel to the same time as above

3.4 SEAWATER COOLING SYSTEM STUDY

3.4.1 Types of Cooling System

As shown in Figure 3-3, there are three (3) methods to cool the steam turbine condenser, i.e. seawater cooling system, wet cooling tower and air cooling system.

It is difficult to adopt the wet cooling tower for the Mtwara project as it needs a lot of fresh water, because the site is located at an area, where there is no sufficient fresh water. Air cooling system can be adopted everywhere as long as there is enough space, however, the efficiency of GTCC is at its worst the air cooling system is used.

Since both the Kisiwa site and the Mikindani site face the sea in the absence of mangrove trees, there is a possibility to adopt the seawater cooling system. To adopt the seawater cooling system, it is mandatory to confirm that there is no significant heat accumulation and hot seawater recirculation. As the Mikindani site faces the outer sea, such issues do not seem to occur. However, the Kisiwa site is located in the middle of a narrow bay, it is necessary to simulate the conditions of the above issues, in order to adopt the seawater cooling system.

3.4.2 Field Survey Results of the Kisiwa Bay

The site survey results are show as follows;

1) The maximum seawater temperature around the planned intake mouth is 32.6°C (average 30.96°C).

2) The seawater velocity is 0 ~ 0.3m/s including the fluctuation at sea level. There is no significant tidal flow to/from the outer sea.

3) The sea depth around the planned intake/discharge mouths is around 10m, around 4m upstream and around 14m downstream. Generally, the Kisiwa Bay is not so deep.

3.4.3 Simulation Results of the Seawater Cooling System in the Kisiwa Bay

The simulation is conducted by the hydrodynamic 3-D surface water modeling software, DELFT3D with the bathymetry and shoreline data, meteorological conditions, tidal elevation and current data and the intake/discharge design conditions, etc.

The simulation results for one (1) 300MW GTCC power plant with a temperature rise of 7°C (△T = 7°C) in the condenser was carried out. Figure 3-16 and Figure 3-17 show the typical samples of simulation results.

Although a hot spot with more than 3 degree Celsius elevation from the baseline (white color zone) is observed at the limited sea surface area around the discharge mouth as shown in Figure 3-16, it disappears in the middle of the sea as shown in Figure 3-17. The mixing zone, which exceeds by 3 degree Celsius, is observed within the limited area, and there are no endangered species such as coral reefs at that mixing zone. The results are considered to satisfy the Environmental, Health, and Safety Guidelines (EHS guideline) of International Finance Corporation (IFC).

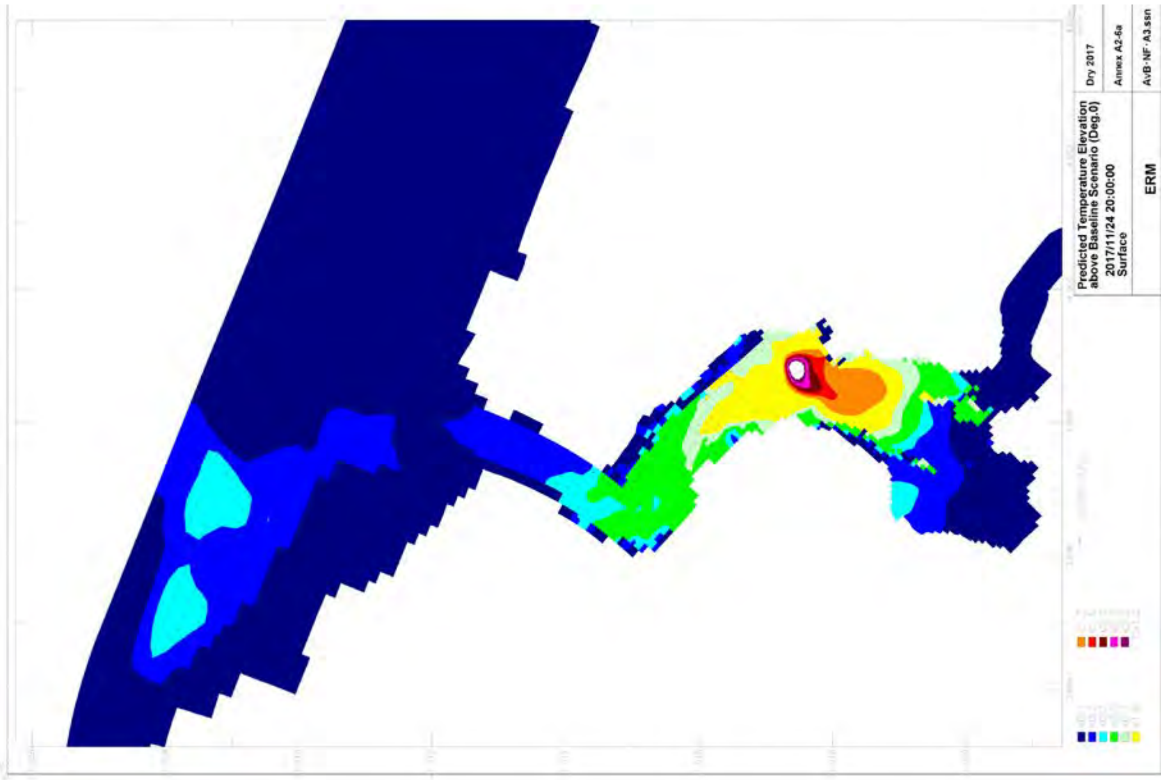


Figure 3-16 Temperature Elevation at Surface

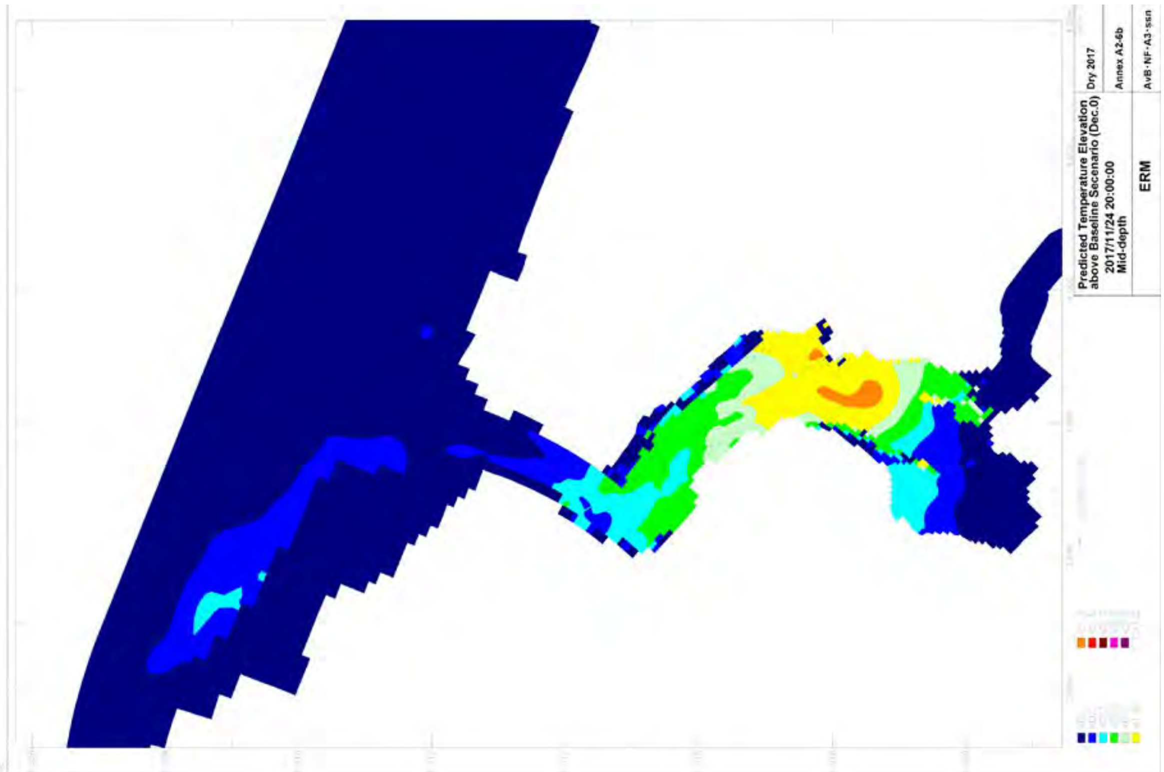


Figure 3-17 Temperature Elevation at Mid-depth

Another criteria for the seawater cooling system is the limitation of average condenser outlet seawater temperature. Average condenser outlet seawater temperature must be less than 40°C in consideration of the hot water recirculation effect. If the average condenser outlet seawater temperature exceeds 40°C, fouling such as mussel will attach to the condenser tube surface, which degrades the condenser efficiency.

According to the simulation results, the average increase in seawater temperature from the discharge mouth to the intake mouth considering the hot seawater recirculation effect is 0.83°C. Therefore, the average condenser outlet seawater temperature is 30.96°C + 0.83°C + 7°C = 38.79°C < 40°C[5].

The results of the simulation shows that the adoption of the seawater cooling system for the Mtwara GTCC power plant is justified.

The details of simulation results are explained in Section 12.1.6 “Result of survey” 2) Thermal water discharge modeling.

[5] If seawater temperature exceeds 40°C, fouling such as mussel will attach the tube surface of the condenser. It degrades the condenser efficiency.

3.5 SUMMARY OF STUDY RESULT

Table 3-6 shows the result of studying the Kisiwa site and Mikindani site as candidate sites for the project.

Table 3-6 Summary – Study Result of Alternative Sites

Study Items			Kisiwa site	Mikindani site
Land Use			Power Plants should be installed in the power plant site or Industrial area as designated by Mtwara Master Plan	
			Designated as power plant site	Designated as residential site
Land Height			0~30m above sea level	4~5m above sea level
Environmental and Social Considerations	Resettlement		11 households (HHs), within the area and the valuation was conducted in 2016. (Affected properties were three structures with 15 people living, according to the interview with the villager.)	･Several households are expected to be relocated because of the land acquisition. ･The neighboring settlement, Pneba Puan, is very close to the site and it seems difficult to meet the noise limit for residential area. Therefore, this settlement (164 HHs, approximately 900 people) seems to be subjected to relocation and compensation if any mitigation measures are not applied to meet the noise limit.
	Land Acquisition		･In progress: Only payment process remains. ･Area: 160 ha	･No activity for land acquisition ･Expected area: Around 12.5 ha
	Compensation		･For the Loss of Crops, Lands, Properties, Disturbance allowances. ･Approved total compensation value based on Tanzanian legislation: TZS 3,611,943,872.09	･For the Loss of Crops, Lands, Properties, Disturbance allowances. The extent of compensation value has been confirmed by conducting valuation survey. ･Mitigation Measures for Noise (35 dB) at Pneba Puan Hamlet for 164 HH (approximately 900 people) is required. (See the explanation of Resettlement above.)
	Ecosystem		Some mangrove will be cut down to install intake and discharge facilities in case of seawater cooling.	Coral might be damaged due to thermal water discharge
	Fishery		Around 62 fishermen are active in the creek	Around 300 fishermen are active around the site
	Navigation route		No navigation route	There used to be a route connecting both sides of the Mikindani Bay near the site
	Land price		According to the valuation in 2016 based on Tanzanian legislation: Land price per acre TZS 7,000,000	According to Mtwara District Council, the land price of Mikindani site is expected to be at least double the price of Kisiwa site, since it is near the town.
Other Technical Items	Length of gas pipeline		Ca. 13km from BVS 01	More than 13km from BVS 01
	Transportation		The results of route survey shows that, transportation to both sites is technically possible. Heavy equipment will be transported to the site by beaching and light equipment will be transported by road	
	Cooling system for S/T		Seawater cooling system	Seawater cooling system
	Power generation capacity		Power complex in 160 ha area (more than 3000MW seems to be possible, although large-scale site preparation work is required)	Suitable for a 300MW GTCC
	Transmission lines	Voltage	400kV	
		Circuit	Double circuits	
		Length	Approx. 268km	Approx. 274km
		Tower	Approx. 682 towers	Approx. 700 towers

Sources: JICA Study Team

3.6 CONCLUSIONS

In this Section, site selection study is conducted for the Kisiwa site and the Mikindani site (Mtwara New site).

Although the Mikindani site was considered as the best candidate site for the new power plant based on the Basic Survey (2016), it becomes quite difficult to construct a new power plant at the Mikindani site due to the designation of site use, set by the regional government afterward.

Because the site is designated as a residential area, new power plants cannot be constructed under the current designation. Also, the change of site designation turned out to be unacceptable. But it is possible to solve other issues concerning the site.

On the other hand, it becomes clear that the Kisiwa site proposed by TANESCO, which was second best site in the Basic Survey (2016), doesn’t have significant problems with respect to the construction of a new power plant. Especially, the adoption of seawater cooling system for the steam turbine condenser is determined to be feasible by the study.

As a result, the Kisiwa site is selected as the candidate site for the Mtwara GTCC power plant project.

CHAPTER 4

GENERAL STUDY ON THE POWER PLANT

CHAPTER 4 GENERAL STUDY ON THE POWER PLANT

4.1 SELECTION ON PLANT TYPE

4.1.1 Introduction

As described in Chapter 3, Kisiwa site has been finally selected as the location for the Mtwara GTCC power plant. Moreover, PSMP2016 shows that there is a plan to construct a new GTCC with a rated output of 300 MW class, namely the Mtwara thermal power plant. Therefore, considering the site conditions and TANESCO's requirement, JICA Study Team conducted a basic study for the each facility of the power plant, such as the gas turbine and the condenser cooling system.

4.1.2 Gas Turbine

(1) Consideration of Candidate GTCC

For the optimum design of the Mtwara GTCC power plant, the optimum model has to be selected from the candidate models that have been proven for their performance and matches the output scale of 300 MW.

There are 2 types of GT machine, one is the aero-derivative type and the other is the heavy duty type. Regarding the aero-derivative type, GTCC configuration is limited to 2 blocks[1] for 300MW class GTCC due to GT capacity. On the other hand, there are 2 types of GTCC configurations for the heavy duty type, i.e. 1 block[2] and 2 blocks.

Therefore totally, there are 4 types of GTCC, i.e. 1) Heavy duty type with 1 block, 2) Aero-derivative type with 2 blocks, 3) Heavy duty type with 2 blocks, 4) Heavy duty type with 1block.

In the Study, three models indicated below are considered as candidate models.

1) H-100 [MHPS] × 2 units × 1 block
2) LM6000PF+ [IHI (GE)] × 2 units × 2 blocks
3) SGT-800 [Siemens] × 2 units × 2 blocks
4) 6F.03 [GE] × 2 units × 1 block

Table 4-1 compares the GTCC of each supplier.

1 2 × (2 GTs - 2 HRSGs – 1 ST)
2 2 GTs - 2 HRSGs – 1 ST

Table 4-1 Comparing GTCC of Each Supplier

Supplier		MHPS	IHI(GE)	Siemens	GE
Model		H-100 × 2 units × 1 block	LM6000 PF+ × 2 units × 2 blocks	SGT-800 × 2 units × 2 blocks	6F.03 × 2 units × 1 block
Launch		2013	2016	2010	1991
Type		Heavy Duty	Aero-derivative	Heavy Duty	Heavy Duty
Feature*	Characteristics on ambient temperature	Base	Relatively large decrease in the output and efficiency due to temperature rise (Using chiller is standard)	Base	Base
	Net Output [MW] (ISO base)	339.4**	270.0	326.2	272.0
Spec*	Net Efficiency [%] (ISO base)	56.9**	55.3	58.6	57.4
	Number of GT	2	4	4	2

Sources: 2019 GTW Handbook & Brochures by Manufacturers,

* From 2019 GTW (Gas Turbine World) Handbook (except for **)
** Estimated by JICA Study Team
*** This is the price of a different model of LM6000 series, because the GTW does not contain information of the mentioned model.
**** This is the price of a different model with lower spec, because the GTW does not contain information of the mentioned model. Actual price seems to be higher than the price mentioned.

According to the previous survey report carried out by JICA, the maximum single unit capacity in which the system frequency can be maintained within the operational limit in case of unit shutdown, is 233MW for 2024 and 253MW for 2025 (Figure 4-1). The CODs (Commercial Operation Date) of GT simple cycle operation/GTCC operation are expected to be in 2024/2025 respectively. The single unit capacity of H-100 is the largest among the candidate models. Under the maximum operation condition, the maximum output drops of H-100 are 104MW/158MW for the GT simple cycle operation phase (2024)/the GTCC operation phase (2025) respectively; and the GT generator drops and the ST generator outputs are suppressed in the case of GTCC. From the view point of maximum single unit capacity, all of the candidate models are applicable for both the GT simple cycle operation phase (2024) and GTCC operation phase (2025).

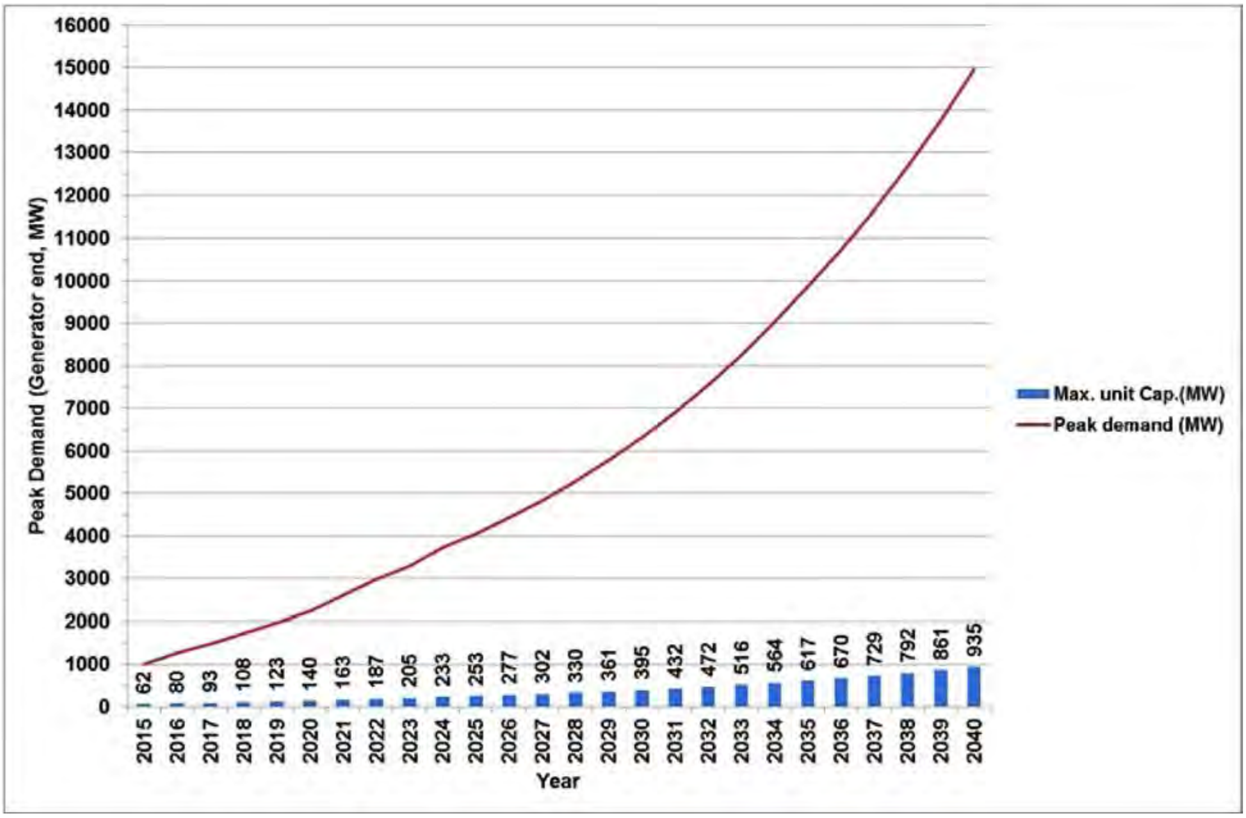


Figure 4-1 Maximum Allowable Single Unit Capacity which can maintain System Frequency

Sources: JICA (2017). Final report on the project for formulation of power system master plan in Dar es Salaam and coast regions and review of power system master plan 2012 in the United Republic of Tanzania: review of power system master plan 2012, pp. 8-35.

(2) Dual Fuel System

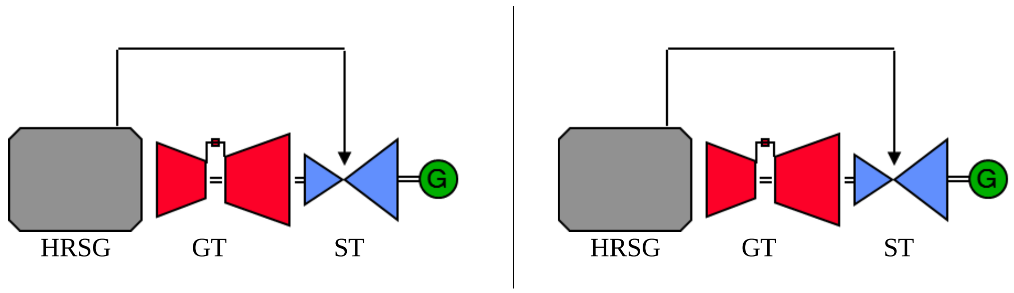
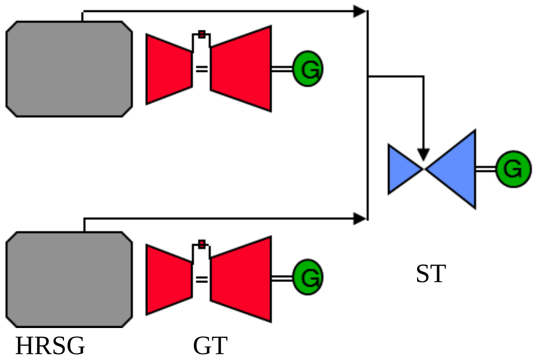
In case of long-term shutdown of gas supply, the GT with a dual fuel system, which is capable of burning liquid fuel such as light oil - used as an emergency backup, is generally recommended. However, it is necessary to suppress the amount of NOx generated. This can be achieved by spraying steam or water into the combustion chamber, which will lower the combustion temperature. After discussing with TANESCO, it was decided to not use the dual fuel system for this project, based on TANESCO's request.

4.1.3 Power Block Configuration on Shaft (2-on-1, 1-on-1)

(1) GTCC Configuration

In regard to the construction work of GTCC, the configuration of GTCC has to be studied carefully. Basically, the system configuration is divided into 2 types (single-shaft type and multi-shaft type) as shown in Figure 4-2. Single-shaft type consists of one GT, one ST and one generator on the same shaft.

On the other hand, multi-shaft type consists of multi-GTs, one ST and multi-generators. One generator is connected with each GT and ST. Therefore, the number of generators is same as the total number of GTs and ST.

Shaft type	Configuration
Single-shaft	1-on-1 ×2 units  The system that consists of GT and ST on the same shaft
Multi-shaft	2-on-1 ×1 unit  Each GT and ST is installed separately and each GT and ST has a generator.

Source: JICA Study Team

Figure 4-2 Configurations of Single-shaft Type and Multi-shaft Type GTCC

(2) Main Characteristics of GTCC Configuration

1) Output and Heat rate

Generally, it is possible to increase ST output by adopting the multi-shaft type GTCC, which has a little higher generator output and a little lower heat rate during the base load operation. On the other hand, in case the required generation output has to be reduced by half, single shaft type GTCC can be operated with high efficiency, because one block can be stopped and the other block can be operated at the rated condition.

2) Operability

GTCC is operated based on only the automatic control of fuel flow to GT. It is completely an automatic operation. Therefore, there is no difference between multi-shaft type and single-shaft type.

3) Number of main equipment

Compared to the multi-shaft type, the single-shaft type needs one less generator, but it requires one additional ST and an auxiliary equipment.

4) Installation area

As for multi-shaft type, the efficiency of area usage will be decreased because ST is installed separately. On the other hand, the placement of equipment can be flexible.

5) Construction cost

Construction cost of single-shaft type will be a little higher because of the increase in auxiliary equipment.

6) Serviceability

While there is a little difference in configuration, basically, there is almost no difference in terms of serviceability between the two types.

7) O&M cost

Basically, there is almost no difference in terms of O&M cost between the two types.

8) GT/ST handling during maintenance period

When one GT can't be operated due to inspection or unplanned maintenance, multi-shaft type GTCC can be operated at almost 50% output. When the ST can't operate, it is possible to operate two GTs independently using bypass stack.

On the other hand in the case of single-shaft type, when the GT or ST can't be operated, due to situations such as inspection of each shaft, it is possible to continue high efficiency operation while securing 50% output.

9) GT simple operation

Multi-shaft type can be also operated as an open cycle GT. In addition, it is possible to start sole power generation relatively early, at the time of construction. On the other hand, with regard to the single-shaft type, in order to operate as an open cycle GT, it is necessary to install clutch system in the ST or to have the flow of gland steam and the cooling steam.

10) Summary of Examination Results

Each configuration is evaluated and the summary is shown in Table 4-2.

TANESCO assumes that the power plant has to be operated as a base load plant. Therefore, high power and high efficiency are required. Also, early operation of the power plant is strongly requested.

JICA Study Team recommends multi-shaft 2-on-1 GTCC because it has many advantages in terms of output, efficiency, construction cost, and GT simple operation in accordance with TANESCO's requirement.

Table 4-2 Characteristic of Each Shaft Type

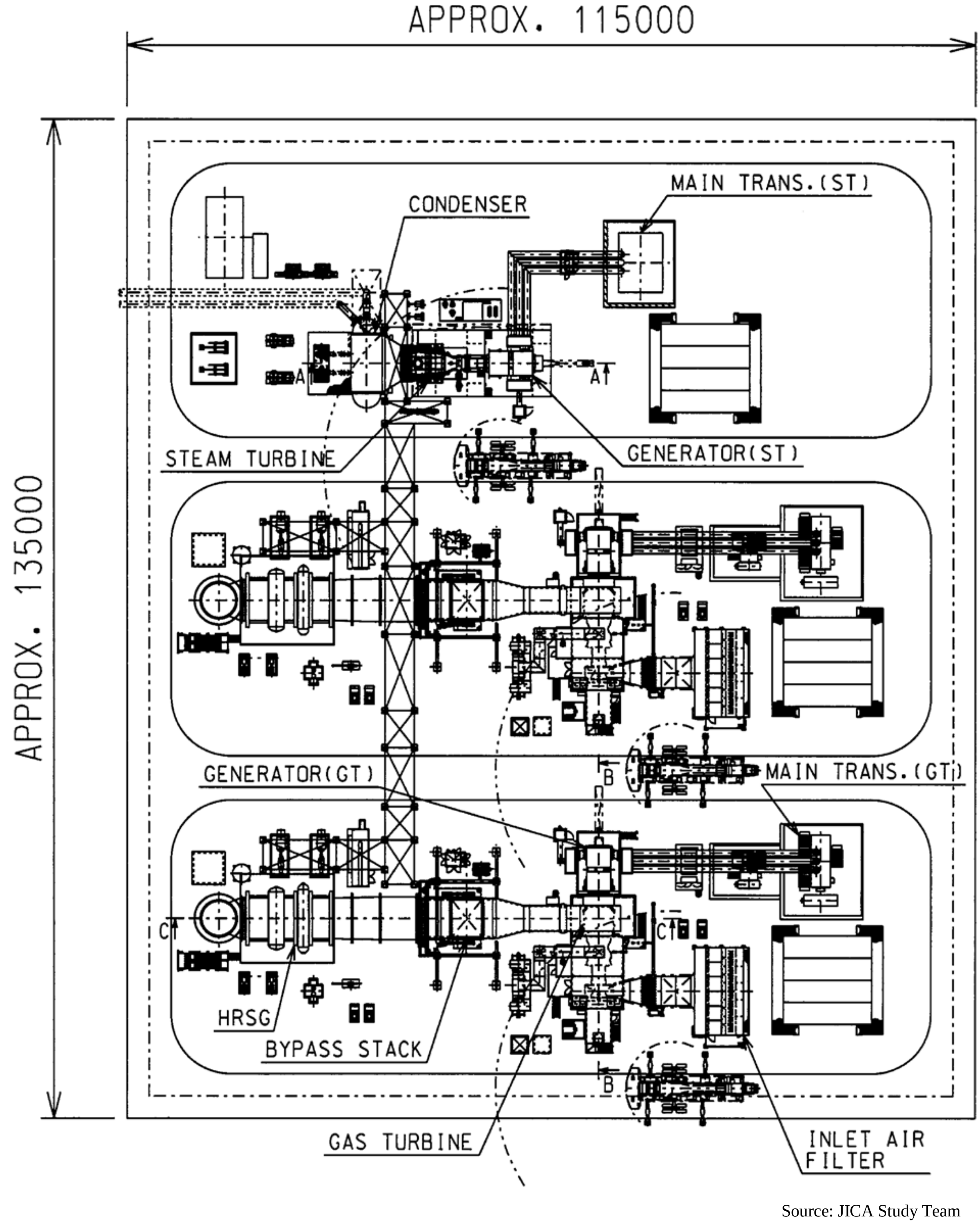
Item	Multi-shaft type (2-on-1)	Single-shaft type (1-on-1)
Output	Base	A little low
Heat rate	Base	A little high ※high efficiency at partial load of GTCC
Operability	Base	Same
Number of main equipment	Base GT:2, HRSG2, ST:1, GEN:3	Many GT:2, HRSG:2, ST:2, GEN:2
Installation area	Base	A little compact
Construction cost	Base	A little expensive
Serviceability	Base	Same
O&M cost	Base	Same
GT/ST handling during maintenance period	It can be operated at about half load.	Same ※it is possible to operate at high efficiency
GT simple operation	Easy	Difficult

Source: JICA Study Team

4.1.4 The Layout of GTCC

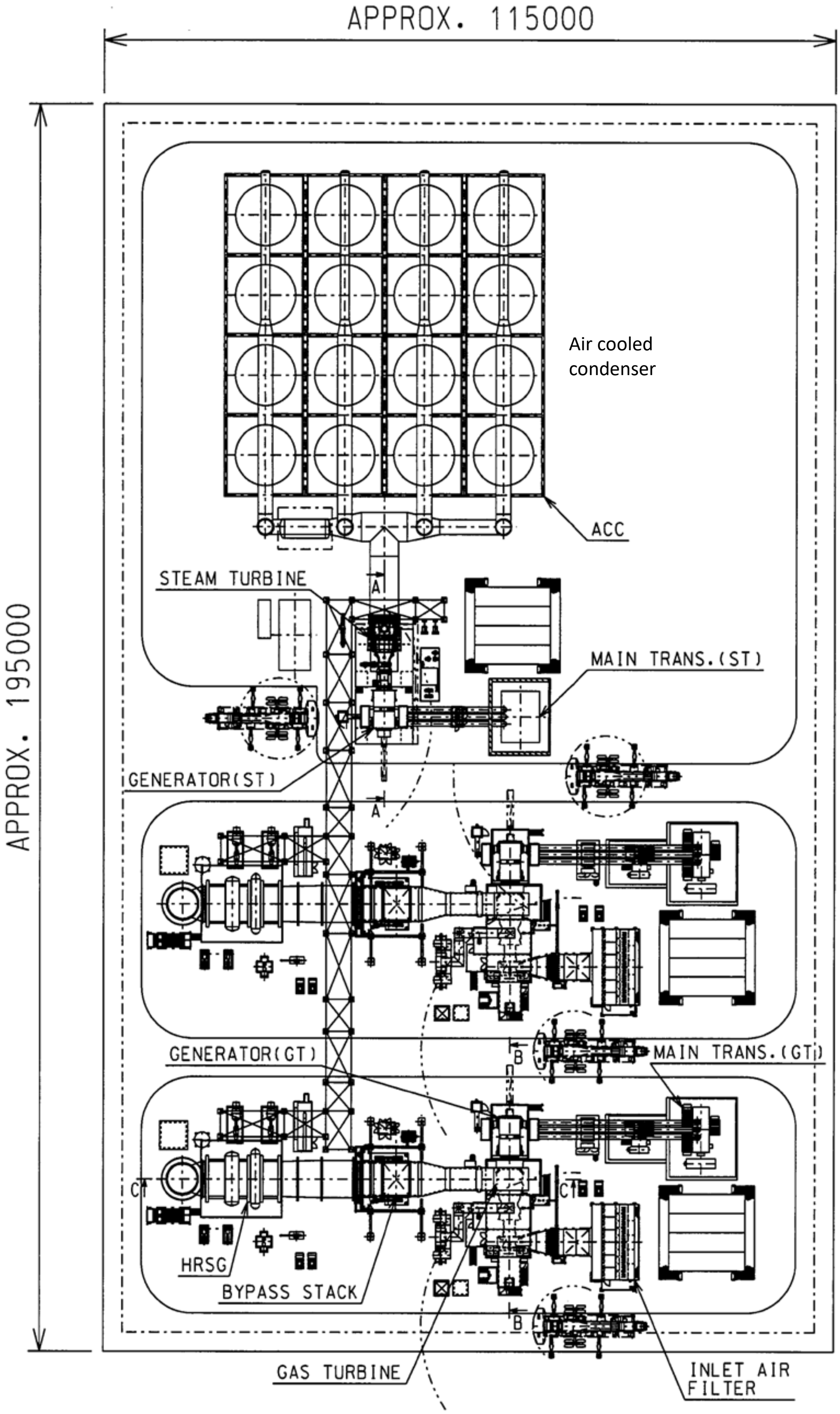
Aero-derivative GT or heavy duty GT can be used for the 300 MW class multi-shaft type 2-on-1 GTCC. Also, the layout of GTCC changes according to the type of condenser cooling system.

Typical GTCC layouts, for each type of GT and condenser cooling system (air cooled condenser system or seawater cooling system), are shown in Figure 4-3 to Figure 4-6 for 1 block and 2 blocks respectively.



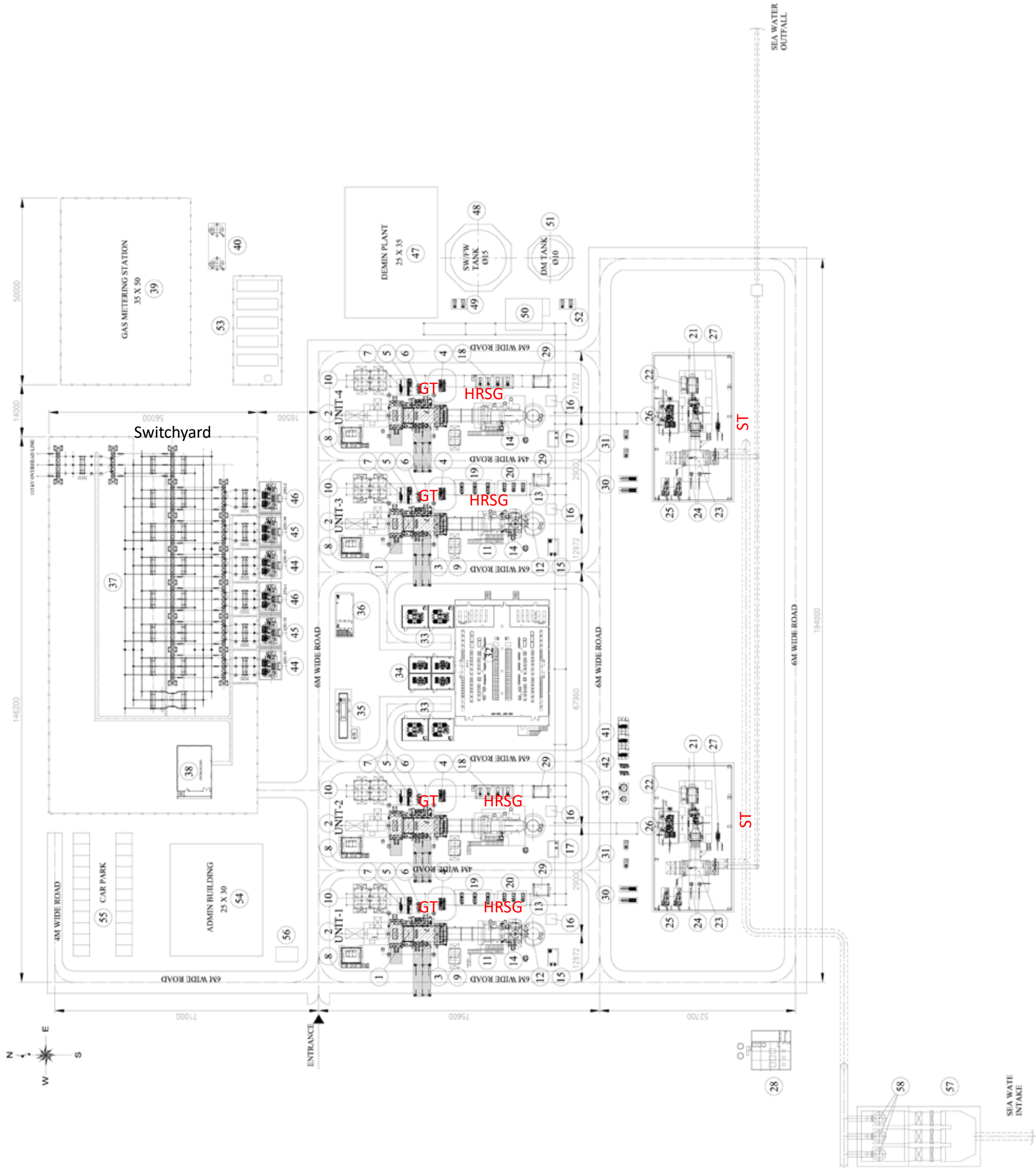
Source: JICA Study Team

Figure 4-3 Typical GTCC Layout of 1 Block with Seawater Cooling System



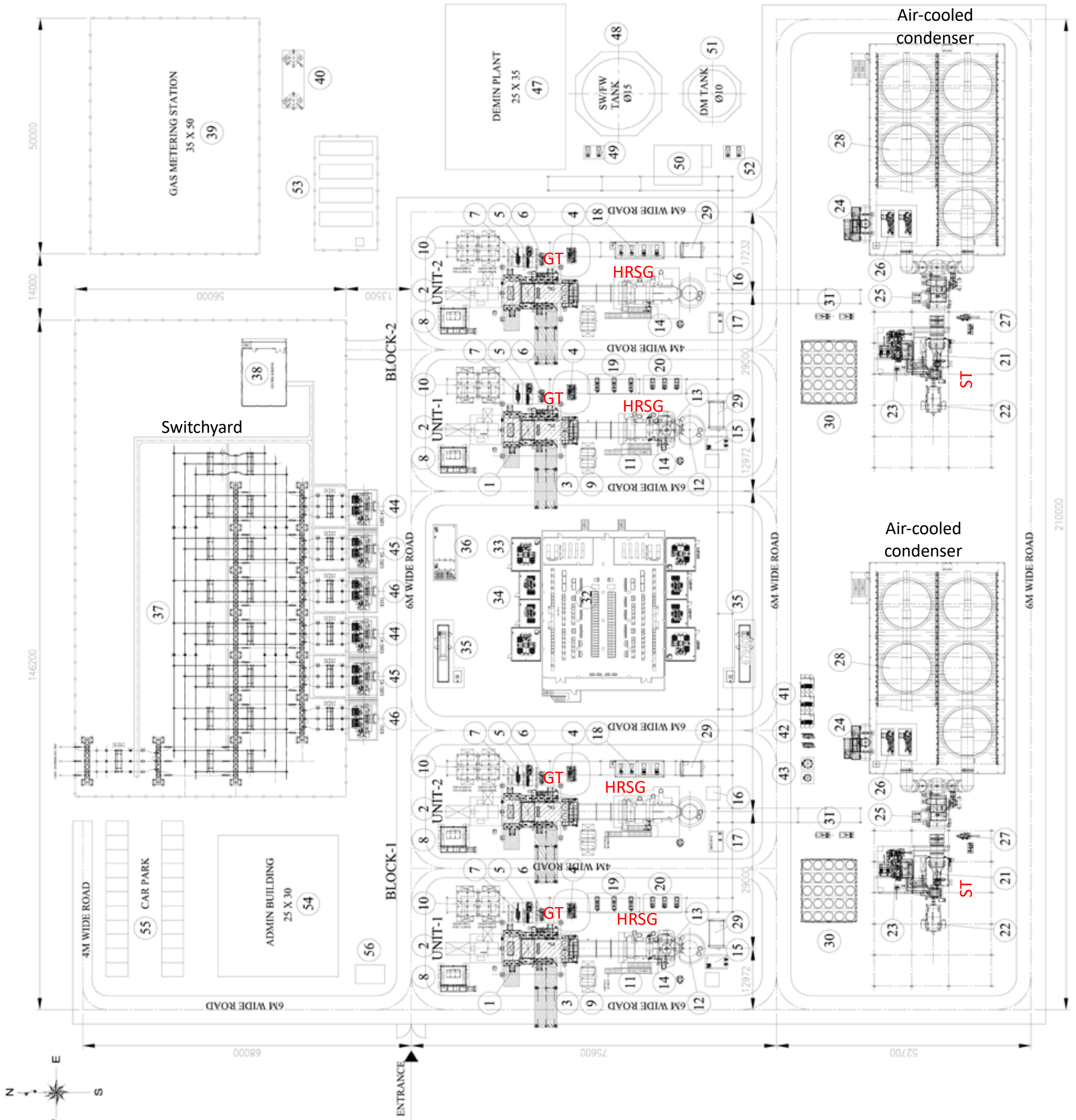
Source: JICA Study Team

Figure 4-4 Typical GTCC Layout of 1 Block with Air Cooled Condenser System



Source: JICA Study Team

Figure 4-5 Typical GTCC Layout of 2 Blocks with Seawater Cooling System



Source: JICA Study Team

Figure 4-6 Typical GTCC Layout of 2 Blocks with Air Cooled Condenser System

4.1.5 Condenser Cooling System

(1) Outline

Generally, there are three types of ST condenser cooling system— the seawater cooling system, the wet cooling tower system, and the air cooled condenser system. For each type, the constraints in the environmental condition of the site, the operation cost, the installation cost, and the efficiency of ST shall be considered. Therefore JICA Study Team has examined the cooling systems considering those constraints.

(2) Mechanical Examination of Condenser Cooling System

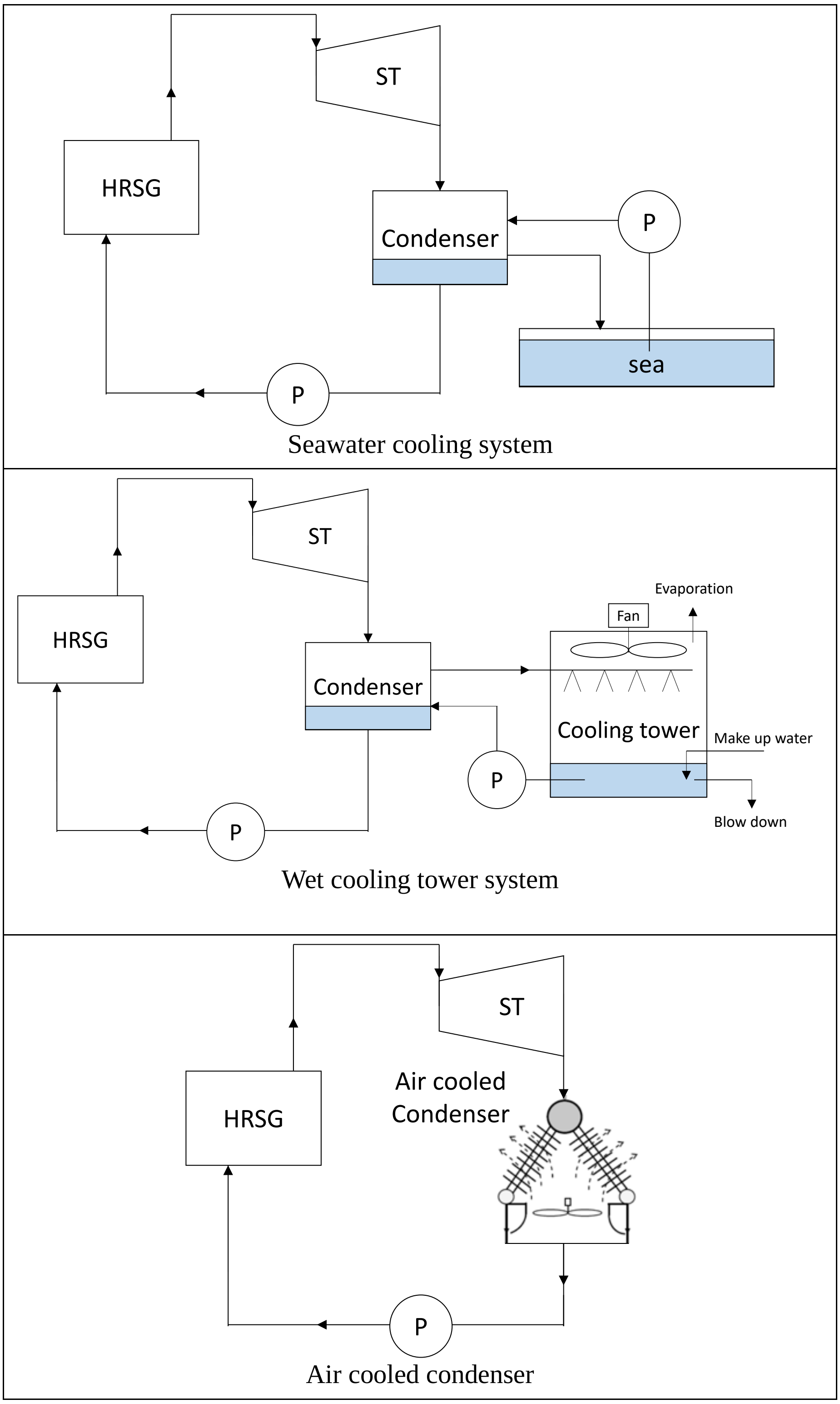
Table 4-3 shows the characteristic of each cooling system.

Table 4-3 Characteristics of Condenser Cooling Type

Type	Seawater cooling	Wet cooling tower	Air cooled condenser
Installation cost	Base	Lower	Higher
Efficiency of GTCC	Base	Lower (Relative efficiency : within -1 %)	Lowest (Relative efficiency : over -2 %)
Fresh water consumption	Base (100 %)	Higher (about 5000 %)	Same (100 %)
Space of land	Base	Almost same	Larger
Required equipment	• Intake/discharge channel • Intake/discharge pipe • circulating water system • bar-screen system • rotary-screen system	• Cooling tower • Circulating water system	• Air cooled condenser • Cooling fan
Note	• It is necessary to avoid hot water recirculation and heat accumulation. • Equipment needs to be installed on the coast line.	• Needs a lot of fresh water.	

Note: Model GTCC: H-100 (300MW class), ISO conditions (101.33 kPa, 15°C 60% RH)

Source: JICA Study Team



Source: JICA Study Team

Figure 4-7 Schematic System Diagrams of ST Cooling Type

Figure 4-7 shows schematic system diagrams of each ST condenser cooling type.

1) Seawater Cooling System

Seawater cooling system uses sea water as a coolant to convert steam into condensed water. This cooling system contributes to higher plant efficiency and can reduce fuel cost compared to the other cooling systems. However, it has some restrictions such as avoidance of hot water recirculation and heat accumulation, environmental impacts on seawater, and installation condition along the coastline.

2) Wet Cooling Tower System

As for wet cooling tower system, the cooling water for the condenser and air are directly brought in, and the water is cooled by the latent heat when the cooling water evaporates. The efficiency is slightly lower than seawater cooling system because the degree of vacuum inside the condenser is slightly low. Furthermore, since the circulated cooling water is gradually lost by evaporation and blow-down, it is necessary to supply water at about 2% of the circulation amount every day. Therefore, a large amount of fresh water is required.

3) Air Cooled Condenser System

As for air cooled condenser system, the steam exhausted from the ST is indirectly cooled by the air in the tube. There is no need for water intake/discharge facility and circulating water system because water is not required as coolant. However, it is necessary to increase the size of the condenser, because the thermal conductivity of the coolant air is lower than that of water. Therefore, the system requires a vast land, and the installation cost is high. Moreover, the output and efficiency of the steam turbine are the lowest among all the three systems.

(3) Overall Study of Condenser Cooling System in Kisiwa site

JICA Study Team needs to choose one type of ST condenser cooling system from the three types mentioned above. In this Section, considering the conditions of Kisiwa site, JICA Study Team examined which condenser cooling system is applicable for the plant.

1) Cooling water consumption

When seawater cooling system is adopted, condenser cooling water of maximum 32,400 m^3/h will be necessary. Kisiwa site is located near the bay, therefore it is quite easy to obtain the required amount of cooling water by installing intake facilities. According to the simulation results of seawater cooling system, no problem is found in terms of impact on the environment around Kisiwa site, caused by the hot discharged seawater. Simulation result is described in detail in Chapter 12. In the case of wet cooling tower system, it is necessary to supply fresh water of about 650m^3/h (about 2% of the circulation water amount). However, around the Kisiwa site, there is no water source that can supply the above amount of water to the plant. Detail information about the water sources is described in Section 4.2. On the other hand, seawater cooling condenser system will require supplemental “make-up water” of about 12.5 m^3/h. In the case of air cooled condenser system, the water required to operate the plant is “make-up water”.

2) Cooling capacity evaluation

In order to evaluate the preliminary feasibility of the seawater-cooled condenser, we manually calculated the recirculation of hot seawater before the computer simulation. As a result of the calculation, it is clear that the amount of heat supplied from the power plant is less than the volume of heat transferred to air. Therefore the feasibility of the seawater-cooled condenser is confirmed at the first look.

3) Installation area of major equipment

In the case of seawater cooling system, it is necessary to install some equipment near the coast line. Kisiwa site is located along the coast line. The power generation equipment can be installed 60 m away from the coastline, and there is enough space to install the above equipment.

In the case of wet cooling tower system or air cooled condenser system, there is no need to install equipment on the coast line. And Kisiwa site is a large area of 160 ha. Therefore, all the cooling systems can be constructed inside the planned area.

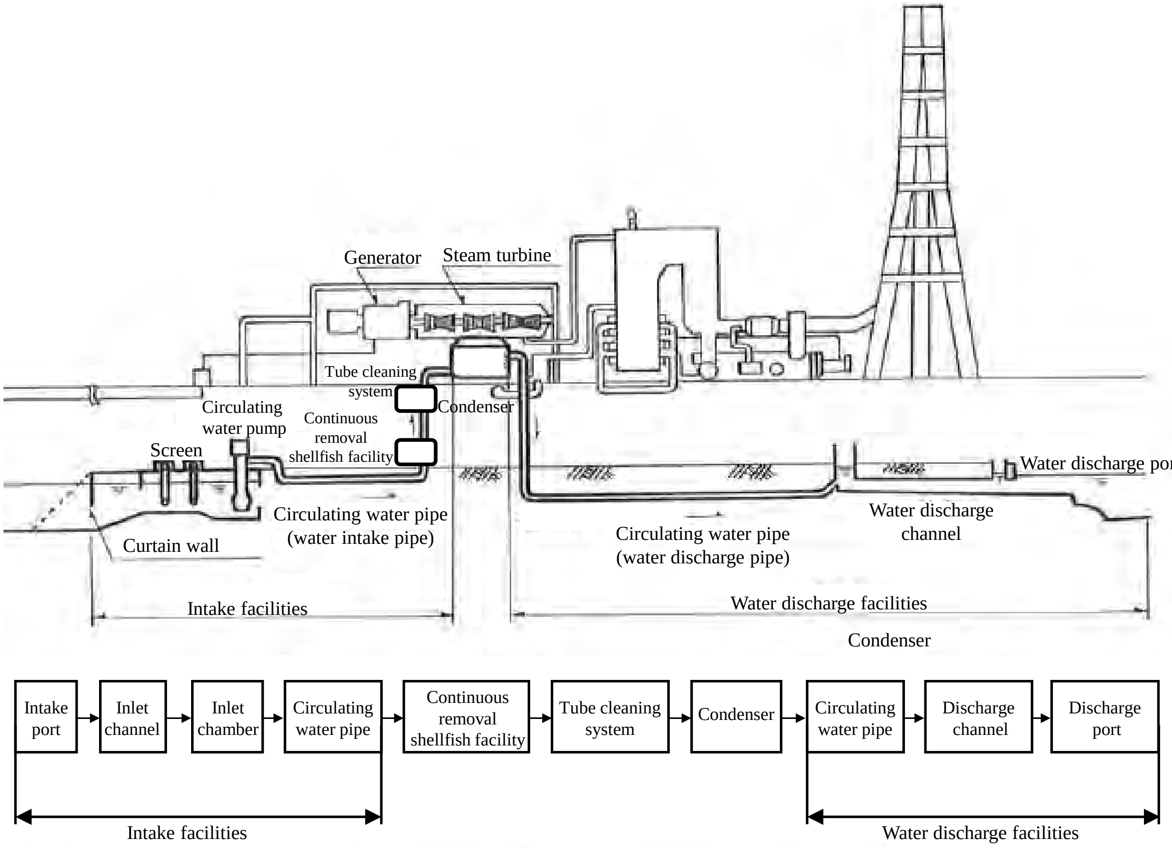
4) Conclusion

Seawater cooling system and air cooled condenser system can be adopted considering the conditions of Kisiwa site. On the other hand, it is not possible to adopt wet cooling tower system. This is because it is difficult to secure the required amount of fresh water for the wet cooling tower system around the Kisiwa site.

(4) Overall Study of Water Intake/Discharge Facilities

Figure 4-8 shows the outline of intake/discharge cooling water facilities.

These facilities consist of: intake facilities (water intake port, screen system, circulating water pump), circulating water pipe (water intake pipe) that deliver seawater to the condenser; and condenser, another set of circulating water pipe (water discharge pipe) that delivers seawater from the condenser to the water discharging facility; and the water discharge facilities (water discharge channel, water discharge port) on the coast of the site.



Source: Design Guideline of Thermal and Nuclear Power Plant Civil Engineering Structures (Japan Electric Power Civil Engineering Association, 1996)

Figure 4-8 Outline of Intake/Discharge Cooling Water Facilities

There are various types of intake/discharge cooling water facilities, and it is necessary to adopt the optimum facility considering the surrounding environment of the site.

Each intake/discharge cooling water facility and its associated types are shown below.

1) Water intake port

In the intake cooling facilities, the facility where water is taken from the sea is called a water intake port. It is necessary to consider the following items to select the installation point of the water intake port along with the discharge port.

- Impact on maritime environment
- Hot discharge water re-circulation
- Impact on ship's sailing

There are two types of water intake port— the deep water intake and the surface water intake. The deep water intake system is further classified as— the curtain wall type and the water intake tower type. The plant efficiency is higher when the temperate of cooling water is lower.

Table 4-4 shows the characteristic of each water intake port type.

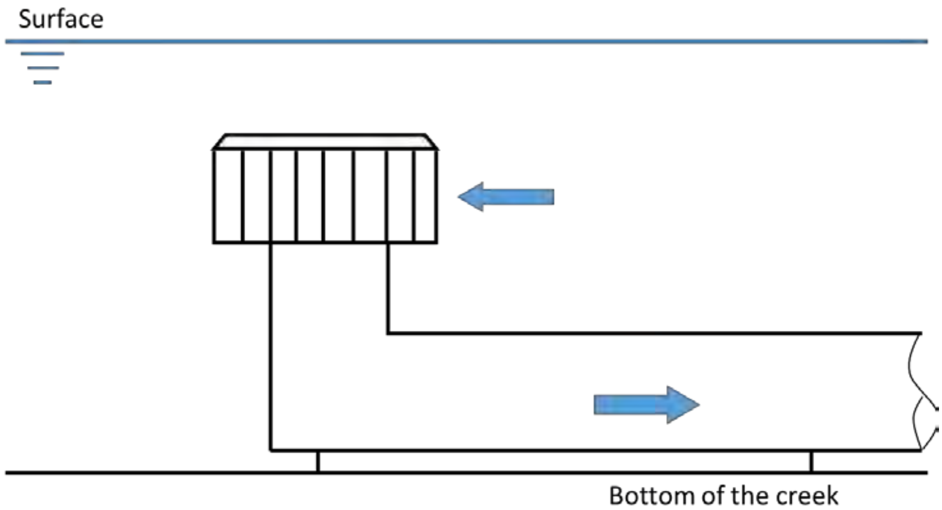
Table 4-4 Characteristics of Each Water Intake Port Type

Type	Water intake tower	Curtain wall	Surface intake
Temperature of intake water	Base	High	Highest
Power generation efficiency	Base	Low	Lowest
Construction cost	Base	Same	Low
Note	It is possible to take water from a low water-temperature point, because the installation position of the intake tower can be selected.	It is basically set on the coast. When installed in the offshore area, the construction cost becomes huge.	There is a possibility of troubles due to ocean garbage, because it may take garbage along with the water.

Source: JICA Study Team

Around Kisiwa site, the bay is shallow, the flow is weak, the amount of seawater is low, and the water temperature is high. High water temperature will lower the plant efficiency. It is important to intake water with low temperature. In general, water intake tower can take lower temperature water and prevent recirculation of hot discharge water. Therefore, the JICA Study Team recommends the tower type as the best candidate for this project.

A schematic diagram of the tower type is shown below.



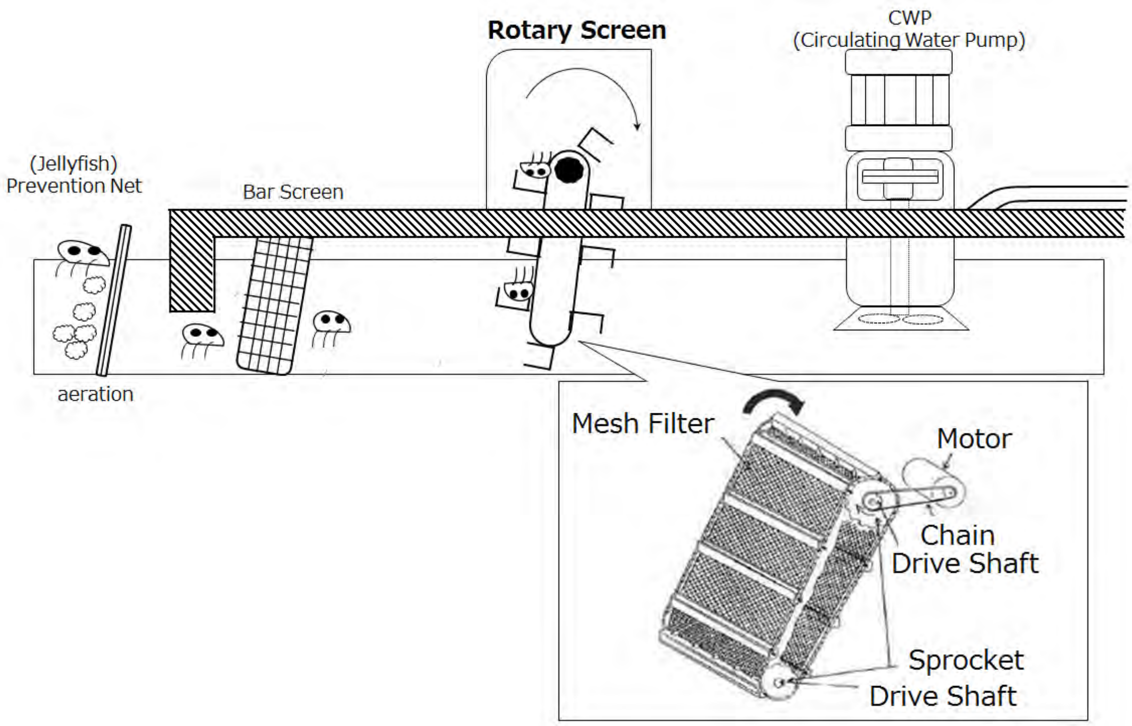
Source: JICA Study Team

Figure 4-9 Schematic Diagram of Tower Type

2) Screen facility

The screen is a facility for removing jellyfishes, shellfishes, marine litter, etc. from the seawater for condenser cooling. There are two types of screens: bar screen and rotary screen. The bar screen is a facility to remove large objects such as marine litter. The purpose of installing the bar screen is to protect the water intake facilities from damage. On the other hand, the rotary screen facility can remove small objects such as marine creatures that pass through the bar screen. The purpose of installing the rotary screen is to prevent the inflow of foreign objects which cause clogging inside the condenser.

During the field survey, the JICA Study Team confirmed that the number of jellyfish in Kisiwa site is lesser when compared to Japan. The standard rotary screen facility is selected. Outline of the rotary screen facility is shown below.



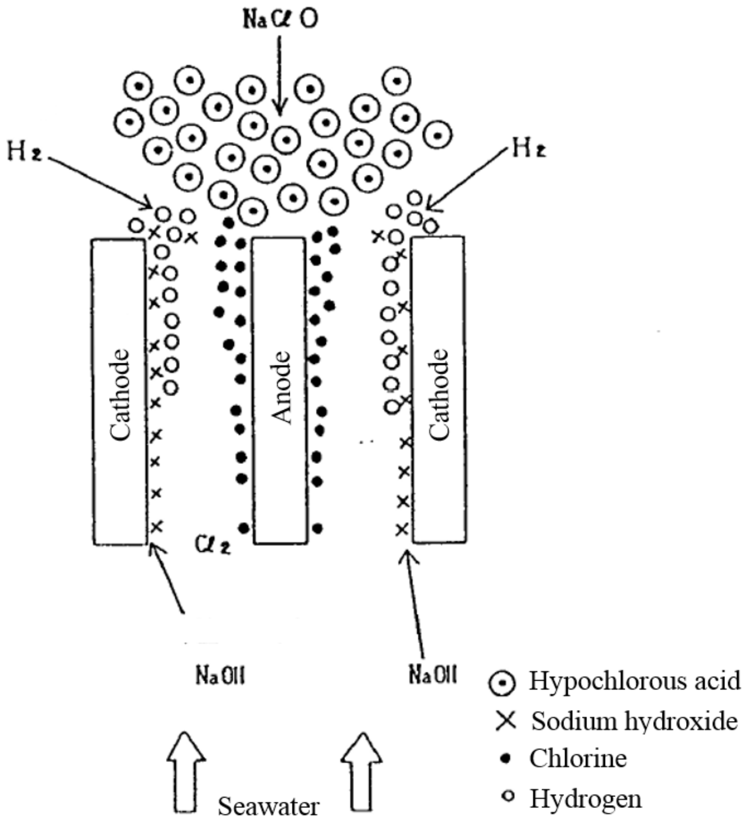
Source: JICA Study Team

Figure 4-10 Outline of the Rotary Screen Facility

3) Seawater electrolyzer

Seawater electrolyzer prevents the growth of marine creatures at the seawater intake facilities. If marine creatures grow at the seawater intake facilities, especially between the Circulating Water Pump (CWP) and condenser, it will cause obstruction in the condenser and increase the CWP power. And an obstruction in the condenser will lead to unplanned outage of the plant, due to the tube damage and reduced efficiency of GTCC.

The principle of seawater electrolyzer is shown below. Hypochlorous acid suppress growth of marine creatures. And it will be fully consumed by the marine creatures or the decay, so hypochlorous acid will not be detected in the discharge water.



Source: JICA Study Team

Figure 4-11 Principle of Seawater Electrolyzer

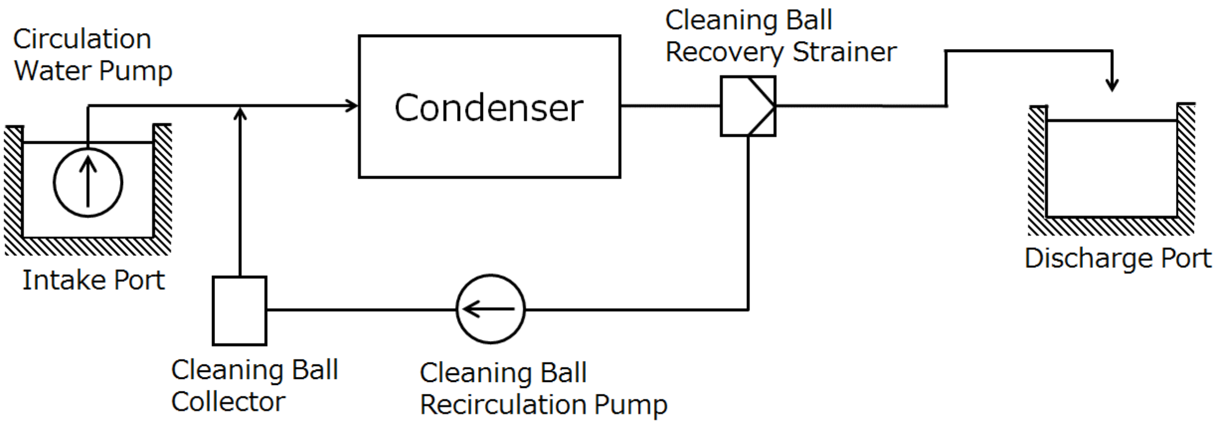
4) Facility for Continuous Removal of Shellfish

The facility to continuously remove shellfish for the condenser prevents the inflow of shellfish to the condenser and prevents the obstruction of condenser tube. This facility is installed at the inlet side of the condenser and it collects the shellfish using the strainer. This collected shellfish is discharged automatically to the discharge pipe of condenser.

5) Condenser tube cleaning system

Condenser tube cleaning system prevents marine creatures from sticking to the inner surface of the cooling tubes by feeding and circulating special balls in the cooling tubes.

During the field survey, some turbidity was identified at the bay. So, JICA Study Team recommends installing a condenser tube cleaning system to avoid clogging of the thin tubes. Outline of the condenser tube cleaning system is shown below.



Source: JICA Study Team

Figure 4-12 Outline of a Condenser Tube Cleaning System

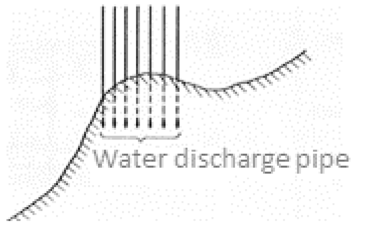
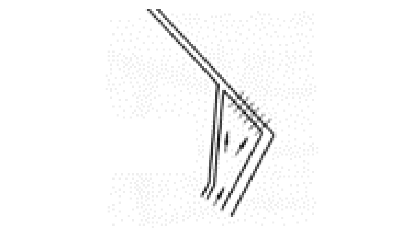
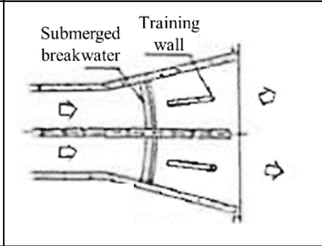
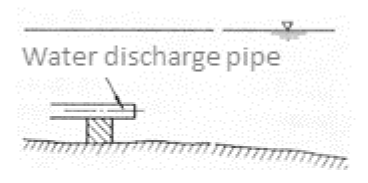
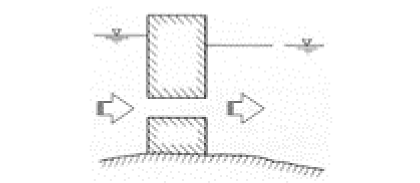
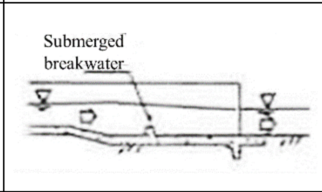
6) Discharge cooling water facilities

The facility that discharges hot water from the condenser is called a water discharge facility. The water discharge port must be able to discharge stably, regardless of the natural conditions such as waves and tidal drift. Also, the hot discharge water has higher temperature than the surrounding sea, and a large amount of water is to be discharged. Therefore, it is necessary to consider the following items to select the installation point of the water discharge port and the water discharge type.

- Impact on maritime environment
- Hot discharge water re-circulation
- Impact on ship's sailing

The water discharge port type is categorized into— the surface water discharge type and the underwater discharge type. The surface water discharge type has relatively little dilution and mixes with the seawater around the port. The underwater discharge type can quickly reduce the water discharge temperature by mixing with a large amount of seawater around the discharge port. Also, it is defined as a coastal discharge type or offshore discharge type depending on the location of the water discharge port. Table 4-5 shows the characteristic of each water discharge port type.

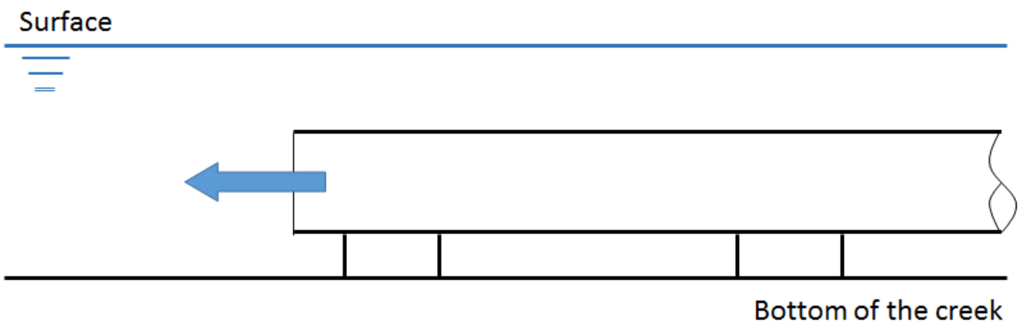
Table 4-5 Characteristic of Each Water Discharge Port Type

Type	Underwater discharge type		Surface water discharge type
	Offshore discharge type	Seawall discharge type	
	Open channel type	Seawall pipe type	Open channel type
Structure overview: Ground plan			
Structure overview: Cross section			
Outline	Extend the water pipe to the offshore, and discharge almost horizontally from the pipe near the sea floor.	Install a pipe or slit in the lower part of the seawall, and discharge with a relatively high flow velocity.	Connect to the seawall through a drainage channel such as a culvert, and directly discharge from there.
Depth of installation place	For mixed dilution, it becomes more effective with depth. From the construction point of view, the depth at which the water pipe can be installed is restricted.	Mixing with the surrounding water becomes effective with depth.	Can be installed even if it is shallow
Flow velocity at discharge port	In order to mix and dilute with the surrounding water, the discharge flow rate should be relatively high. The flow velocity is generally 2 m/s or more.	In order to mix and dilute with the surrounding water, the discharge flow rate should be a relatively high. The flow velocity is generally 2 m/s or more.	By widening the channel, it is possible to discharge at a low flow velocity.
Initial dilution	Dilution in the vicinity of the water discharge port is more effective than the seawall pipe type, since the surrounding water also entrains from behind the pipe.	Initial dilution depends on the discharge water flow and the floating effect of the hot waste water.	The dilution effect by initial mixing can't be expected much.
Diffusion area of hot waste water	In general, the diffusion area is smaller than that of the surface water discharge type.	In general, the diffusion area is smaller than that of the surface water discharge type.	The diffusion area is wide. In that area, the water temperature around the water outlet is high
Note	It is necessary to design in such a way that the inspection of facilities, cleaning the inside of the pipes, etc. is possible. This type does not need the coastline for water discharge port	In order to construct the water discharge port, a suitable coastline is required. Due to the discharge effect, it is not suitable in places where ship's navigation frequency is high.	In order to construct the water discharge port, a suitable coastline is required.

Source: Design Guideline of Thermal and Nuclear Power Plant Civil Engineering Structures (Japan Electric Power Civil Engineering Association, 1996)

Based on the hearing from TANESCO, construction of structures exposed to the ground, at 60m away from the coastline, is not allowed. Therefore, it is not possible to select seawall discharge type. In addition, seawall discharge type will lead to the construction of a large structure because of the shallow tidal flat. Therefore, JICA Study Team recommends adopting the offshore discharge type as a candidate in this project.

The schematic of the offshore discharge type is shown below.



Source: JICA Study Team

Figure 4-13 Schematic of the Candidate Discharge Facility

7) Examination of the water intake/discharge point

In Japan, it is said that the distance [m] between the intake and discharge cooling water facilities has to be more than 20 times of the circulating cooling water amount [m^3/s] to avoid water recirculation[3]. For the 300 MW class power plant, it is estimated that the circulating water volume is about 9 m^3/s. Therefore, the required distance between the intake and discharge cooling water facilities is about 200 m ($9 \times 20 = 180 \fallingdotseq 200$) or more. Based on this distance, the JICA Study Team preliminarily determined the installation position of the water discharge equipment.

Based on the results of sea-depth survey (shown in Figure 4-14) during the field survey, JICA Study Team examined the preliminary installation points of the intake/discharge cooling water facilities.

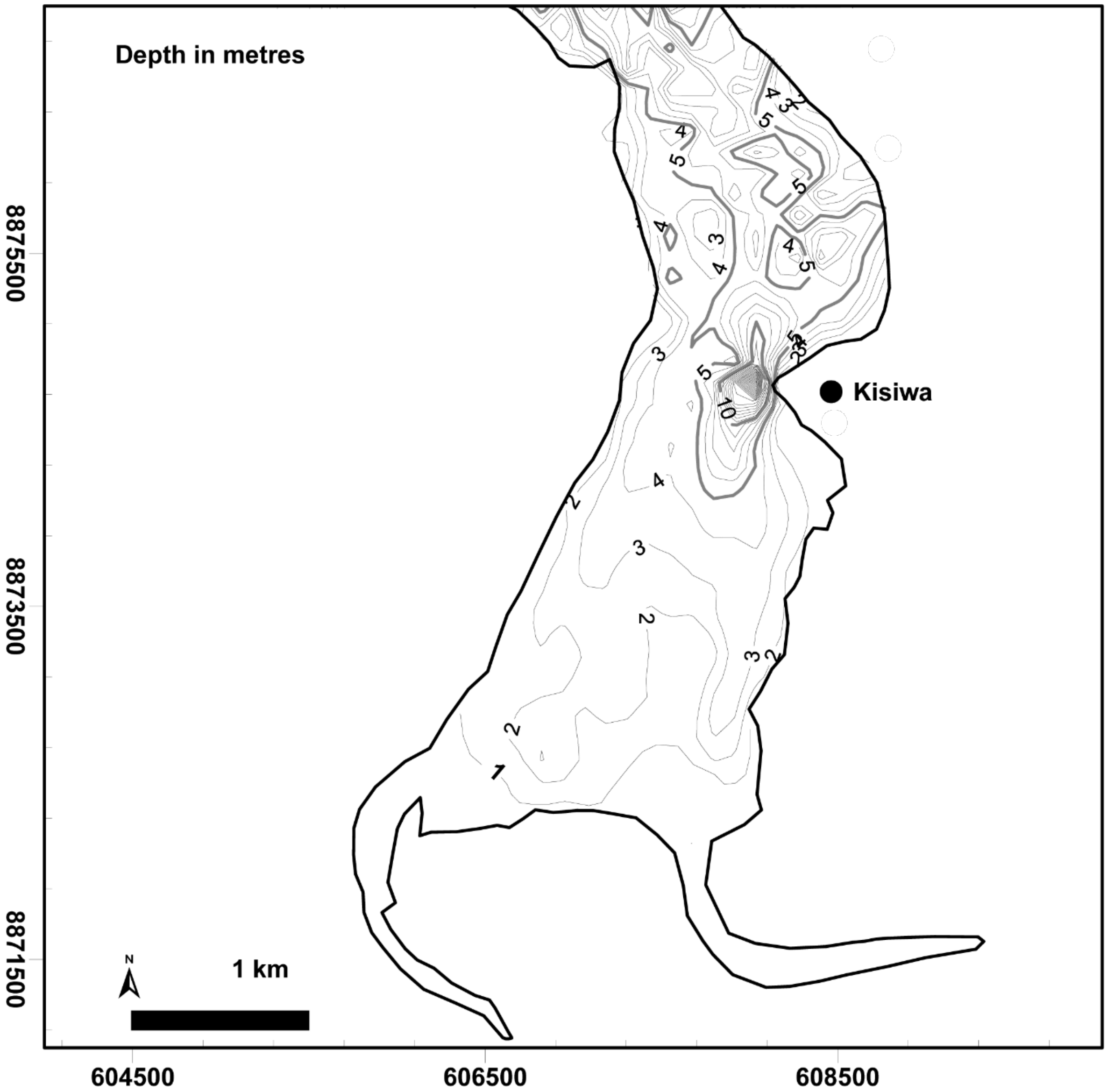
As for the candidate installation point of the water intake port, JICA Study Team selects a point with about 15 m depth, about 200 m away from the nose area, (sandy beach) at the northwest of the site, that satisfies the following conditions.

- Water is taken from deep water to take in low temperature water
- The distance between the water discharge port and the water intake port is 200 m or more
  - Located as close as possible from the coast
- Avoid trimming of mangrove forests as much as possible

The candidate installation point for the water discharge port is in the north part of the bay which satisfies the following conditions.

- The distance between the water discharge port and the water intake port is 200 m or more
  - There is enough water depth and the water discharge port will not appear above the sea surface during a low tide.
- Located as close as possible from the coast
- Avoid trimming of mangrove forests as much as possible

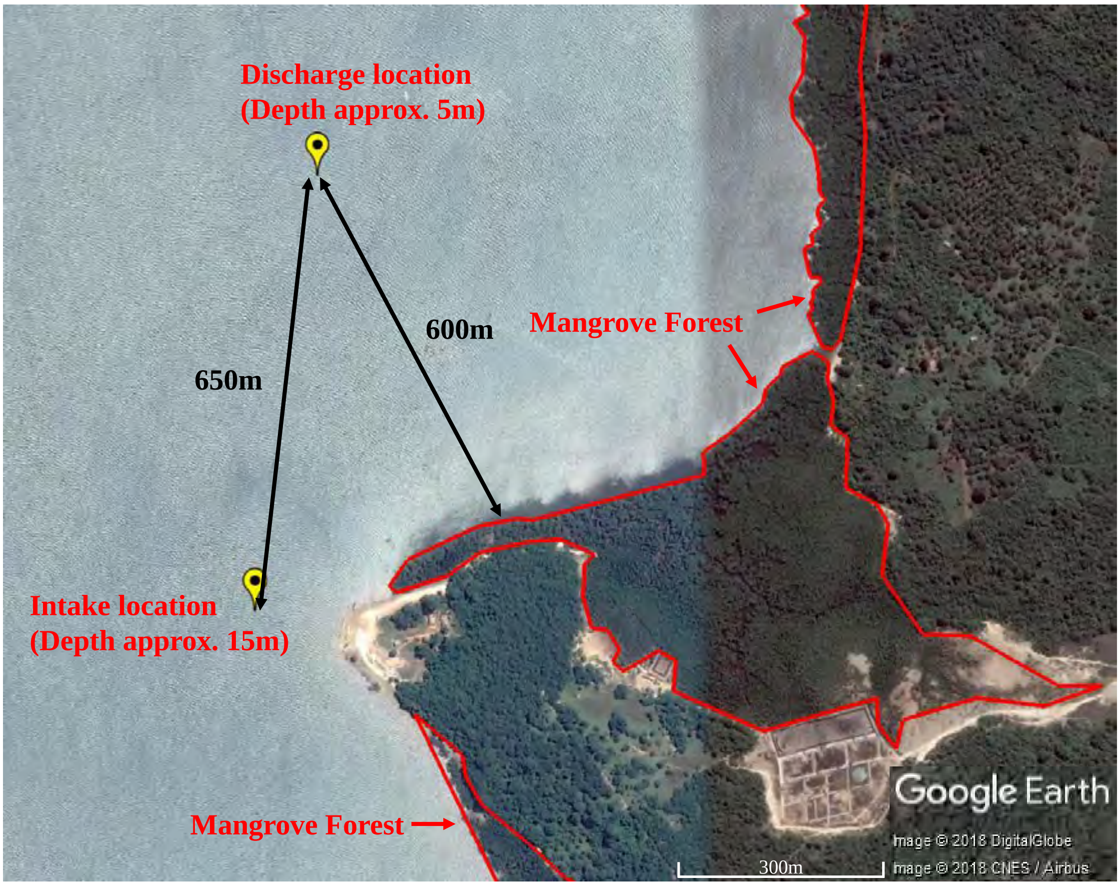
[3] Design Guideline of Thermal and Nuclear Power Plant Civil Engineering Structures (Japan Electric Power Civil Engineering Association, 1996).



Source: JICA Study Team

Figure 4-14 Result of Sea-depth Survey

Figure 4-15 shows the candidate installation point of the water intake/discharge port.



Source: JICA Study Team

Figure 4-15 Candidate Installation Point of the Water Intake/Discharge Port

Based on the above intake/discharge cooling water type and facility positions, hot water simulation is conducted. The result is described in Chapter 12.

(5) Conclusion

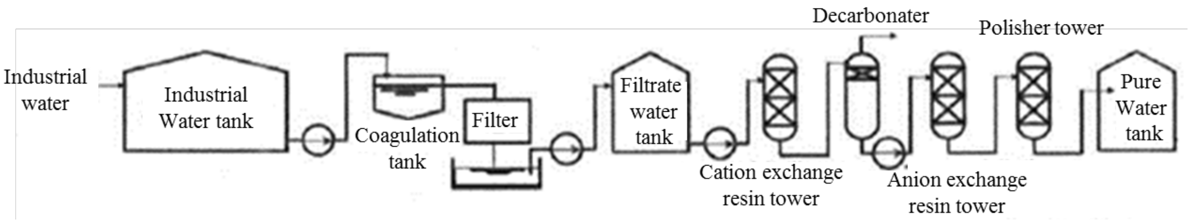
The current data shows that seawater cooling system is preferable for this project, compared to air cooled condenser system.

Considering the construction cost and power generation efficiency, the seawater cooling system is economically superior to air cooled condenser system. Moreover, the hot water simulation result shows that the influence on the environment is limited when adopting the seawater cooling system. Therefore, JICA Study Team recommends adopting the seawater cooling system as the candidate in this project.

Proper intake/discharge location and facility type will be finally examined by evaluating the construction cost, the power generation efficiency and the environmental impact during the detail design stage.

4.1.6 Plant Water Supply and Treatment System

High quality water is required for industrial water. Therefore, the supplied water without treatment is not suitable to be used as industrial water. It is necessary to install water treatment equipment such as pretreatment equipment and demineralized water equipment. Figure 4-16 shows an example of a typical water treatment system.



Sources: Mitsubishi Heavy Industries technical report Vol.50 No.3 (2013)

Figure 4-16 Outline of Water Treatment System

It is necessary to supply approximately 300 m^3/day, which is the amount of water used when the 300 MW class GTCC power plant operates at 100% load.

JICA Study Team originally planned to supply water from Mtwara-Ruvuma River water supply project. However, the project has not progressed since 2016. Therefore, an additional study for the alternatives has to be conducted in this report.

After the second field survey, JICA Study Team was informed that one water public corporation can supply water to the power plant. The water public corporation is MTUWASA, which is responsible for water supply to Mtwara region.

The information obtained from MTUWASA and the field survey results are briefly described below.

The current water supply capacity of MTUWASA in the Kisiwa and Mikindani area is about 1,200 m^3/day. Furthermore, MTUWASA has a plan to expand its supply capacity to about 650 m^3/day in the region. The water source is located about 8 km from Kisiwa site.

From the above information, we can confirm that the amount of water required for the power plant can be secured by water supply from MTUWASA. Details are described in Section 4.2.

4.1.7 Fuel Gas Supply System

It is necessary to ensure that the natural gas satisfies the conditions required for firing in the gas turbine. Generally, the temperature and compression of the gas has to be adjusted. This will be performed at the fuel gas receiving station which requires the below equipment.

- Shut-off valves
- Flow meter
- Separators for removing foreign substance
- Gas compressor or gas pressure reducing facility (If necessary)
- Gas heaters (If necessary)
- Gas flow and pressure regulating system
- Gas detectors

- Fire extinguish system
- Gas sampling systems

(Installation of these equipment should be included in the scope of the contractor)

Natural gas supplied to the gas turbines should meet the minimum gas fuel supply pressure. Depending on the type of gas turbine, the level of gas pressure will change. Table 4-6 shows the gas pressure requirements for the gas turbine candidate models. These pressures are just typical values. They depend on gas property and temperature.

JICA Study Team confirmed to TPDC about the following matters. And if these matters are fully satisfied, there is no need to install gas compressor or gas pressure reducing facility.

- The pressure of the gas supplied is more the pressure required by gas turbine.
- Gas pressure reducing facilities will be prepared in the gas pipeline project.
- TPDC will adjust gas pressure to owner's request.

Table 4-6 Gas Pressure Requirements for the Gas Turbine Candidates

	H-100	LM-6000PF+	SGT-800	6F.03
Gas pressure	37bar (gauge)	50bar (abs)	30bar (abs)	30bar (abs)

Source: JICA Study Team

4.1.8 Generator Feeder

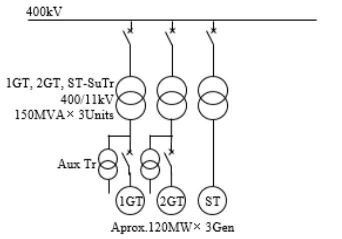
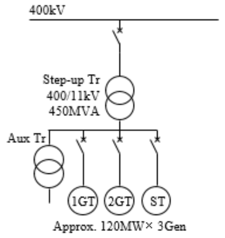
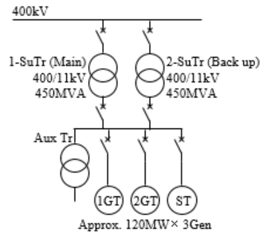
There are several configurations for the generator feeders, which connect generators to the grid. The optimal configuration has to be determined taking into consideration the impact to the grid, the reliability of power supply, costs, etc. In order to construct the 300MW class power plant, H-100 and 6F.03 requires 1 block of 2-on-1. LM6000PF+ and SGT-800 require 2 blocks of 2-on-1. The configurations of the generator feeders are compared and shown in Table 4-7 and Table 4-8.

Taking into consideration the maximum operational limit for the unit drop, i.e., 233MW in 2024 and 253MW in 2025, the 1 feeder configuration of H-100 and 6F.03 is not recommended, but the 2 feeders and 3 feeders configuration of them are applicable. The 2 feeders, 4 feeders and 6 feeders of LM6000PF+ and SGT-800 are applicable.

For H-100 and 6F.03, the 3 feeders configuration are considered to be an optimal configuration. Because, the total cost of transformers and circuit breakers of the 3 feeders is lower than that of the 2 feeders. Therefore JICA Study Team recommends 3 feeders configuration for H-100 and 6F.03.

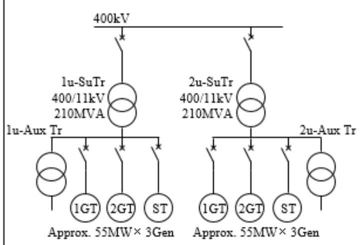
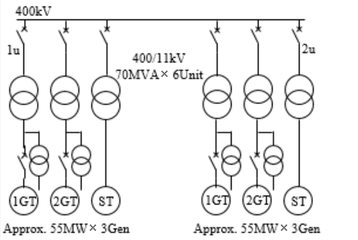
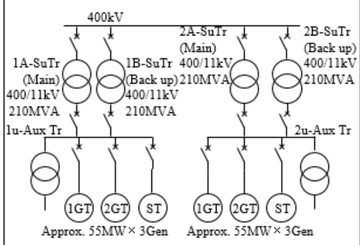
For LM6000PF+ and SGT-800, the 2 feeders configuration will be an optimal configuration. All the 2 feeders, 4 feeders and 6 feeders configuration satisfy the condition of the unit drop. In addition, the total cost of transformers and circuit breakers of the 2 feeders is lower than other configurations. Therefore, JICA Study Team recommends 2 feeders configuration for LM6000PF+ and SGT-800.

Table 4-7 Configuration of Generator Feeders (H-100, 6F.03)

Evaluation	Recommend	Not Recommend	Not Recommend
Configuration	3 Feeders	1 Feeder	2 Feeders
System Diagram			
advantage	• Partial load power supply is possible even if a step-up transformer or a circuit breaker fails • Grid system frequency can be maintained within the operational limit even if the above described facility fails	• Construction and maintenance costs are low due to the small number of step-up transformers	• Full load power supply is possible even if a step-up transformer or a circuit breaker fails • Grid system frequency is not affected even if the above described facility fails
disadvantage	• Construction costs and maintenance costs are high due to the large number of step-up transformers(3 units)	• When the step-up transformer or the circuit breaker fails, the unit stops • When the above described facility fails, grid system frequency deviates from the operational limit	• In normal condition, a step-up transformer and a circuit breaker are used as spare (Back up) • Construction costs and maintenance costs are high due to the large number of step-up transformers(2 units)
Number of transformers	150MVA×3units	450MVA×1unit	450MVA×2units
Number of Circuit Breaker	3 for Transformer, 2 for Generator	1 for Transformer, 3 for Generator	4 for Transformer, 3 for Generator

Sources: JICA Study Team

Table 4-8 Configuration of Generator Feeders (LM6000PF+, SGT-800)

Evaluation	Recommend	Not Recommend	Not Recommend
Configuration	2 Feeders	6 Feeders	4 Feeders
System Diagram			
advantage	• Construction and maintenance costs are low due to the small number of step up transformers(2 units)	• Partial load power supply is possible even when step up transformer or circuit breaker fails	• Full load power supply is possible even if a step-up transformer or a circuit breaker fails • Grid system frequency is not affected even if the above described facility fails
disadvantage	• When the step up transformer or the circuit breaker fails, the unit stops	• Construction costs and maintenance costs are high due to the large number of step up transformers(6 units)	• In normal condition, a step-up transformer and a circuit breaker are used as spare (Back up) • Construction costs and maintenance costs are high due to the large number of step-up transformers(4 units)
Number of transformers	210MVA×2units	70MVA×6units	210MVA×4units
Number of Circuit Breaker	2 for Transformer, 6 for Generator	6 for Transformer, 4 for Generator	8 for Transformer, 6 for Generator

Sources: JICA Study Team

4.1.9 Power Complex Planning

As Kisiwa site is a large area of about 160 ha, it is possible to expand it as a power complex site in the future. Therefore, this study considers the site layout and installation plan for not only 300MW, but also for additional power facilities for the future, which includes studies on the transportation route of equipment and materials.

For the future, TANESCO has plans to construct a power complex with a total capacity of 600MW by 2040.

The first 300 MW class GTCC is planned to be constructed with the seawater cooled condenser. With regard to the future 300 MW class GTCC, it is not determined whether the future unit will be constructed with the seawater cooled condenser or air cooled condenser, at this moment.

As described in Chapter 12, the hot seawater simulation results show that the influence on the environment is unclear when adopting the seawater cooling system for a total of 600MW power complex. Therefore, JICA Study Team recommends surveying the actual effects of the discharged seawater during the operation period of the 300MW class GTCC. The cooling type of the condenser should be selected, depending on the result of the survey.

In the site layout study, the JICA Study Team considers space for the future 300 MW class GTCC with the air cooled condenser, because the air cooled condenser needs more space than seawater cooled condenser.

4.2 SUPPLY PLAN OF THE NATURAL GAS AND WATER

4.2.1 Overview of Natural Gas Supply in Tanzania

Recently, natural gas utilization began in Tanzania. In 2004, Songo Songo gas field and gas system were developed to supply gas for power generation and industrial use in Dar es Salaam district. After that, Mnazi Bay gas field was also developed and gas supply for the existing Mtwara power plant started in 2007. Then, the construction of new gas pipeline, for approximately 500 km (diameter 36 inch) from Mnazi Bay gas field to Dar es Salaam with a transport capacity of 784 MMscfd, was completed in July 2015. It increased the natural gas supply capacity from onshore and shallow water gas fields significantly. According to the information from TPDC, the maximum gas demand in February 2018 was 190 MMscfd. It is clear that the capacity of gas supply facility is quite large. A new branch line from the Songo Songo gas field was also constructed to connect with the new gas pipeline. In order to increase production volume, TPDC has been developing production wells. And now, gas is supplied to the gas power plants with a total output of about 600MW. Furthermore, Kinyerezi-2 (240 MW) gas power plant was commissioned in December 2017 and it will commence commercial operation in September 2018. Figure 4-17 shows the current pipelines and the shallow water gas fields in Tanzania.

In addition to the shallow water gas fields, in February 2016, the Ministry of Energy disclosed the news that huge gas fields had been discovered in the offshore deep water blocks in 2010, and they were expected to become important supply sources in the future. According to PSMP, these deep water gas fields are expected to be developed around 2025-2030. Once these plans are executed, it will become possible to supply gas to a significant number of gas power plants with an aggregated capacity of nearly 10,000 MW.[4]

Source: JICA Study Team

Figure 4-17 Pipeline and Shallow Water Gas Fields in Tanzania

The Gas Supply Company (GASCO), a subsidiary of TPDC, is responsible for the operation and maintenance of domestic gas pipeline. GASCO has never experienced any accident related to gas supply. And they have no concern about operation and maintenance of their facilities. Regarding construction of gas pipeline, foreign companies construct the large diameter gas pipelines such as the pipeline from Mnazi Bay gas field to Dar es Salaam. However, the operation and maintenance of gas pipeline is carried out by local companies. On the other hand, GASCO constructs small diameter pipelines such as the distribution pipe for restaurant. GASCO is also willing to construct large-diameter pipeline by themselves in the future.

4 According to PSMP 2016 update, suppose a half of the reserve in deep water gas fields is allocated for domestic consumption, it will be possible to run 15,000 MW of gas power generation for 20 years. Therefore it is possible to run 10,000 MW of gas power generation considering the industrial consumption.

4.2.2 Gas Supply to Kisiwa Site

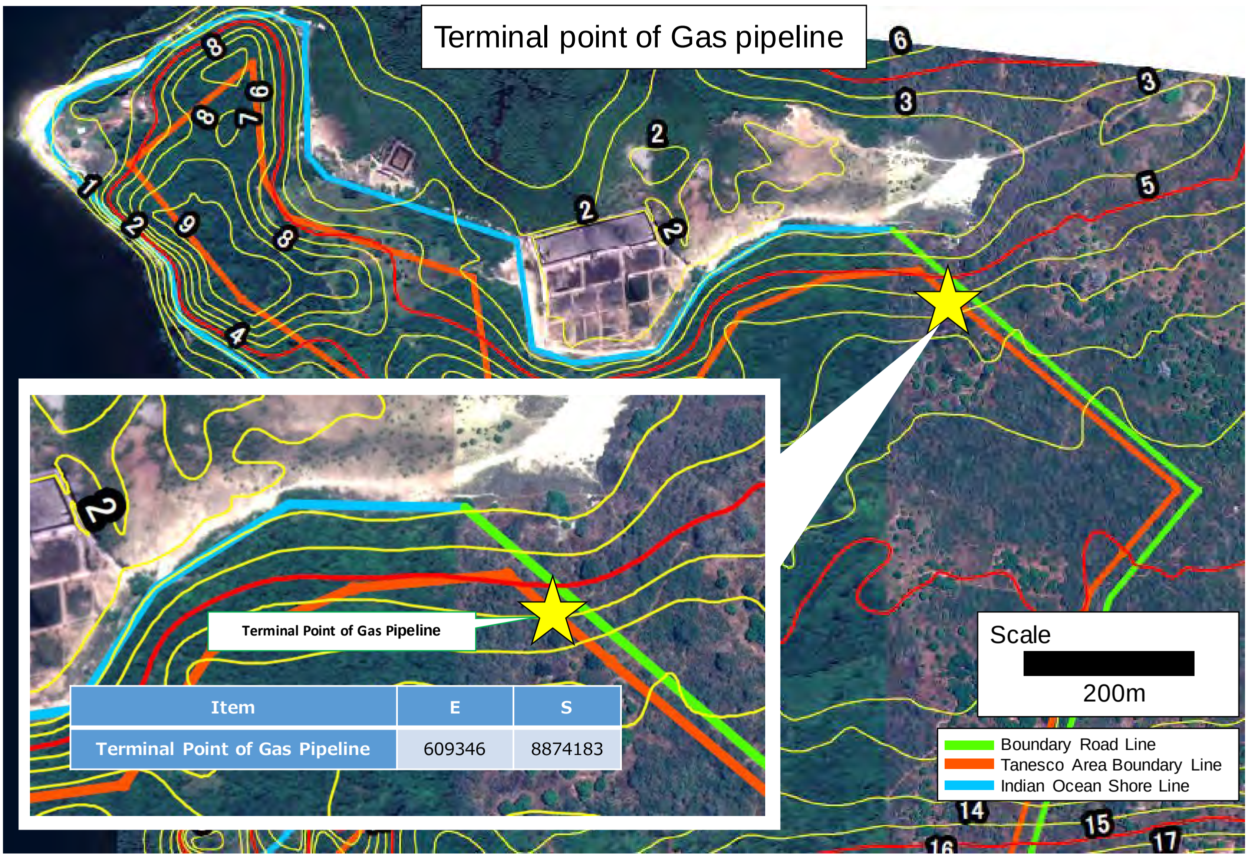
As mentioned above, the gas field at Mnazi Bay has been connected to Dar es Salaam by approximately 500 km pipeline in July 2015. For Kisiwa site, gas will be supplied through an approximately 13 km pipeline from the block valve station No.1. (BVS 01). BVS 01 is located between Mnazi Bay and Dar es Salaam.

Gas pressure is expected to be approximately 90 bar at BVS 01, which is sufficient to supply gas to Kisiwa site. At operation phase, TPDC can supply gas to Kisiwa site at the required pressure by adjusting the design of their gas supply facilities.

(1) Gas Supply Route to Kisiwa site

Detailed study of the new gas pipeline is described in Section 13.3.

TANESCO and TPDC have been planning the pipeline construction. They designed the route for the new pipeline, considering social aspect, avoidance of Dangote land. TANESCO and TPDC actually went to the site and mutually agreed with the location of the delivery point on March 23, 2018. Figure 4-18 shows the terminal point of gas supply from TPDC.



Item	E	S
Terminal Point of Gas Pipeline	609346	8874183

Source: JICA Study Team

Figure 4-18 Terminal Point of Gas Supply in Kisiwa Site

As mentioned in Section 4.1.6, the gas pressure required changes based on the type of gas turbine. Therefore, TANESCO should decide and inform TPDC as soon as possible the type of gas turbine.

The new gas pipeline for Kisiwa site will be constructed exclusively for the site. Therefore, gas supply to Kisiwa site will not be susceptible to the gas consumption of the neighboring facilities.

Figure 4-19 shows the route plan of gas pipeline from BVS 01 to Kisiwa site.

Source: JICA Study Team

Figure 4-19 Route Plan of Gas Pipeline from BVS 01 to Kisiwa Site (TPDC's Plan: Approx. 13km)

Length of this pipeline is approximately 13km. The diameter of steel pipe is 12 inch. Pressure loss at the terminal point is approximately 1 bar, as mentioned in Section 13.3. This value of loss is sufficient to operate the candidate gas turbines without a gas compressor. TPDC will decompress to the required pressure using their decompression equipment near Kisiwa site.

Regarding stability of gas supply, TPDC has never experienced any accident related to gas supply as mentioned in Section 4.2.1. The gas supply network consists of redundant pipelines. Therefore, even if accidents happen somewhere in that system other than the line between BVS 01 to Kisiwa site, it is unlikely that the gas supply will stop. According to TPDC, even if an accident happens on the pipeline between the Mnazi bay gas field and BVS 01, TPDC can switch gas source to the Songo Songo gas field and continue supplying gas. In this case, the accident point is isolated by each BVS. This situation is the same for maintenance of gas facilities as well. However, contractually, gas supply stoppage is allowed for several days in a year. If an accident occurs on the gas pipeline, GASCO should respond to the accident.

(2) Gas Supply Volume and Property

It is assumed that the required volume of gas for this project is about 51.9 MMscfd. This value is calculated using the specifications of the gas, provided by TPDC. The capacity of the Mtwara - Dar es Salaam gas pipeline has already been increased to 784 MMscfd.

Moreover, TPDC declared that the predicted volume of gas for Kisiwa site is available because of the huge gas reserve margin. According to TPDC, reserves of natural gas in Tanzania are estimated to be 57.54 Tcf. This value is almost same as the one mentioned in PSMP 2016 update. Table 4-9 shows the gas reserve of Tanzania as described in PSMP 2016 update. For this project, it is possible to use gas from Songo Songo and Mnazi-Bay gas fields, which are connected to the gas pipelines from the Mnazi Bay gas field to Dar es Salaam at the moment. Total available gas (P1+P2) is 7.5 Tcf. According to “The project for review of the natural gas utilization plan in Tanzania - final report” (NGUP), the reserve volume is quite large, compared to the 41.3 Tcf of natural gas reserve existing in Malaysia, one of the LNG giants in the world. Reserves of natural gas in Tanzania will be reviewed in the undergoing update activities of NGUP.

Table 4-9 Gas Reserve in Tanzania described in PSMP 2016 Update

Category	Gas fields	Proven Reserve	Provable Reserve
		P90	P50
		P1	P1+P2
Land/Shallow Water		Tcf	Tcf
	Songo Songo	0.88	2.5
	Mnazi-Bay	0.262	5
	Mkuranga		0.2
	Nyuni	0.045	0.07
	Ruvuma		0.178
	Ruvuma		2.17
	Sub-total		10.118
Deep Water	Block-2		25.4
	Block1,3&4		21.73
	Sub-total		47.13
Total			57.25

Source: PSMP 2016 Update

TPDC predicts the future gas demand and production as mentioned below in Table 4-10 and Figure 4-20. In the TPDC’s gas demand and production outlook, the demand, excluding the power demand, is nearly twice the value quoted in PSMP 2016 update. TPDC might be predicting excessive gas demand. TPDC adjusts “production capacity” according to the gas demand outlook. In this table, operation of Kisiwa site is supposed to start in 2021. However, according the latest information, the 1st GT is expected to start commercial operation in the year 2024. As explained in Table 4-10, the critical year of gas balance is 2022, the Mtwara GTCC power plant seems to be on the safe side in terms of gas supply.

Gas demand is expected to increase to 581 MMscfd by 2025. It is expected that the gas demand will not change for several years, and during that time, the gas production will be 620 MMscfd after 2026. Even if all of this gas demand is satisfied with the Mnazi Bay gas field, the capacity of the gas pipeline from the Mnazi Bay gas field to Dar es Salaam is sufficient to continue supplying gas. Because, the capacity of the gas pipeline is 784 MMscfd as mentioned in Section 4.2.1.

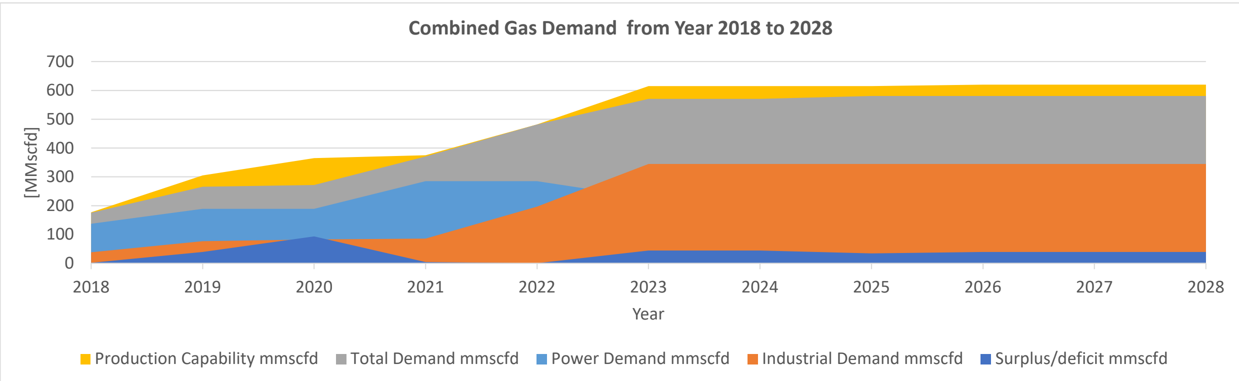
Table 4-10 Gas Demand and Production Outlook from Year 2018 to 2028

Combined Gas Demand from year 2018 to 2028

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Power Demand mmscfd	137	189	189	285	285	226	226	236	236	236	236
Industrial Demand mmscfd	38	77	83	86	197	345	345	345 *	345	345	345
Total Demand mmscfd	175	266	272	371	482	571	571	581	581	581	581
Production Capability mmscfd	177	305	365	375	482	615	615	615	620	620	620
Surplus/deficit mmscfd	2	39	93	4	0	44	44	34	39	39	39

* In the PSMP 2016 update, the demand excluding the power demand is 175 MMscfd at 2025.

Source: TPDC



Source: TPDC

Figure 4-20 Graph of Gas Demand and Production Outlook from Year 2018 to 2028

As mentioned in Section 2.3, TANESCO has plans for power development. Some of them are included in the TPDC's gas demand outlook. Table 4-11 and Figure 4-21 show updated gas demand outlook, which is reflected in the latest power development plan. As mentioned above, TPDC might be predicting excessive gas demand. However, TPDC's industrial demand outlook data is used for safe prediction in the updated gas demand outlook.

Considering the possibility of gas development delay from deep water, the gas supply possible years to Mtwara and Somanga GTCCs without gas supply from the deep water are estimated under the following conditions.

1) Table 4-10 received from TPDC is adopted as gas demand. 581 MMscfd which is prospected from 2025 in the table is also used as gas demand after 2029.

2) Among the gas reserves from land/shallow water in Table 4-9, those from Songo Songo and Mnazy Bay are counted. On that condition, gas reserve is estimated as 7.5 Tcf by P1+P2 basis in Table 4-9.

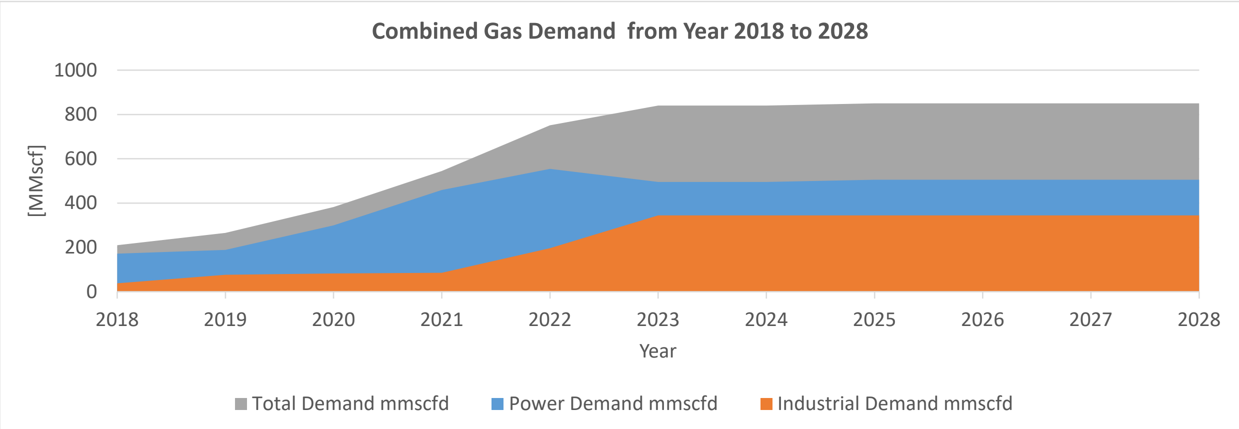
As the results, JICA Study Team judged that it is possible to supply gas to Mtwara and Somanga GTCCs for about 30 years without gas from the deep water.

Table 4-11 Updated Gas Demand Outlook from Year 2018 to 2028

Combined Gas Demand from year 2018 to 2028

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Power Demand mmscfd	172	189	300	459	555	496	496	506	506	506	506
Industrial Demand mmscfd	38	77	83	86	197	345	345	345	345	345	345
Total Demand mmscfd	210	266	382	545	751	840	840	850	850	850	850

*The industrial demand is quoted from the TPDC' gas demand outlook. Source: JICA Study Team



Source: JICA Study Team

Figure 4-21 Updated Graph of Gas Demand Outlook from Year 2018 to 2028

There are some gaps between this outlook and the TPDC's outlook. Therefore TANESCO should provide TPDC with information about the power development plan and gas consumption outlook, when each plan is materialized.

This gas demand will not change until large gas consumption projects start, such as the LNG export project or the new gas power plant. In the TANESCO's power development plan, gas demand for the power plant will be 296.43 Bcf per year in the year 2040. Here it is assumed that all power plants will be operated at 85.9 % of Capacity factor. If the industrial demand does not change, the total gas demand will be 422.24 Bcf per year. This means that it is possible to continuously supply for approximately 136 years, by using the reserves which have already been found at present, even in the case of maximum demand. Generally, in countries where the history of gas development is short, such as Tanzania, it is possible that the gas reserves increase as the development progresses.

As shown in Table 4-11 and Figure 4-20, that future gas demand is expected to be three times higher than the present demand. This means that the sales income will increase due to the gas tariff. Therefore more funding may be provided for the development of gas fields, and the gas reserves may increase further in the future. Regarding gas supply for Kisiwa site, gas from Mnazi Bay gas fields will preferentially be supplied to Kisiwa site, because there is no other power plant near the gas field, which is a big gas source in the south coast of Tanzania. At present, except for this project, there are no plans to construct new power plants in the south coast of Tanzania for the next few years. According to MOE, gas will be preferentially supplied to important infrastructure like this project. And in the master plan of NGUP, it is also mentioned that priority will be given to the domestic gas demand for various sectors including thermal power generation.

Most of the gas reserves exist in the deep water gas fields. Gas reserves at land and shallow water are estimated approximately to be 10 Tcf. Even if the development of deep water gas fields are delayed, it will be possible to continuously supply gas for approximately 24 years using only the gas reserves at land and shallow water, even in the case of maximum demand. As mentioned in the PSMP 2016 update, the development of deep water gas fields needs tens of billions of dollars as capital. In order to justify the huge upfront investment in deep water field development, a sizable gas demand must be secured. This would be possible only with the LNG project, while it would be difficult to secure the required cash flow with smaller projects.

The LNG project has not progressed. Initially, the LNG project, which would utilize the deep water fields, were planned to start around 2025 in NGUP. However the host government agreement has not been completed and the bids for consultancy services had been invited in April 2018. It will take approximately 9 year to carry out all the procedure pertaining to the LNG plants, after the completion of host government agreement. This means, the LNG plants can begin operating only after 9 years. Therefore it seems that operation of deep water gas fields will not start until at least 2027. In May 2019, the energy minister said in the parliament that construction of LNG project is expected to start in 2022 and will be concluded in 2028. The LNG project has not progressed, however the progress of LNG project is highly anticipated. The project still has high potential because of the huge gas reserve.

In Tanzania, there are opinions that the natural gas of Tanzania should be used in Tanzania. However, politicians and government officials are aware that huge amount of investment is needed for deep water field development, and the domestic gas demand is too small to nurture the development of deep water fields, due to activities of NGUP etc. Therefore, they are trying to proceed with the LNG project.

According to NGUP, there is a plan to start a fertilizer plant or co-production plant of methanol, ammonia and fertilizer to develop the gas industry in Tanzania. This plan is considered as a top project leading to the development and utilization of deep water gas fields. And activities of NGUP phase 2 are currently in progress. In May 2019, the energy minister announced in the parliament that the construction of the new fertilizer plant will start in 2021 and is expected to be commissioned in 2024. Therefore, this could encourage the progress of the LNG project in the future.

As mentioned above, there are some gaps between the updated gas demand outlook and the TPDC’s outlook. However, the reserves of natural gas are enough, as the capacity of the gas pipelines from the Mnazi Bay gas field to Dar es Salaam, and from the Songo Songo gas field to Dar es Salaam is 889 MMscfd in total (From the Mnazi Bay gas field to Dar es Salaam: 784 MMscfd, From the Songo Songo gas field to Dar es Salaam: 105 MMscfd). Therefore, if TPDC upgrades gas processing facility with reference to TANESCO's power development plan, it is possible to meet the future gas demand.

The gas turbine should be designed to operate on the specified natural gas. Table 4-12 shows the composition and properties of the gas which will be supplied to Kisiwa site from the Mnazi Bay gas field. This data has been provided by TPDC, which will supply gas to Kisiwa site. Assuming that the gas of the mentioned composition and properties as shown in the Table 4-12 will be used at Kisiwa site, natural gas at 2.2 MMscf per hour, 51.9 MMscfd and 16.3 Bcf per year will be needed.

Table 4-12 Gas Composition and Properties supplied to Kisiwa Site

No.	Parameter/Component or Characteristic	Quality Standard Limits or Range
1.	Methane	87.0 - 99.0 mol. %
2.	Ethane	1.8 - 5.1 mol. %
3.	Propane	0.1 - 1.5 mol. %
4.	Inert gases	Max. 7.0 mol. %
5.	Carbon Dioxide	Max. 4.0 mol. %
6.	Oxygen	Max. 0.2 mol. %
7.	Nitrogen	Max. 5.6 mol. %
8.	Hydrogen Sulphide	Max. 5.7 mg/m^3
9.	Total Sulphur	Max. 10.0 mg/m^3
10.	Water	Max. 73.0 mg/m^3
11.	Hydrocarbon DewPoint	Max. 2.0°C at 3500 kPa
12.	High Heating Value	35.1 - 42.3 MJ/m^3
13.	Wobbe Index	41.0 - 52.0 MJ/m^3
14.	Specific Gravity	0.57 - 0.62
15.	Temperature limits	2.0 - 50°C
16.	Mercaptan Sulphur	Max. 5.0 mg/m^3

Source: TPDC

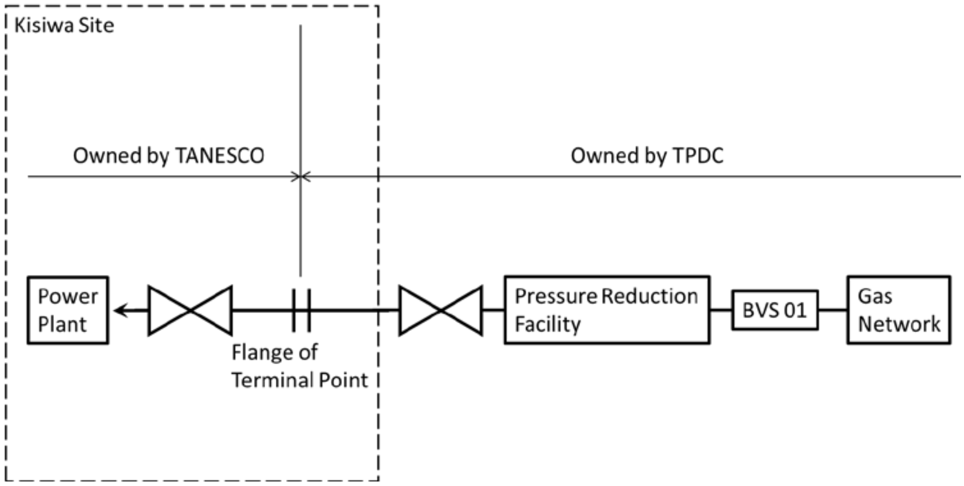
(3) Scope of Gas Pipeline Work and Terminal Point

Figure 4-22 shows the terminal point of the gas pipeline schematic at the boundary of Kisiwa site. The arrow indicates the ownership of the gas supply facilities after the construction.

The ownership of the gas supply facilities is as shown below.

- Outside the terminal point: TPDC
- Inside the terminal point: TANESCO

Each owner takes full responsibility for operation and maintenance of the gas supply facilities.



Source: JICA Study Team

Figure 4-22 Gas Pipeline Terminal Point

4.2.3 Overview of Water Supply in Tanzania

Tanzania is not regarded as a country rich in water resources when compared with other countries.

According to "Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines" published by UNICEF, it is reported that the percentage of people who have access to basic quality drinking water sources is 50% in Tanzania. It is also reported that 13% of Tanzanian people still rely on untreated surface water.

According to "The united nations world water development report 2014", it is reported that the total renewable water resources of Tanzania are evaluated to be vulnerable. The numerical value of the resource is 1,700 – 2,500 m^3 per capita per year. Table 4-13 shows the breakdown of long-term annual renewable water resources in Tanzania.

Table 4-13 Long-Term Annual Renewable Water Resources in Tanzania

Surface water	92.27 km^3/year
Groundwater	30 km^3/year
Overlap between surface water and groundwater	26 km^3/year
Total renewable water resources	96.27 km^3/year

Source: Food and Agriculture Organization of the United Nations

4.2.4 Water Supply to Kisiwa Site

The Mtwara- Ruvuma River water supply project can supply water to Kisiwa site. The project will supply water from Ruvuma River to Mtwara- Mikindani municipality, located about 60 km from Ruvuma River. There are 23 villages located within a radius of 12 km from the main pipeline route.

However, the Mtwara- Ruvuma River water supply project has not progressed due to financial issues.

Therefore, an alternative plan is necessary for the Mtwara- Ruvuma River water supply project. MTUWASA is implementing a development project for the deep wells located near the Mbuo River.

3 deep wells will be developed in this project, and the total water supply volume is expected to be about 1,850 m^3/day. They have developed 2 deep wells, and the present water supply volume capacity is about 1,200 m^3/day. Currently, the water, supplied solely to the demand in Kisiwa village and surrounding area, is about 400 m^3/day. On the other hand, the water demand of this project is approximately 300 m^3/day at Kisiwa site. MTUWASA committed that the use of water for the Project is totally acceptable. In addition, the residence of O&M staff has an additional water demand of about 60 m^3/day. The water pipeline project described in Section 13.4 will satisfy this demand from the new well. As mentioned in Section 13.4, appropriate pumping test shall be carried out at the basic design stage in order to ensure the capacity of the third deep well.

Water supply volume of the third deep well is expected to be about 650 m^3/day. In addition, there is a well about 2 km south of the above wells. About 30 m^3/hr of water is flowing out from the well without pumping. Furthermore, MTUWASA continuously develops water sources in order to prepare for the future demand growth, especially for the planned Mikindani industrial zone. As mentioned in Section 13.4, for the alternative wells, two candidate sites, which are several kilometers away from the third deep well, have been discovered.

According to customers of MTUWASA, currently, the water supply is not sufficient. Water supply is often stopped. The reason is that no electricity is supplied to the pumps. This means that the electricity supply situation is not good in Mtwara. However, if the Mtwara GTCC power plant starts operating, the issue of water supply caused by power shortage will improve. This project is also important for stabilizing water supply in Mtwara.

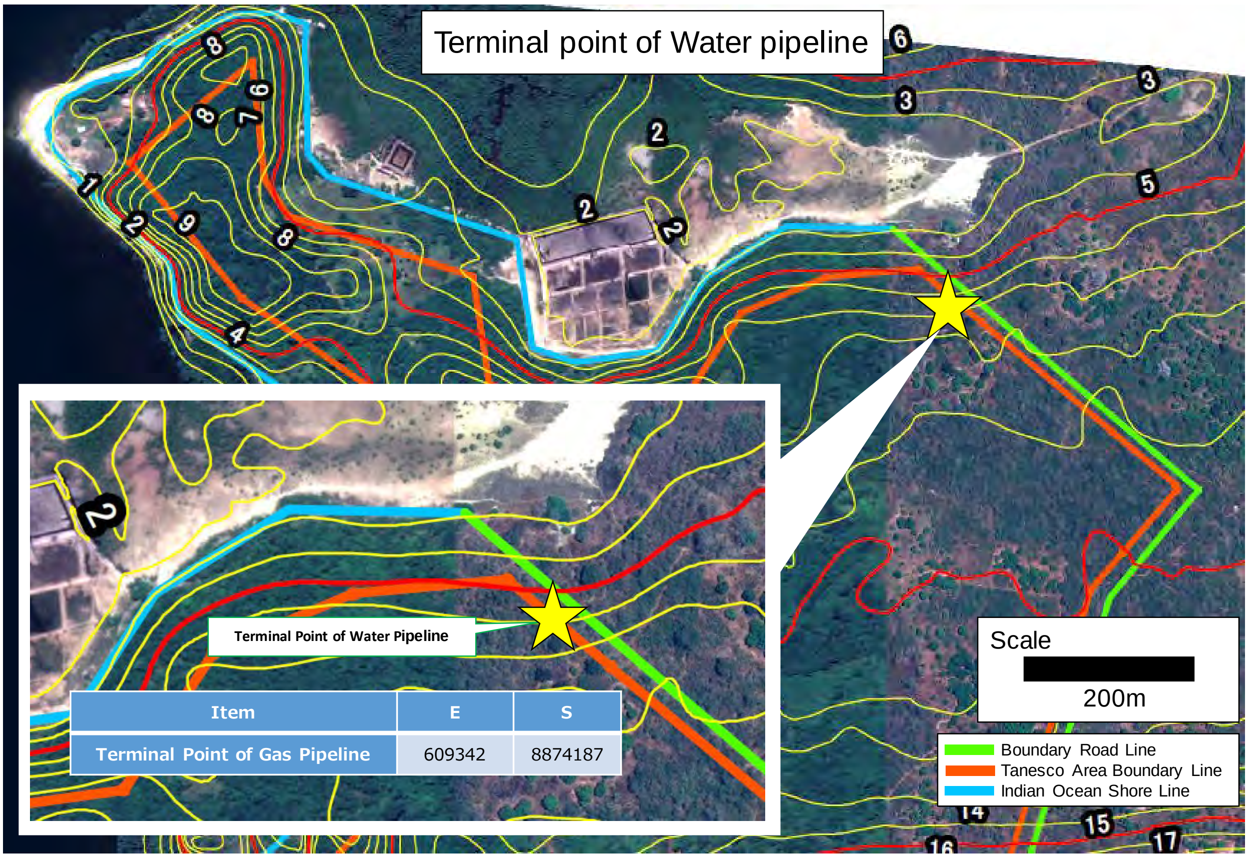
(1) Water Supply Route to Kisiwa site

Detailed study of the new water supply system is described in Section 13.4, including O&M of the facilities.

MTUWASA and TANESCO have been planning for the pipeline construction.

As described in Section 13.4, the construction period of the water pipeline for Kisiwa site will be approximately 9 months.

During this study, TANESCO actually went to the site and determined the delivery point for water at the Kisiwa site. Figure 4-23 shows the terminal point of water supply from MTUWASA.

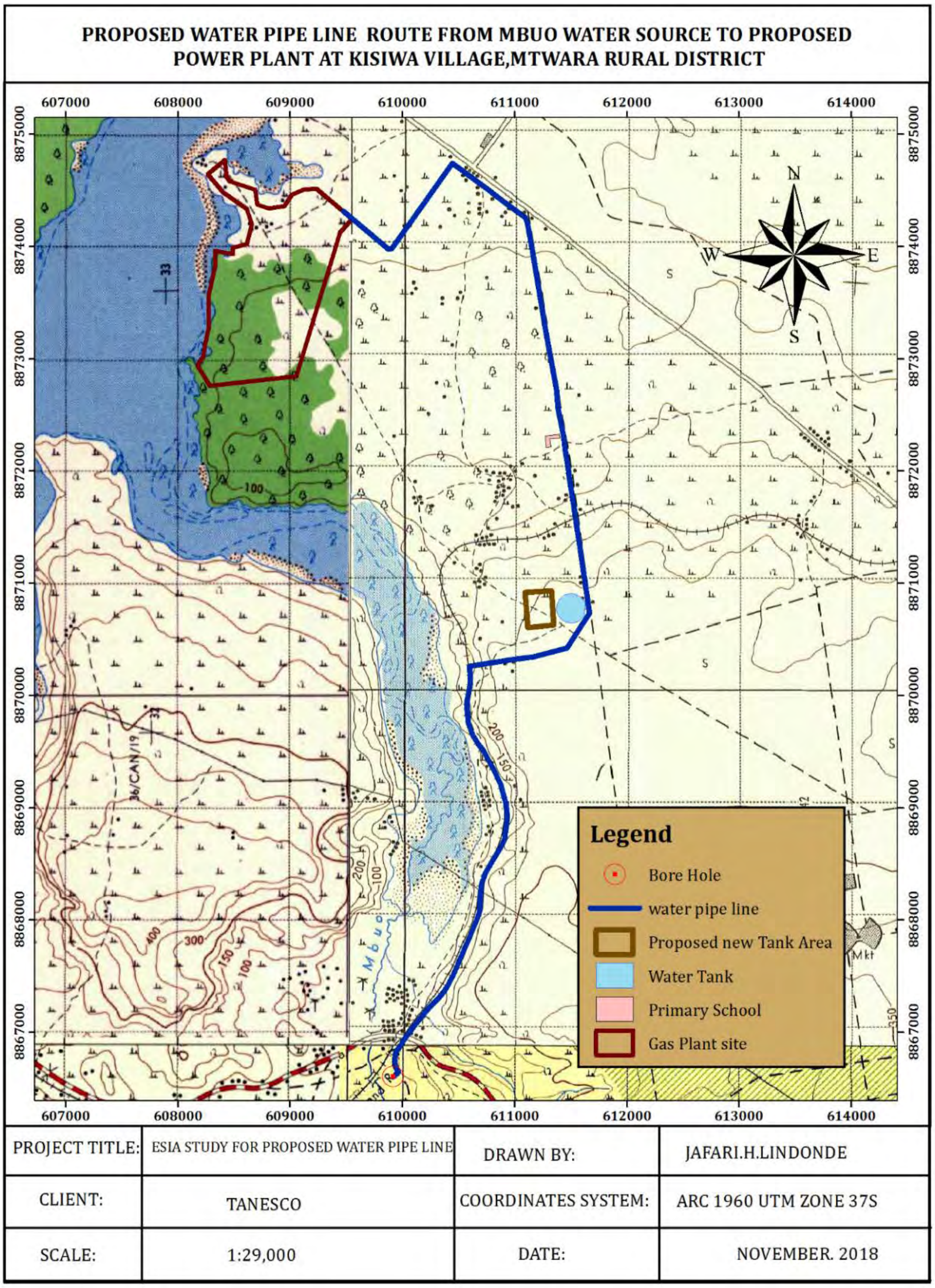


Source: JICA Study Team

Figure 4-23 Terminal Point of Water Supply in Kisiwa Site

TANESCO will construct pipeline to the delivery point, and MTUWASA will supply water to Kisiwa site. The new water pipeline to Kisiwa site will be constructed exclusively for Kisiwa site.

Figure 4-24 shows the route plan of water pipeline from the wells to Kisiwa site. Length of this pipeline is approximately 12 km.



Source: ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT FOR THE PROPOSED CONSTRUCTION OF WATER SUPPLY PIPELINE FROM MBUO VILLAGE TO THE PROPOSED GAS POWER PLANT (11.1 km) LOCATED AT KISIWA VILLAGE IN MTWARA DISTRICT, MTWARA REGION

Figure 4-24 Route Plan of Water Pipeline from the Wells located near Mbuo River

No.1 deep well

No.2 deep well

No.3 deep well

Well which is located 2km south of the other wells

Source: JICA Study Team

Figure 4-25 Pictures of the Wells located near Mbuo River

Hereafter, the deep wells in Figure 4-25 are described as "deep wells located near Mbuo River".

(2) Water Supply Volume and Property

Water supply capacity of the deep wells located near Mbuo River is approximately 1,200 m^3/day, and it will increase up to approximately 1,850 m^3/day as mentioned above. Currently, the water demand for the deep wells located near Mbuo River is approximately 400m^3/day. Water demand of Kisiwa site is approximately 300 m^3/day. Therefore, MTUWASA declared that the use of water for the project is affordable. MTUWASA predicts the water demand and production outlook of Mtwara region as shown in Table 4-15.

Yearly water demand in 2017 is 5,028,605 m^3. This is equivalent to 13,777 m^3/day. Water demand is expected to increase to 6,441,155 m^3/year, 17,647 m^3/day by 2026.

Table 4-14 Water Demand and Production Outlook from Year 2016 to 2026 in Mtwara Region

(Unit: m^3)

Year	Water demand	Water production
2016	4,891,730	6,988,185
2017	5,028,605	7,082,542
2018	5,169,495	7,179,854
2019	5,314,035	7,279,500
2020	5,462,955	7,382,371
2021	5,615,890	7,487,853
2022	5,773,205	7,596,322
2023	5,946,580	7,722,831
2024	6,106,815	7,829,250
2025	6,271,795	7,938,981
2026	6,441,155	8,051,443

Source: MTUWASA

As mentioned Section 4.2.4, MTUWASA continuously develops water sources in preparation for the future demand growth. Therefore in the future, the feasibility of water supply to Kisiwa site is expected to be highly guaranteed.

The property/quality of the water from the well is indicated in Section 7.4.2 and Section 13.4.1.

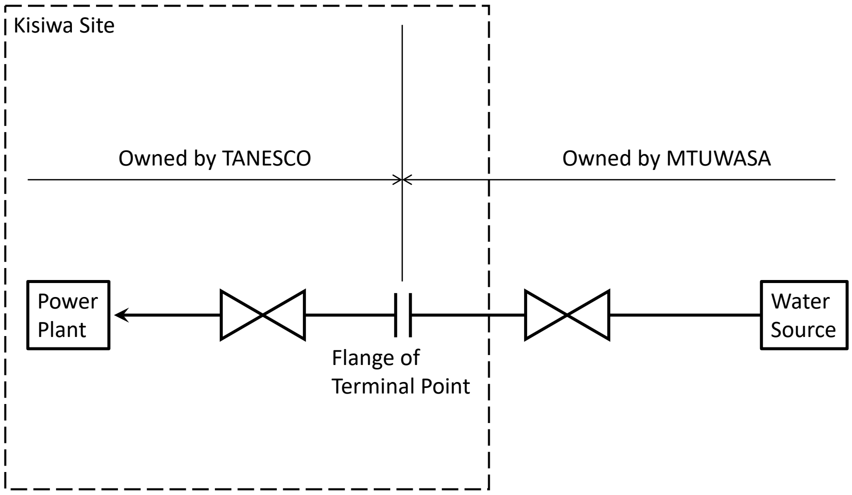
(3) Scope of Water Pipeline Work and Terminal Point

Figure 4-26 shows the terminal point of the water pipeline schematic at the boundary of Kisiwa site. The arrow indicates ownership of water supply facilities after the construction.

Ownership of water supply facilities is as shown below.

- Outside the terminal point: MTUWASA
- Inside the terminal point: TANESCO

Each owner takes full responsibility for construction, operation and maintenance of the water supply facilities.



Source: JICA Study Team

Figure 4-26 Water Pipeline Terminal Point

4.2.5 Alternative Plan for Water Supply

It became clear that there is no problem concerning water supply for Kisiwa site as mentioned above. However, alternative plans for water supply are introduced as mentioned below, in case the Kisiwa site is further developed in the future.

(1) Utilization of Well Water around Kisiwa site

Additional groundwater wells can be used as industrial water. When using groundwater, it is necessary to check groundwater salinity level due to influx of seawater and ground subsidence caused by excessive pumping of groundwater.

During the field survey, JICA Study Team received the survey report on well water conducted in the past, namely the "Dangote well No. 1 to No. 4 - well report". Its contents are shown below for reference.

The well water survey was conducted at the cement factory of Dangote, located about 10 km from Kisiwa site. The report provides analysis results about the quality of water found in the factory premises. Figure 4-27 shows salinity and pH at each point.

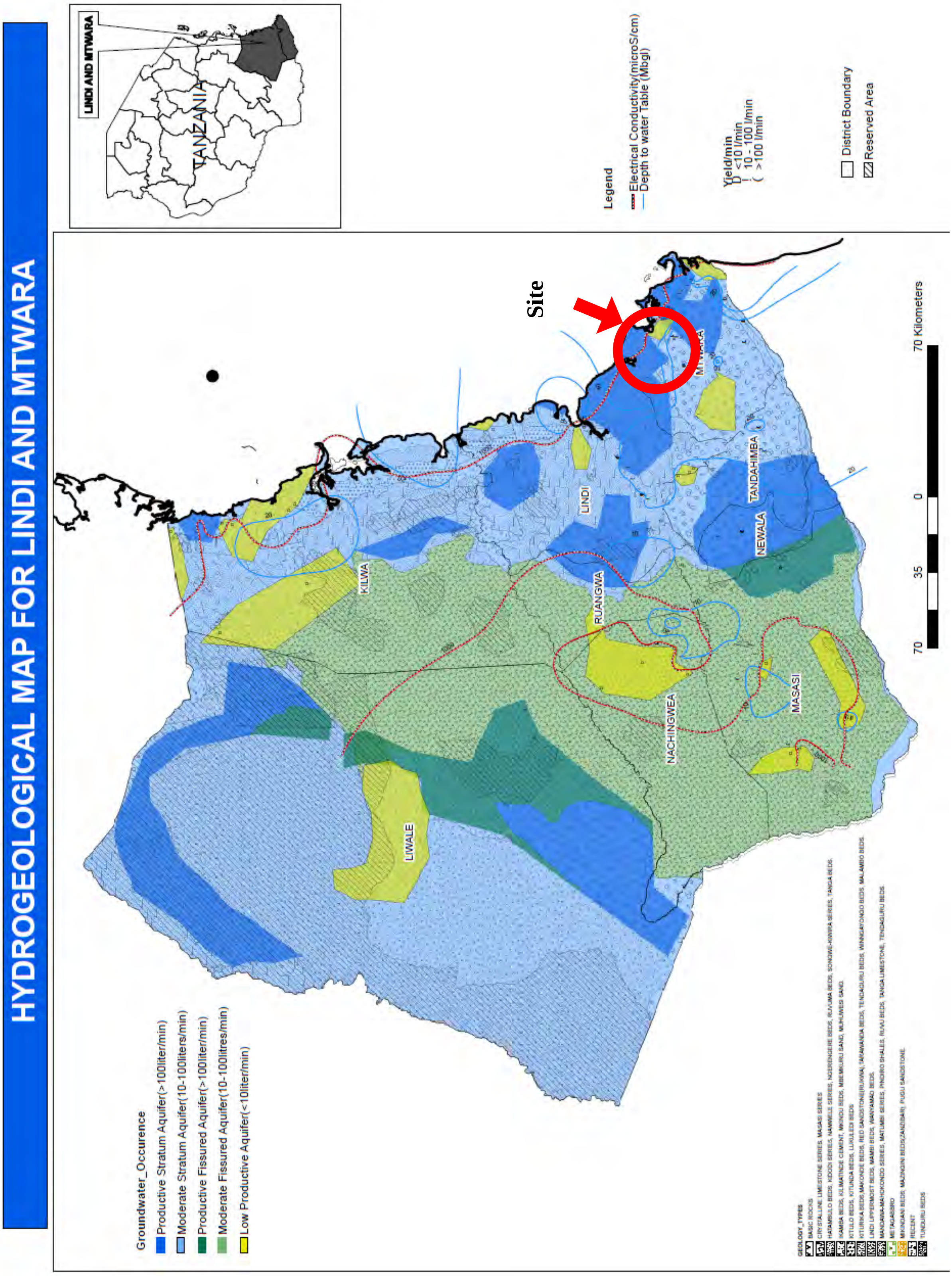
Source: Dangote well No.1 to No.4 well report

Figure 4-27 Water Quality Analysis Result of Dangote Factory

According to WHO criteria, water with a salt concentration of 200 mg/l or less is regarded as drinking water. Furthermore, even the Ministry of the Environment in Japan considers water having a salt concentration of about 10,000 mg / l as brackish water. Therefore, the salt concentration of the well water is fairly low. The pH of the well water satisfies the standard of industrial water.

Figure 4-28 shows the groundwater volume around Kisiwa site.

Water quality analysis in this study is also described in Section 7.4.2 and Section 13.4.1.



Source: Feasibility study on the Makonde water supply scheme, Tanzania –water resources assessment –a volume IV

Figure 4-28 Groundwater Volume in Lindi and Mtwara District

(2) Utilization of Seawater

Desalinated seawater can also be used as industrial water. The main methods of desalination are: the evaporation method (MSF, MED) and the membrane method (RO membrane method). Table 4-15 shows a comparison of these methods.

Table 4-15 Comparison of Seawater Desalination Methods

Item	Evaporation method	Membrane method
Investment amount	High	Low
Energy consumption	Not Good	Good
Required land area	Large	Small
Response at load fluctuation	slow	fast
Environmental impact	Large	Small
Intake seawater quality restriction	No restricted	Restricted

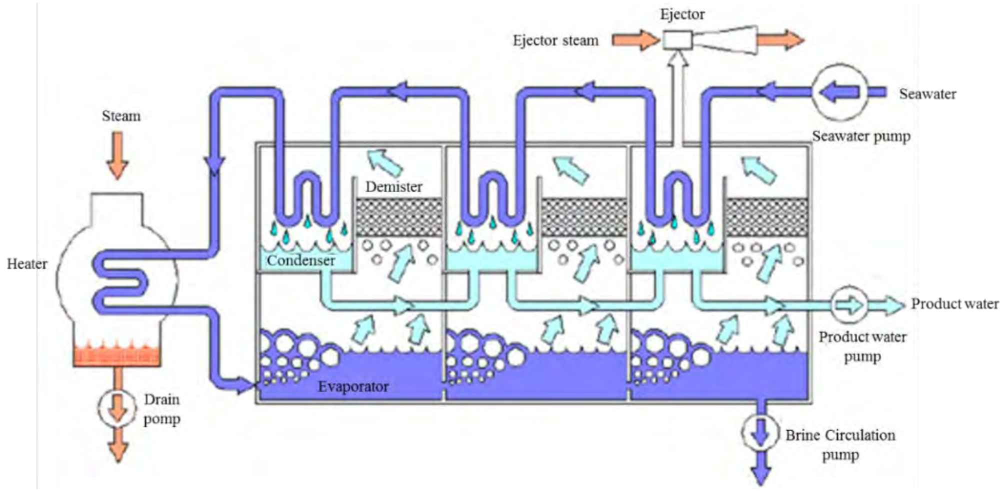
Source: JICA Study Team

Both the methods are explained and compared in detail below. The comparison result shows that the membrane method is more advantageous.

The outline of each method is as follows.

1) MSF: Multi-Stage Flash

In the MSF method, fresh water can be obtained by condensing steam that is generated by boiling and evaporating seawater, heated in a reduced pressure evaporator. In the commercially operated plants, a number of reduced pressure evaporators are combined, so it is called a multi-stage flash system. Heat efficiency is raised by collecting the heat released, when the generated steam condenses. In the Middle East, power generation facilities are often installed along with the desalination facilities, and the surplus steam from the power generation facilities can be used in the desalination facility, so there are many large MSF. Since it was put to practical use in the 1950's, it has abundant operational records, and stable performance and operation are possible without being influenced by water quality change (salt concentration, turbidity etc.) of sea water. The freshwater production capacity per unit is large, which is suitable for mass production. It is the most reliable freshwater source in Middle Eastern oil-producing countries. However, load fluctuation cannot be dealt with promptly, and it takes time to start and stop. Moreover, it cannot be installed and disposed easily, so it is not suitable for small scale plants. The economic efficiency is inferior to the RO membrane method. Equipment cost is higher than the other methods. Both thermal energy and electricity are required, and the total energy consumption is the largest amongst all the seawater desalination methods. In addition, since energy consumption is high, the environmental load is also large. Hot wastewater is generated in equal proportions as the produced water. However, the environmental load caused by the increase in salt concentration is smaller than the RO method, because the concentrated seawater is diluted with a large amount of hot discharge water. Other environmental loads such as vibration and noise seem to be the same as the other methods.

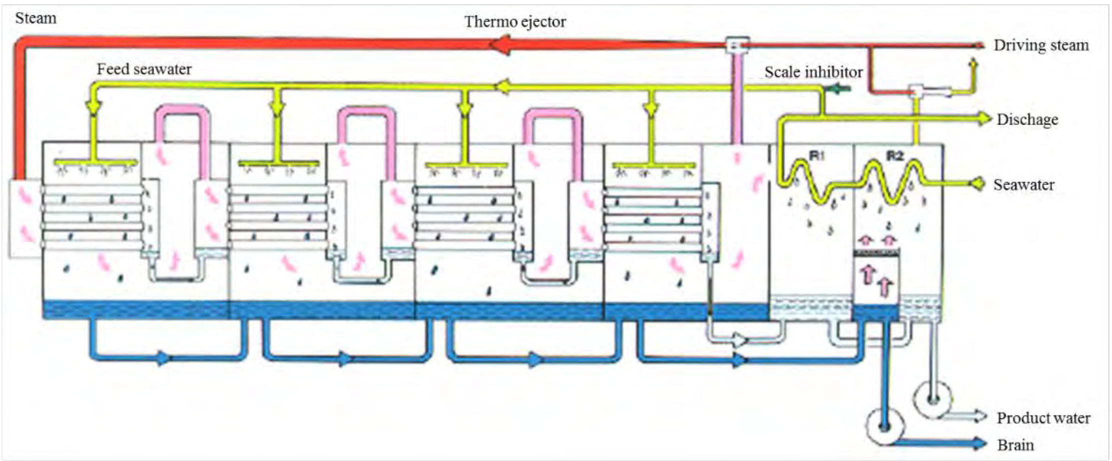


Source: Research organization for information science & technology

Figure 4-29 Outline of MSF Method

2) MED: Multi-Effect Desalination

In the MED method, utility cans are connected, and the steam supplied from other facilities is used as a heat source of the first utility can. After the first utility can, the steam discharged from the previous utility can is used as a heat source to efficiently produce freshwater. The main features are same as the MSF method, which has the same evaporation method. But the MED method is superior in terms of energy consumption, response to load or water quality variation, scale deposition amount, maintenance etc. Furthermore, also in terms of initial investment, the equipment cost of MSE method is lower than the MSF method by 10% or more. Therefore, currently, the main evaporation method is not the MSF method but the MED method.



Source: Research organization for information science & technology

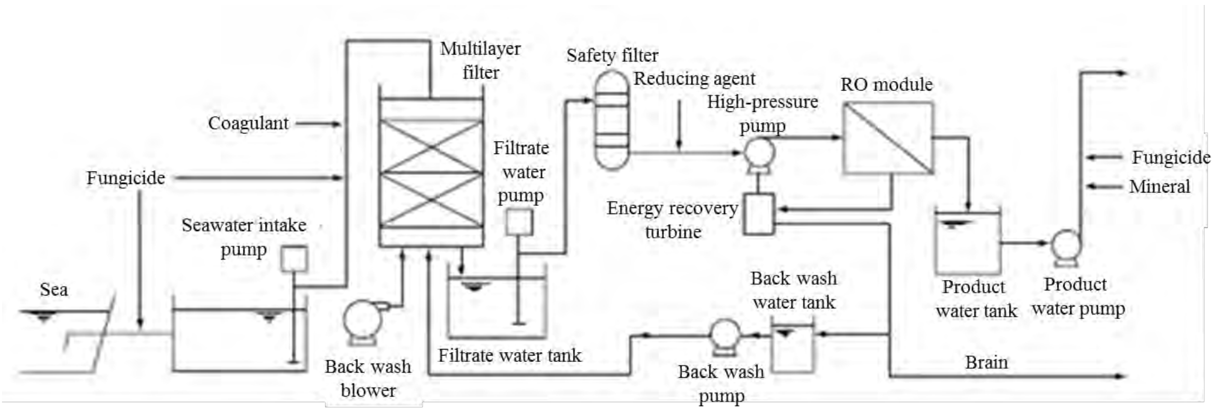
Figure 4-30 Outline of MED Method

3) Reverse Osmosis: RO

In the RO method, fresh water can be obtained by high pressure seawater passing through a special membrane. The membrane allows water to pass but does not allow the salt to pass through. When the salt concentration of the raw water is high, it is necessary to increase the reverse osmotic pressure applied to the membrane. The pretreatment cost increases if the pretreated salt water is apparently filtered with reverse osmosis membranes and the raw water has high salt concentration. Compared with the evaporation method, the RO method has limitations in terms of water quality (salt concentration, contamination degree, etc.). Energy consumption decreases when the salinity concentration of raw water is low. The produced water has a slightly higher salinity concentration than the evaporation method. It contains appropriate mineral content, therefore the amount of added minerals for drinking can be reduced. Furthermore, the plant is unlikely to corrode because it is operated at room temperature. Contamination of the produced water by the equipment is also reduced.

While the evaporation plant has a large scale capacity per unit, the RO plant can adjust its capacity by the number of modules. In large plants, it is possible to cope with large capacity by setting the module group (train) to 5,000 ~ 10,000 m^3/day per unit. In the maintenance and operation of desalination plants by the RO method, there is more work related to chemicals when compared with the evaporation method. However, the number of staff required for maintenance and operation of the plant is almost the same. In the RO method, it is necessary to pay attention to contamination and performance deterioration of the membrane module in particular. Compared to the evaporation method, it is easy to start and stop the plant, and it is possible to operate / stop for each module group, therefore it can respond flexibly to the fluctuations of demand.

RO method is more economical than evaporation method. Since both the construction cost and the energy consumption of the plant are smaller than those of the evaporation method, the RO method is widely adopted as the seawater desalination method in most of the areas, other than the Middle East oil producing country. The evaporation method requires both thermal energy and electricity, whereas, the RO method requires only electricity. Therefore, it consumes less energy than the evaporation method and has less environmental load. Since the waste water temperature is not high, it calls for just countermeasure against the salt concentration. However, it is necessary to pay attention to the salt concentration of the discharge water, because the salt concentration is much higher than the evaporation method. The total environmental load of the RO method is considered to be smaller than that of the evaporation method because the evaporation method has a large amount of waste water with high temperature. Other environmental loads of the RO method, such as vibration and noise etc., seem to be the same as other methods.



Source: Mitsubishi Heavy Industries technical report Vol.39 No.5 (2002-9)

Figure 4-31 Outline of RO Method

CHAPTER 5

ROUTE SELECTION FOR TRANSMISSION LINE

CHAPTER 5 ROUTE SELECTION FOR TRANSMISSION LINE

5.1 INTRODUCTION

This Chapter reports the results of feasibility study for the route selection of the new 400 kV transmission line, which is needed to transmit the power generated by Mtwara natural gas thermal power plant to Dar es Salaam. The line will play an important role as a part of the trunk power system in Tanzania.

Route investigation had been carried out on the candidate sites of substation for the 400kV New Mtwara substation and 400kV Somanga substation via the 400kV New Lindi substation as shown in Figure 5-1. TANESCO is carrying out a feasibility study for a transmission line between Dar es Salaam and Somanga under another project.

Source: JICA Study Team

Figure 5-1 Scope for Route Investigation

5.2 Route Concept

Route selection is one of the most important items in the planning process because its result affects not only the term of construction, but also the costs for land acquisition, installation and so on. A route should be recommended by taking into account its effects.

To select the best route, four (4) candidate routes were prepared according to concepts described in Table 5-1.

Route_1 was reported by the United States Agency for International Development (USAID) in 2015, but the preliminary survey prior to a field investigation suggested that some parts of the route would pass through residential or protected forest areas. Therefore, it was assume that the negotiation for land acquisition will take a longer time than the other candidate routes. Route_1A, a variation of Route_1, can avoid passing through such areas.

Ensuring a smooth flow of traffic for vehicles like a concrete mixer or a big crane car is indispensable for a secure and prompt construction. From this point of view, the Route_2 that runs along the main roads is proposed.

Route_3 is arranged to run along the existing gas pipeline (hereinafter called as “the Pipeline”), almost in parallel. TANESCO proposed this route, as it can lead to a less land acquisition cost.

Table 5-1 Concept for Candidate Route

No.	Candidate Route	Concept
1	Route_1	Reported by USAID in 2015
2	Route_1A	Modified Route_1 Escape from residential, high elevation and protected forest areas
3	Route_2	Along with the national road Easy for laying access roads
4	Route_3	Along with the existing gas pipeline, proposed by TANESCO Easy for land acquisition

Source: JICA Study Team

All four candidate routes are divided into eight (8) sections and compared with each other section-wise. Then the recommended route is formed by putting together the best sections that are evaluated as “Good/Superior” for each section as shown in Figure 5-2.

Incidentally, the routes have same terminal point for each of the sections, and these terminal points are located at places, where the routes cross each other or where new substations are planned.

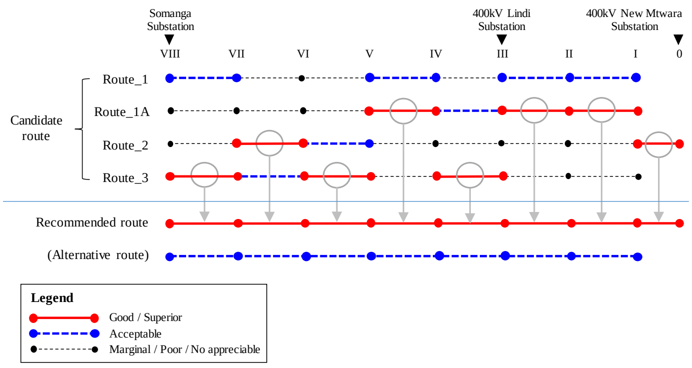


Figure 5-2 Composition of Recommended Route

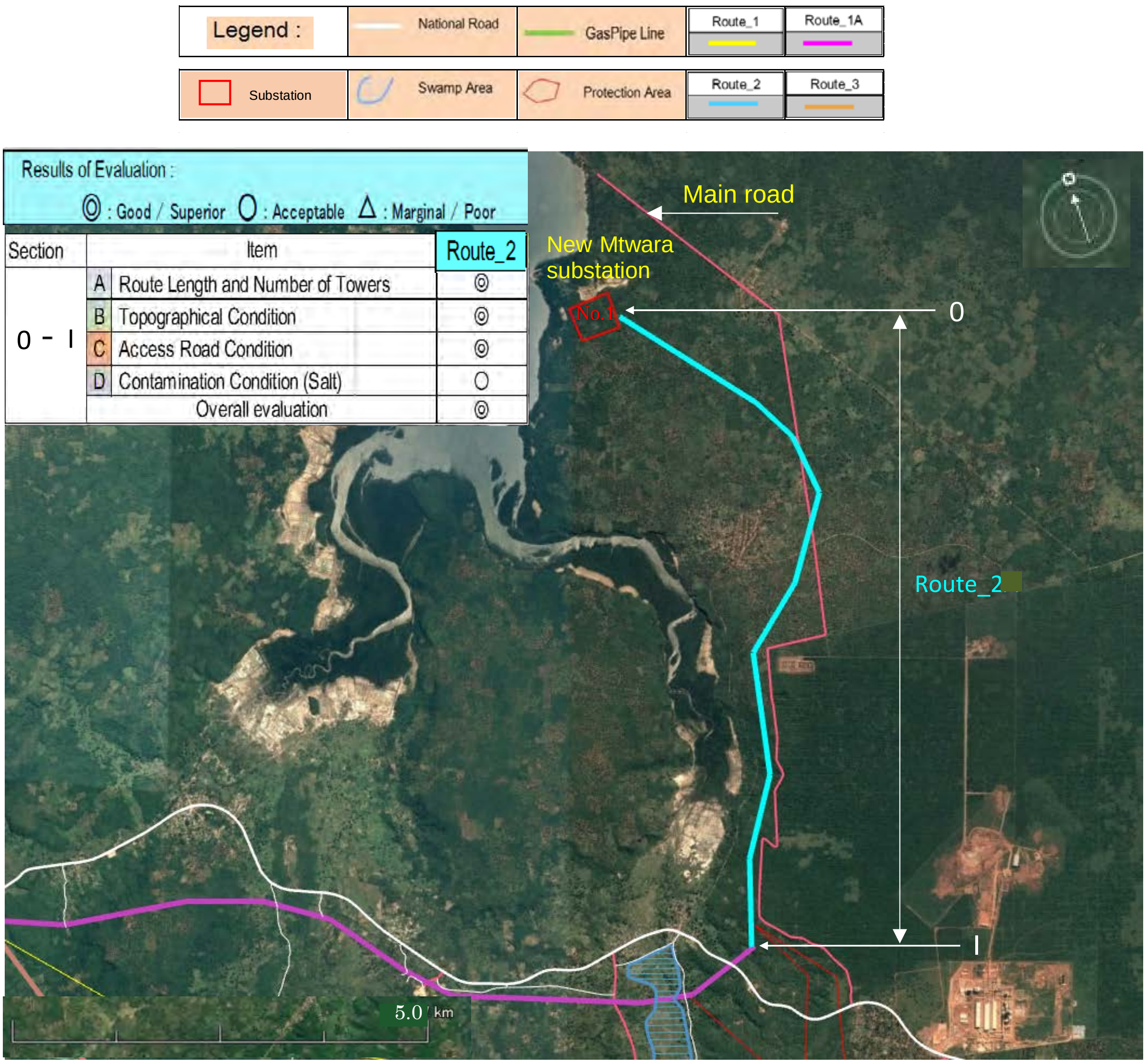
The recommended route and the alternative route are selected as a result of the above process.

5.3 ROUTE INVESTIGATION

The route investigation had been conducted in Tanzania from 16th July 2017 to 5th August 2017 during the dry season.

5.3.1 Section 0-I

The selected optimal transmission line route is the Route_2, with the shortest distance (9 km) from New Mtwara substation to the terminal No.I near the national highway. The 400 kV New Mtwara substation is indicated by the red square No. 1. The route is located along with the main road where large vehicles can pass through. The route passes through cashew nut plantation and bypasses the elementary school area on the way. There is no candidate route other than this optimal transmission line route.



Source: JICA Study Team

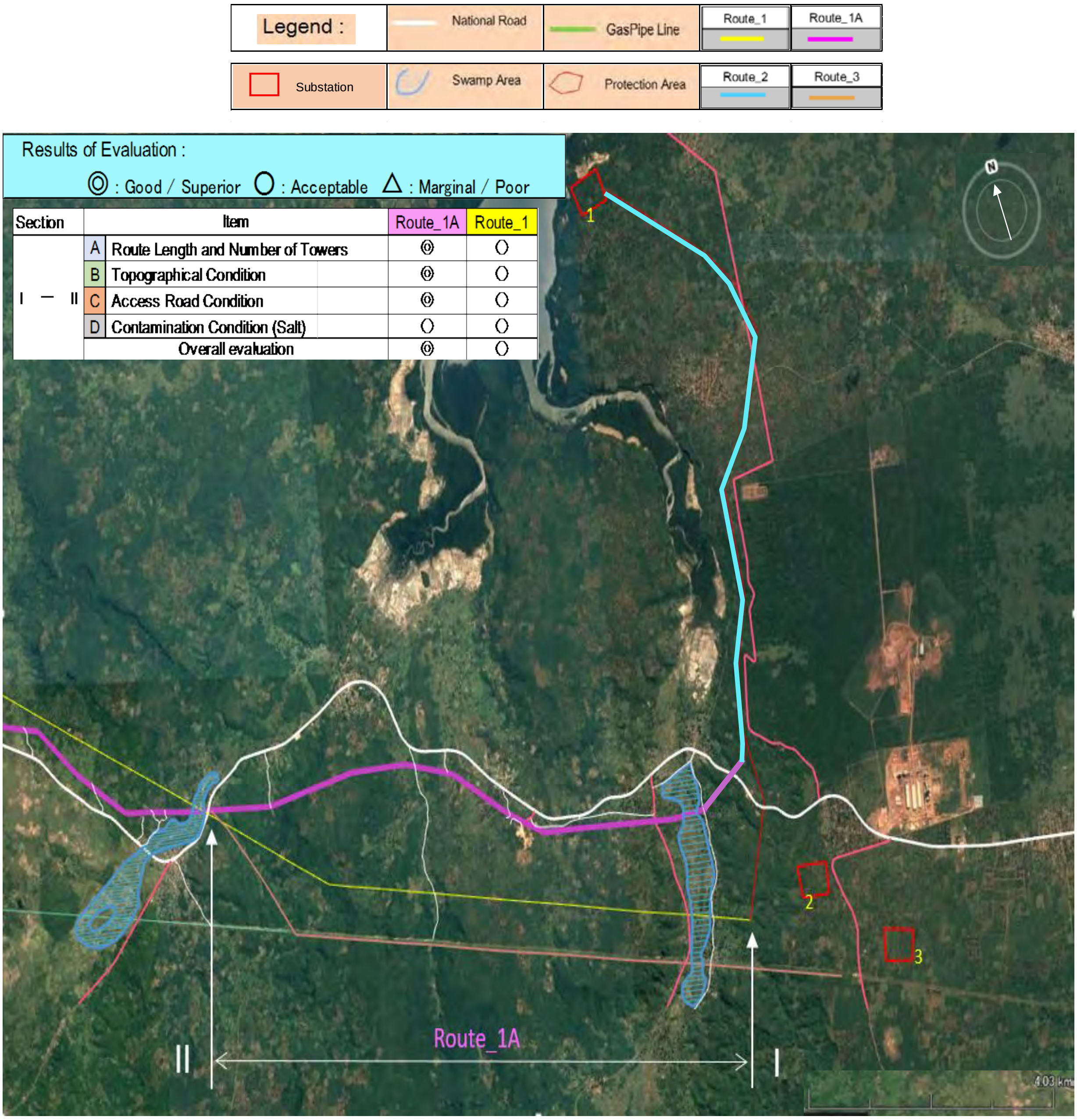
Figure 5-3 Route Map in Section 0-I

5.3.2 Section I-II

The transmission line route, "Route_1A" is a route along with the national highway as shown in Figure 5-4.

Its length is 9.5 km, which is the shortest distance compared to other transmission line route candidates, and the accessibility to the site is excellent among candidates.

Even though the transmission line route crosses national roads and wet submerged areas, the distance between the towers is 490 m to 610 m, and towers can be built without any special requirement.



Section		Item	Route_1A	Route_1
I — II	A	Route Length and Number of Towers	◎	○
	B	Topographical Condition	◎	○
	C	Access Road Condition	◎	○
	D	Contamination Condition (Salt)	○	○
		Overall evaluation	◎	○

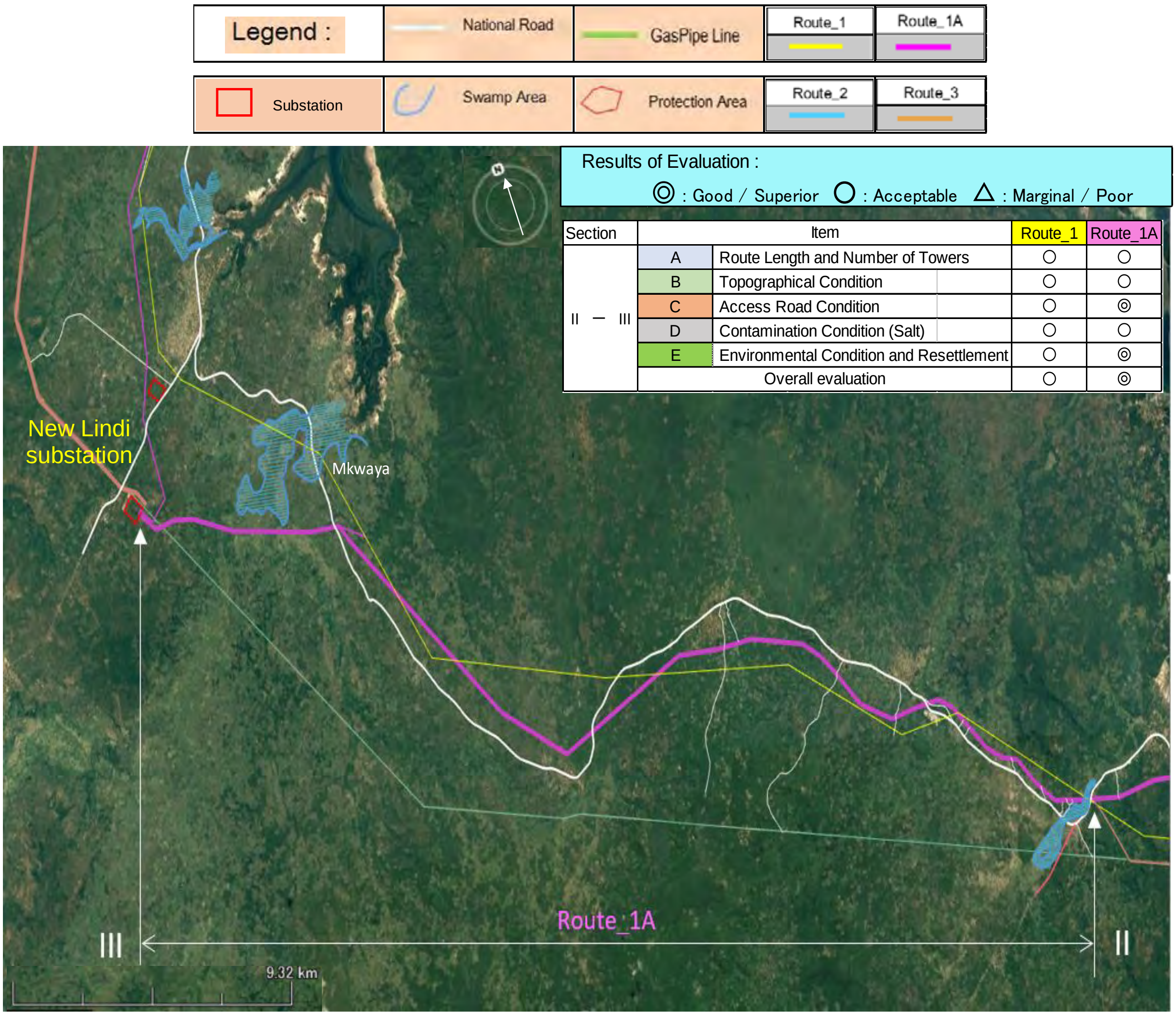
Source: JICA Study Team

Figure 5-4 Route Map in Section I-II

5.3.3 Section II-III

The prospective site for the 400 kV New Lindi substation is at the end point of this Section. Every candidate route has the same length of 40km. But Route_1 and Route_3 are not suitable for the transmission line, because the former is passing through the residential area, the latter is far from the national highway. Therefore, Route_1A is recommended for this Section.

The rainy season causes a swamp area of about 2 km width around the Mkwaya village. Route_1A is planned in such a way that it avoids crossing the swamp area as well.



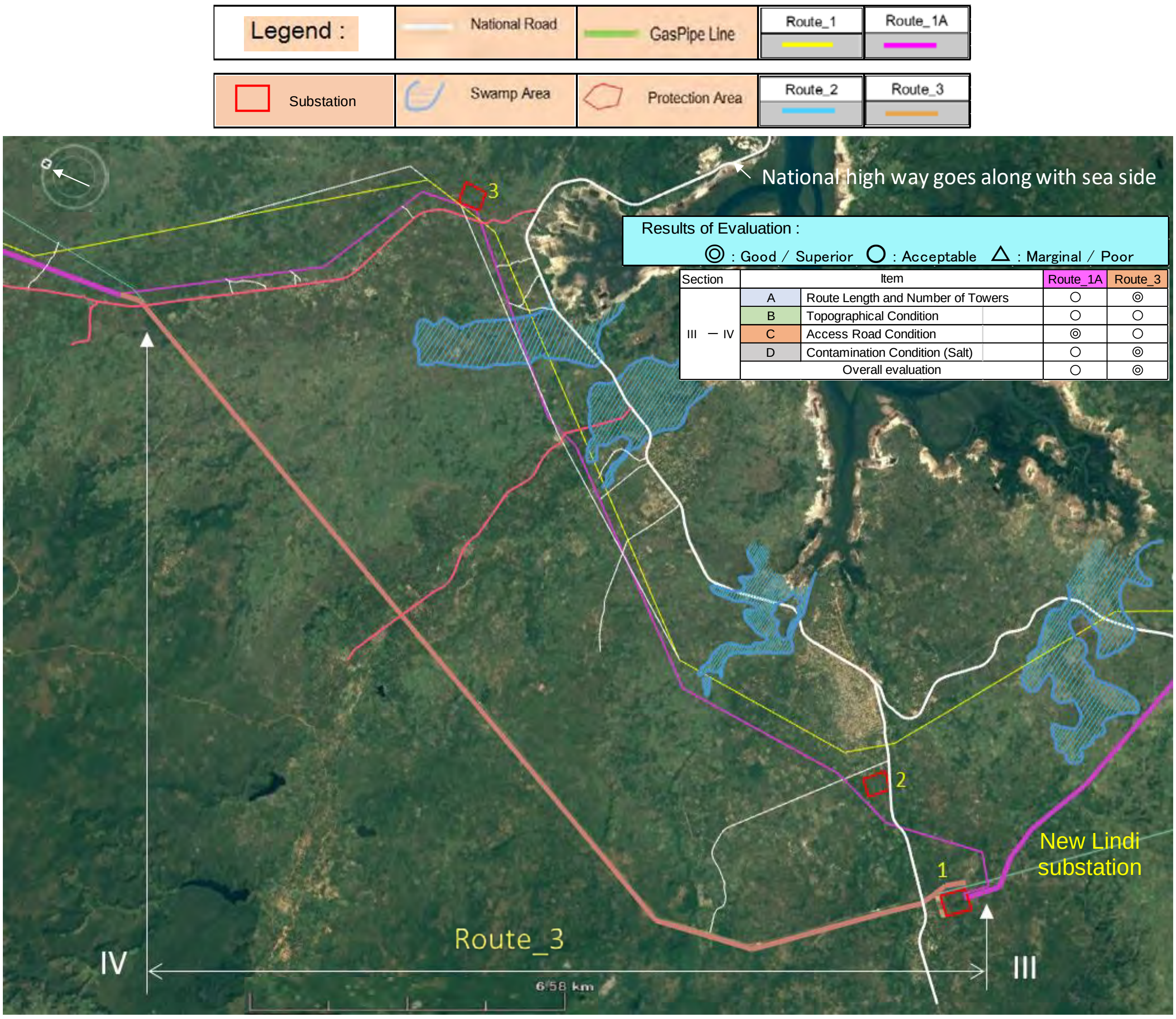
Section		Item	Route_1	Route_1A
II – III	A	Route Length and Number of Towers	○	○
	B	Topographical Condition	○	○
	C	Access Road Condition	○	◎
	D	Contamination Condition (Salt)	○	○
	E	Environmental Condition and Resettlement	○	◎
		Overall evaluation	○	◎

Source: JICA Study Team

Figure 5-5 Route Map in Section II-III

5.3.4 Section III-IV

Candidate routes can be categorized into two groups: those which run along the national highway and those which run along the Pipeline. Although the Pipeline is several kilometers away from the national highway, the length of the Route_3 is 26.3 km, which is short by approximately 5 km than the other Routes along the national highway. It is possible to avoid some swamp areas around the national road, appearing during rainy season, using the Route_3. Since the advantage can compensate for the disadvantage of being far from the national highway in terms of cost, the Route_3 is recommended for this Section.



Source: JICA Study Team

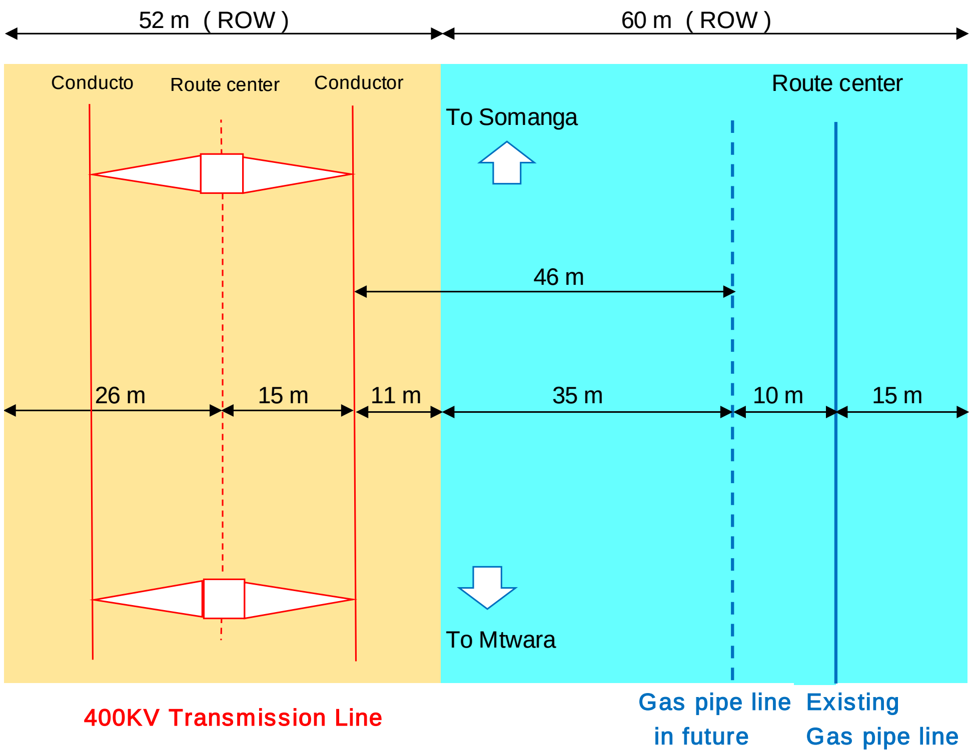
Figure 5-6 Route Map in Section III-IV

On the other hand, the Pipeline has risks of AC interference, and it is also prone to damages caused by casting a foundation pile, AC corrosion, and electric shock, when the transmission line is installed in parallel to the Pipeline. In order to confirm the appropriate distance, which should be ensured between the transmission line and the Pipeline, the JICA Study Team issued a letter to TPDC via TANESCO. Figure 5-7 was created based on the response from TPDC.

As described in Section 13.3.1, in case an additional gas pipeline is installed in the future or an existing gas pipeline is exposed on the ground for maintenance purposes, the electrical voltage caused by the electromagnetic induction of transmission line shall be considered.

Therefore, in order to minimize the effect of electromagnetic induction on the gas pipeline caused by the transmission line, it is necessary to reduce the length of the parallel section, where the transmission line route and the gas pipeline route run in parallel.

As much as possible, the route of the transmission line should be planned in such a way that it is perpendicular to the gas pipeline.



Source: JICA Study Team

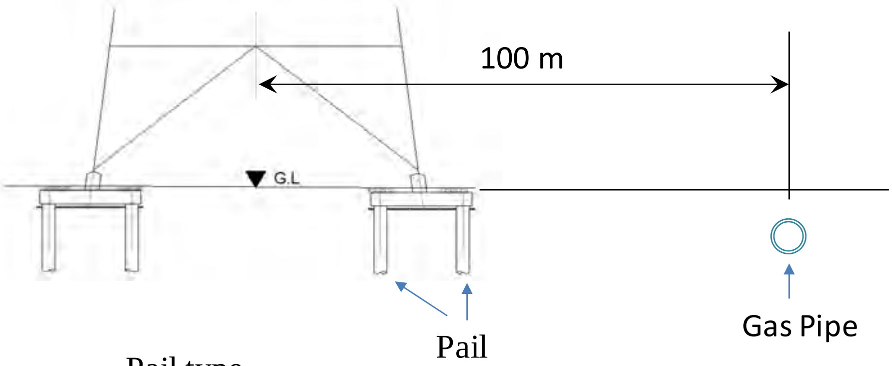
Figure 5-7 Tentative Layout of Transmission Line along with Gas Pipeline

When a pile type foundation is applied for a tower, 100 m or more distance should be ensured between tower and the Pipeline, to prevent the effect of vibration on the Pipeline caused by hammering a pile foundation.

Regarding new gas pipeline for Mtwara GTCC power plant, there will be some sections in which separation distance are about 70m.

In such sections, to prevent vibration effect, pile foundation will be hammering at first and then gas pipeline will be laid.

pile hammer



Pail type

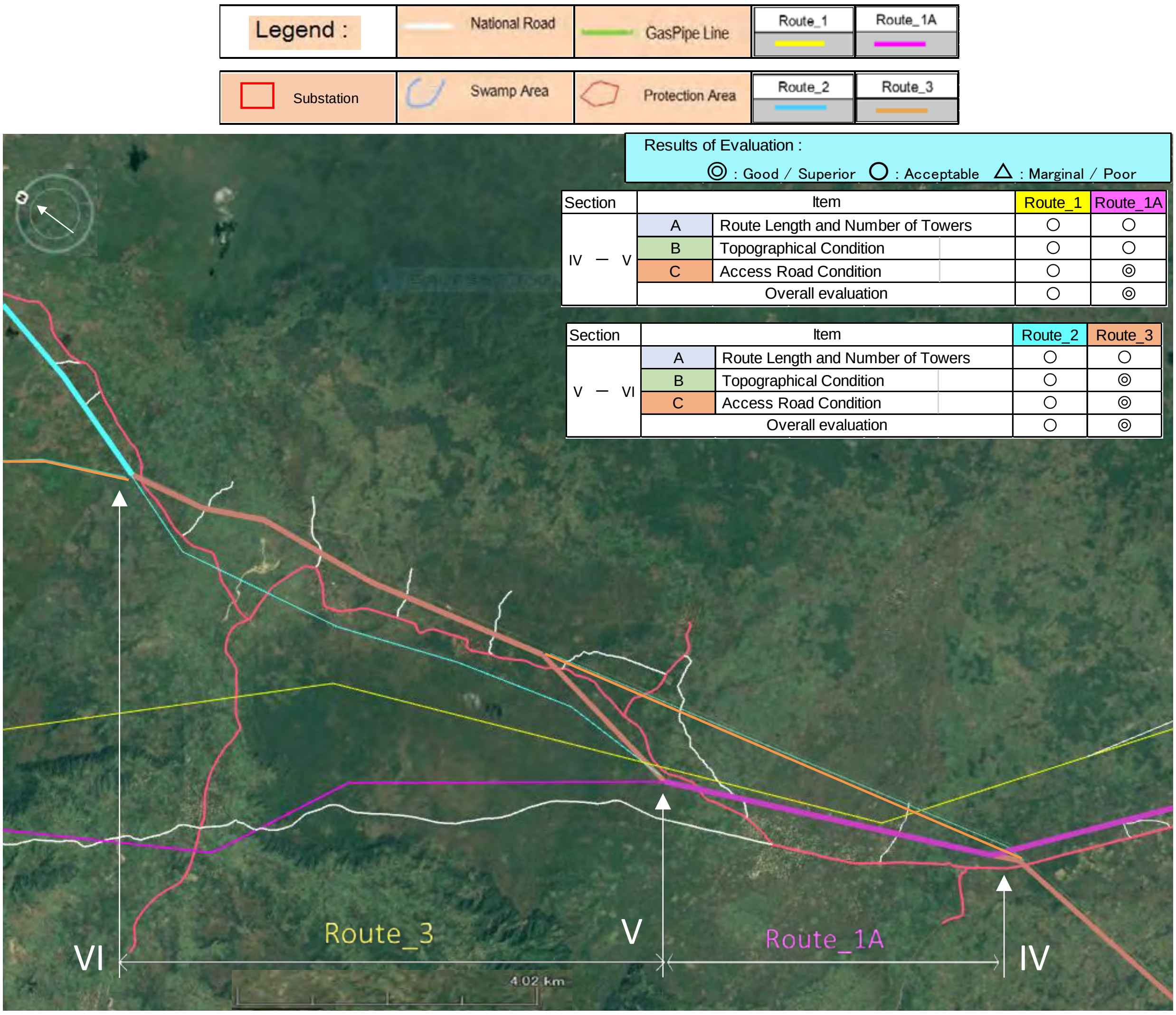
Source: JICA Study Team

Figure 5-8 Necessary Distance between Tower with Pile Type Foundation and Gas Pipe

5.3.5 Section IV-V and V-VI

Between Lindi town and Ruawa village, the national highway detours toward seaside as shown in Figure 5-6. If a route is selected along the national highway, the installation cost will rise. In comparison with the recommended Route_1A, Route_2 is long and the possibility of damage by salt is high. In the land area, there are roads which connect towns and villages to the national highway with a short distance. The JICA Study Team investigated these roads in the feasibility study to evaluate if it is possible to transport the construction vehicles on these roads.

Every candidate route has the same length of 6 km in the Section IV-V. Route_1A can be recommended because the route is close to the main road compared to the others.



Section	Item		Route_1	Route_1A
IV － V	A	Route Length and Number of Towers	○	○
	B	Topographical Condition	○	○
	C	Access Road Condition	○	◎
		Overall evaluation	○	◎

Section	Item		Route_2	Route_3
V － VI	A	Route Length and Number of Towers	○	○
	B	Topographical Condition	○	◎
	C	Access Road Condition	○	◎
		Overall evaluation	○	◎

Source: JICA Study Team

Figure 5-9 Route Map in Section IV-V and V-VI

The main road splits into two at the latter part of the Section IV-V. One (hereinafter called as “the East main road”) leads to the national highway directly and it is relatively easy to drive on this road. At the time of this investigation, the East main road was under renovation for a few kilometers. Taking into account these situations, this road will become suitable for transportation use. The other road is not suitable for transportation, because it is narrow, and it goes through a river without a bridge.

Although Route_2 and Route_3 are along the East main road and both the Routes have same length of around 12km, the latter is recommended for the Section V-VI, because land acquisition may be easier.

Figure 5-10 East Main Road

Figure 5-11 East Main Road under Improvement

Figure 5-12 Road Shrinking

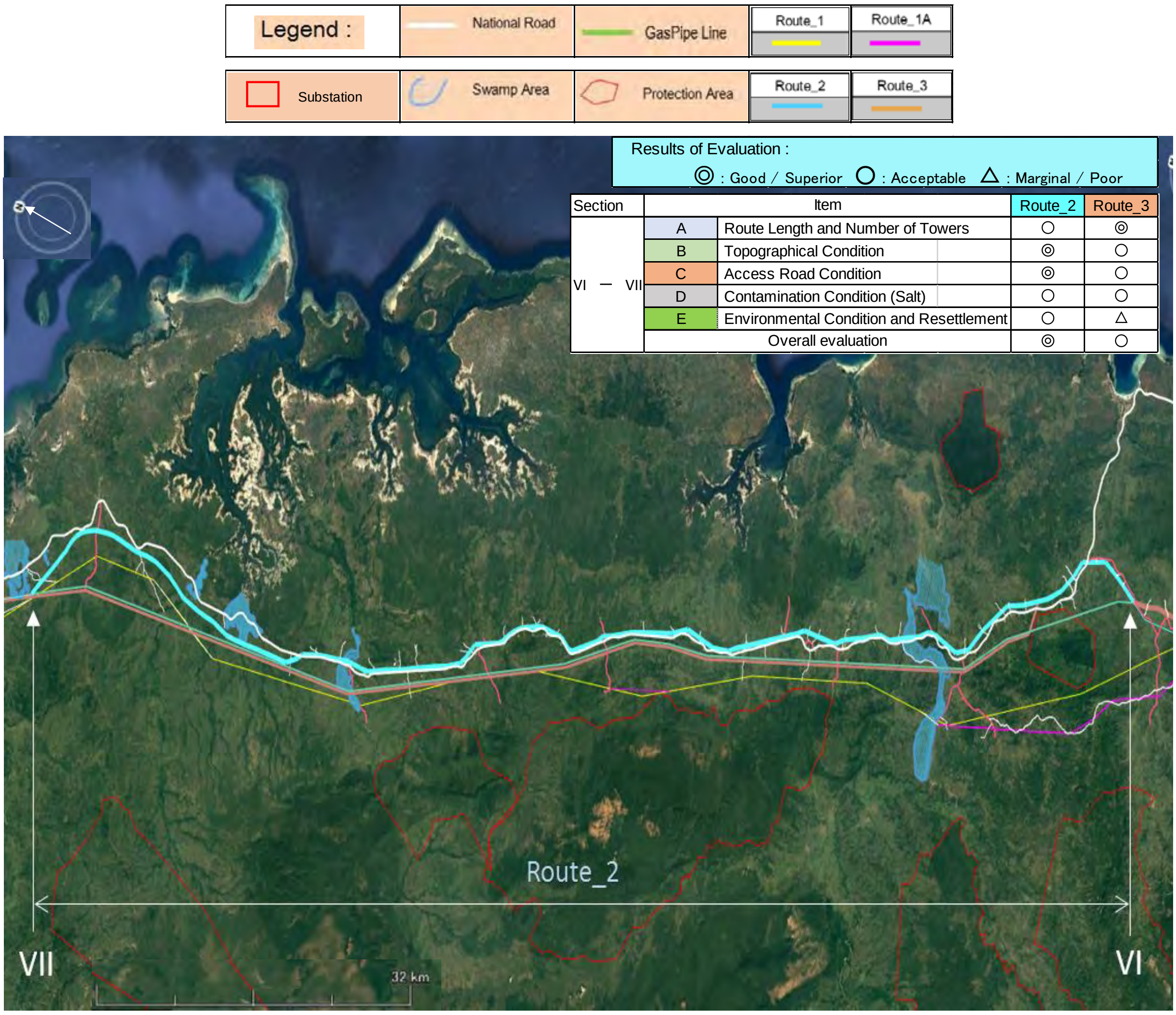
Figure 5-13 Dry River (Dry season)

Source: JICA Study Team

5.3.6 Section VI-VII

Candidate routes can be categorized into two groups: the Routes which run along the sea, and the Routes along the mountain side of the national highway. Route_2, which is along sea side is recommended for this Section. Although the length of this route is 126 km, which is approximately 5 km longer than the others, the route is not only close to the national road, but it is also the only Route, which does not go through the protected forest area. These advantages can compensate for the disadvantage of route length.

A bridge on the path of Route_1 and Route_1A has been broken by a past flood. This suggests that the Routes on mountain side have disadvantages as access roads when compared to the sea side Route.



Section		Item	Route_2	Route_3
VI — VII	A	Route Length and Number of Towers	○	◎
	B	Topographical Condition	◎	○
	C	Access Road Condition	◎	○
	D	Contamination Condition (Salt)	○	○
	E	Environmental Condition and Resettlement	○	△
		Overall evaluation	◎	○

Source: JICA Study Team

Figure 5-14 Route Map in Section VI-VII

Figure 5-15 Broken Bridge

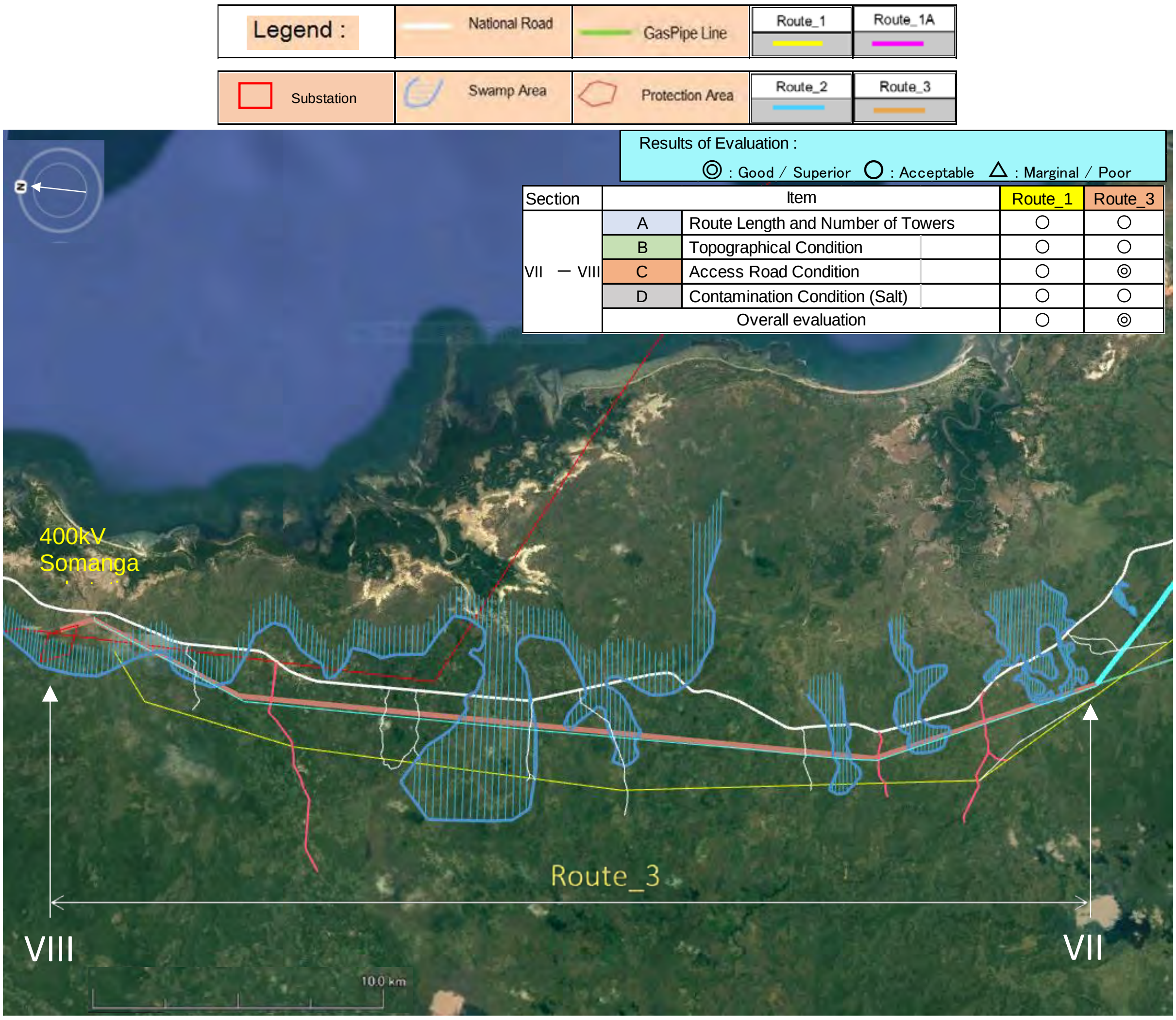
Figure 5-16 River Bank near the Broken Bridge

Source: JICA Study Team

5.3.7 Section VII-VIII

The last section with a length of 37 km is in a harsh environment which hampers the construction of a transmission line. Many large swamps appear during the rainy season. The surface of the path, which branches from the national road, has been cracked by rain. It suggests that access roads should be built with a drainage system.

The Pipeline runs along the national highway, and the distance between them is around 2 km. Since the Pipeline is laid on a topographically advantageous condition like a hill, and the Route is close to the national highway, Route_3 is recommended for this Section.



Section		Item	Route_1	Route_3
VII — VIII	A	Route Length and Number of Towers	○	○
	B	Topographical Condition	○	○
	C	Access Road Condition	○	◎
	D	Contamination Condition (Salt)	○	○
		Overall evaluation	○	◎

Source: JICA Study Team

Figure 5-17 Route Map in Section VII-VIII

Figure 5-18 Cracks on a Road Surface

Figure 5-19 Swamp Area in Dry Season

5.3.8 Common Issue (Access Road)

There are three kinds of access roads to the Construction Sites as follows.

1. Minimum access roads within the Site including public roads permitted for construction

   The Employer TANESCO shall obtain lands or the right of using lands for towers, ROW (right of way), access roads to the Sites including permission to use public roads from the relevant authorities and lands owners.
   The Employer TANESCO shall give the Contractor permission to use such lands and related roads to reach the Sites and to conduct the construction works without disruption. The Contractor shall take countermeasures to mitigate environmental impacts if necessary to satisfy EIA.

2. Temporary access roads outside the Site including public roads permitted for construction

   Temporary access roads used by the Contractor for efficient construction work

   After the contract becomes effective, the Contractor shall re-survey to check the survey pre-conducted by the Employer. Also the Contractor shall confirm the rights to access to the site stated in the report of Environmental Impact Assessment. When the Contractor needs additional access to temporary roads outside the Site and the public roads, the Contractor shall obtain, at his own risk and cost, any additional rights of way or facilities outside Site, which he may require for the purposes of the Works.

   The Contractor shall be responsible for any maintenance which may be required for his use of such access roads, subject to the agreement of relevant authorities, land owners and residence nearby, and the Contractor shall also be responsible for any claims which may arise from the use of such roads.

3. Permanent access roads

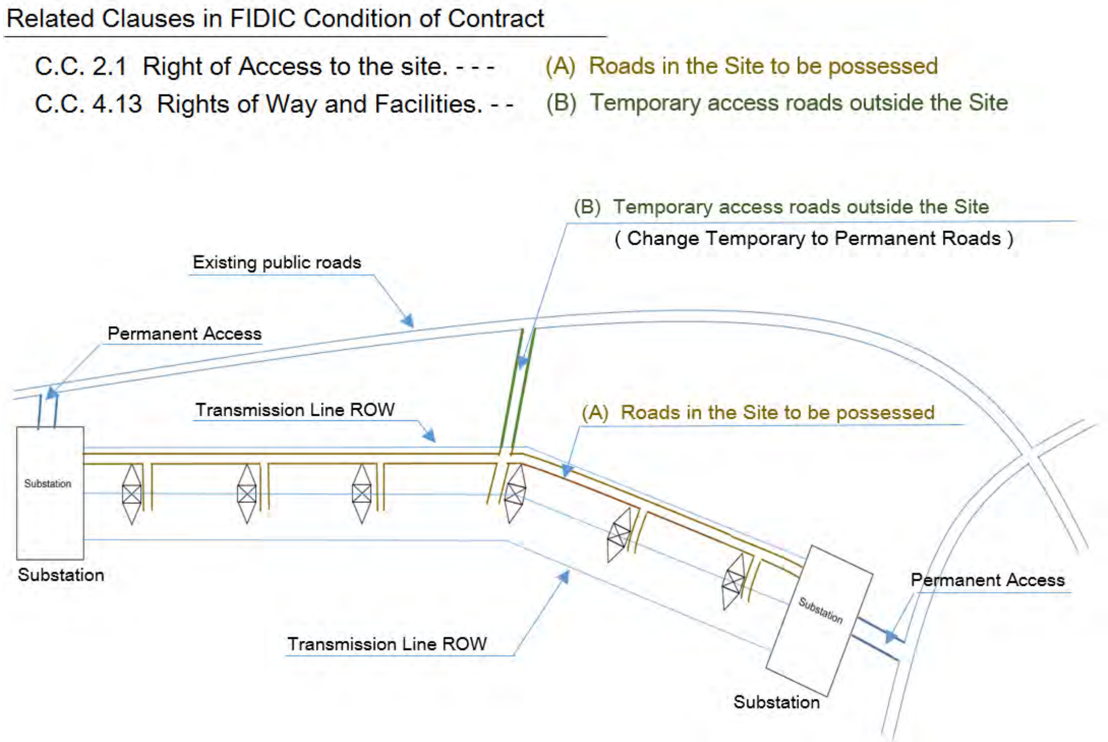
Some of the temporary access roads are used for the maintenance of the Project and for public activities by the third parties like neighboring residents.

In principle, temporary access roads outside the site shall be removed and restored to the original condition as it was, before the construction of the road. However, in case the Employer wants to use the temporary roads to maintain the Project, the roads can be changed into permanent roads by following the procedure of receiving agreement of related authorities, land owners and neighboring residents.

Responsibilities involved in the construction of access roads are shown in Table 5-2 and Figure 5-20.

Table 5-2 Responsibilities for the Construction of Access Roads

Description		(A) Roads in the possessed Site and lands permitted for the Project	(B) Temporary access roads outside the Site	Execution period
Details of Site		Within Site for towers and ROW possessed by Employers, TANESCO, and the public roads	Outside the Site and public roads	
Purpose for road		For the construction works, periodic inspection by the Employer, and maintenance	Construction works only	
Party to be responsible	Preliminary investigation (A)	Employer TANESCO		After Approval EIA
	Negotiation with relevant parties (A)	Employer TANESCO		
	Detailed Site Investigation (B)		Contractor	Construction Stage
	Negotiation with relevant parties (B)		Contractor	
	Construction of access roads	Contractor	Contractor	
	Demolish of access roads	Contractor	Contractor	
	Confirmation for restore of lands	Employer TANESCO	Contractor	
	(Change Temporary to Permanent Roads)	Employer TANESCO	Employer TANESCO	After Construction
	Negotiation with relevant parties			
	Construction of permanent roads	Employer TANESCO	Employer TANESCO	



Source: JICA Study Team

Figure 5-20 Related Clauses in FIDIC Conditions of Contract

Dirt *Gravel* *Paved*

Source: JICA Study Team

Figure 5-21 Type of Permanent Road

5.3.9 Summary for the Route Survey

The length of the recommended route is estimated to be about 270 km based on the result of the route survey.

The characteristics of the candidate routes for each section are summarized in Table 5-3. TANESCO has agreed with the route proposed by JICA Study Team for the 400 kV transmission line, based on the condition that it will be possible to make minor route changes, if necessary, in accordance with the results of Environmental Impact Assessment.

The Environmental Impact Assessment will be carried out for not only the proposed route with the red bold line but also the alternative one with the blue line, as shown in Figure 5-22.

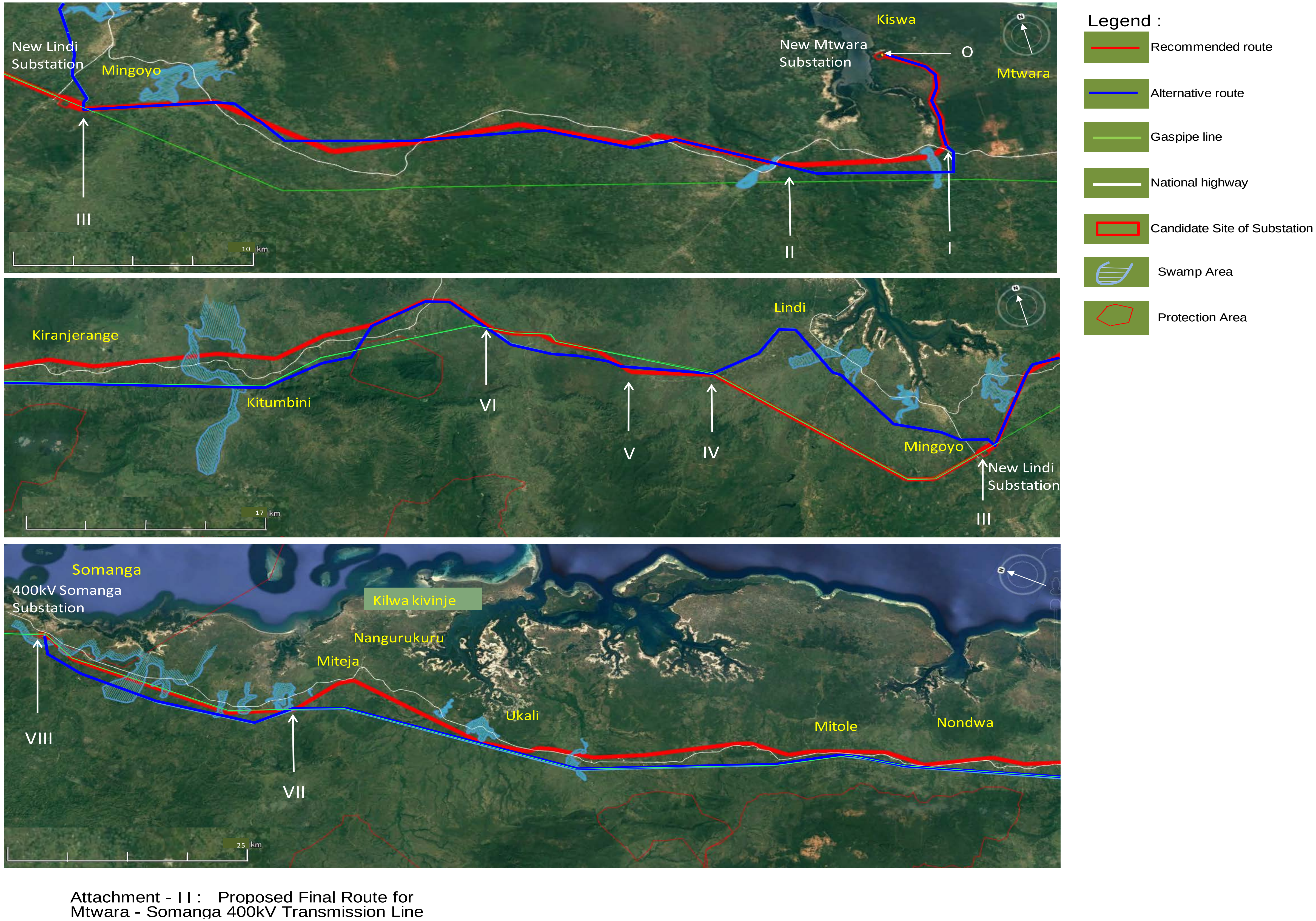
Table 5-3 Comparison of the Routes for 400 kV New Mtwara Substation – 400 kV Somanga Substation 400 kV Transmission Line

Legend :

A	Route Length and Number of Towers for angle point (over 30 degree)	C	Access Road Condition Distance from Main Road
B	Topographical Condition Section Length (Mountainous) · Highest Elevation Level	D	Contamination Condition (Salt) · Length of Swamp Area
E	Environmental Condition and Resettlement		Results of Evaluation : ◎ : Good / Superior ○ : Acceptable △ : Marginal / Poor

Section	Item	Route_1 Planned Route 400kV Double Circuit Transmission in reports made by USAID/TANESCO (March 2015)	Evaluation	Route_1A This is alternative route to minimize areas in mountainous in Route_1 and to make better crossing conditions with river, gas pipe line, housing areas and forest protection area.	Evaluation	Route_2 This is a new route at the East Side of National Road T7□ to get easy access.	Evaluation	Route_3 Additional Route is basically parallel to the Gas Pipe Line. Land negotiation is easy.	Evaluation
0 ─ Ⅰ	A	Not applicable		Not applicable		8.9 km 23 towers (3 points)	◎	Not applicable	
	B					(over 100 m) 0 km 70 m			
	C					Distance from the main Road T7 : 0.1 km to 1.0 km. The access roads are available by widening existing roads. The construction cost of permanent roads is cheap.			
	D					(Salt) 8.9 km			
Ⅰ ─ Ⅱ Substation (1・2)	A	Not applicable		9.5 km 23 towers (0 points)	◎	Not applicable		Not applicable	
	B			(100 m - 150m) 1.0 km 150 m					
	C			Distance from the national Road T7 : 0.2 km to 1.0 km. The access roads are available by widening existing roads. The construction cost of permanent roads is cheap.					
	D			(Salt) 9.5 km (Swamp) 0.2 km					
Ⅰ ─ Ⅱ Substation (3)	A	11.4 km 31 towers (3 points)	○	Not applicable		Not applicable		12.4 km 34 towers (3 points)	◎
	B	(100 m - 125m) 7.0 km 125 m						(100 m - 150m) 5.5 km 150m	
	C	Distance from the national Road T7 : 1.0 km to 1.6 km. There are few existing roads available. The cost of permanent roads is high.						Distance from the national Road T7 : 1.5 km to 3.0 km. There are few existing roads available. The cost of permanent roads is high.	
	D	(Salt) 11.4 km (Swamp) 0.4 km						(Salt) 12.4 km (Swamp) 0.2 km	
Ⅱ ─ Ⅲ	A	41.0 km 111 towers (7 points)	○	40.4 km 103 towers (5 points)	◎	Not applicable	◎	40.5 km 109 towers (1 points)	△
	B	(200 m - 300m) 7.5 km 300 m		(200 m - 300m) 7.5 km 300 m				(200 m - 310m) 10.0 km 310 m	
	C	Distance from the national Road T7 : 0.6 km to 2.0 km. The access roads are available by widening existing roads. The construction cost of permanent roads is cheap.		Distance from the national Road T7 : 0.2 km to 0.8 km. The access roads are available by widening existing roads. The construction cost of permanent roads will be much less.				Distance from the national Road T7 : 1.0 km to 5.5 km. There are few existing roads available. The cost of permanent roads is high.	
	D	(Salt) 19.0 km (Swamp) 2.5 km		(Salt) 19.0 km (Swamp) 0.2 km				(Salt) 10.0 km (Swamp) 0.8 km	
	E	——— (Resettlement) 3 houses		——— Change route to avoid the Housing Area.				——— ———	
Ⅲ ─ Ⅳ Substation (2・3)	A	25.0 km 68 towers (5 points)	△	25.0 km 68 towers (6 points)	◎	Not applicable	◎	Not applicable	
	B	(over 100 m) 0 km 80 m		(over 100 m) 0 km 80 m					
	C	Distance from the national Road T7 : 0.6 km to 1.8 km. The access roads are available by widening existing roads. The cost of permanent roads is cheap.		Distance from the national Road T7 : 1.0 km to 1.8 km. The access roads are available by widening existing roads. The construction cost of permanent roads will be much less.					
	D	(Salt) 10.0 km (Swamp) 1.8 km		(Salt) 7.8 km (Swamp) 1.0 km					
	E	——— (Resettlement) 10 houses		——— Change route to avoid the Housing Area.					
Ⅲ ─ Ⅳ Substation (1)	A	Not applicable		31.5 km 85 towers (9 points)	○	Not applicable	○	27.2 km 71 towers (7 points)	◎
	B			(over 100 m) 0 km 80 m				(200 m - 230m) 5.0 km 230 m	
	C			Distance from the national Road T7 : 1.0 km to 2.3 km. The access roads are available by widening existing roads. The construction cost of permanent roads is cheap.				Distance from the national Road T7 : 6.0 km to 7.0 km. There are few existing roads available. The Construction cost of permanent roads will be high.	
	D			(Salt) 7.8 km (Swamp) 1.0 km				——— ———	
Ⅳ ─ Ⅴ	A	6.0 km 17 towers (2 points)	○	6.2 km 16 towers (0 points)	◎	Not applicable	◎	6.0 km 17 towers (2 points)	○
	B	(over 150 m) 0 km 150 m		(over 150 m) 0 km 150 m				(over 150 m) 0 km 150 m	
	C	Distance from the main Road : 0.8 km to 1.3 km. There are few existing roads available. The construction cost of permanent roads is cheap.		Distance from the main Road : 0.4 km to 0.7 km. The access roads are available by widening existing roads. The construction cost of permanent roads will be much less.				Distance from the national Road T7 : 0.9 km to 1.6 km. There are few existing roads available. The cost of permanent roads is high.	
Ⅴ ─ Ⅵ	A	10.0 km 27 towers (1 points)	△	10.0 km 27 towers (2 points)	△	11.8 km 32 towers (4 points)	○	11.9 km 31 towers (0 points)	◎
	B	(170 m - 260m) 7.0 km 260 m		(190 m - 280m) 7.5 km 280 m		(170 m - 260m) 7.0 km 260 m		(150 m - 250m) 6.0 km 250 m	
	C	Distance from the main Road : 0.8 km to 1.3 km. There are few existing roads available. The construction cost of perm. roads with the slope is high.		Distance from the main Road : 0.7 km to 3.2 km. There are few existing roads available. The cost of permanent roads is high.		Distance from the main Road : 0.2 km to 0.5 km. The access roads are available by widening existing roads. The construction cost of permanent roads is cheap.		Distance from the main Road : 0.2 km to 0.4 km. The access roads are available by widening existing roads. The construction cost of permanent roads will be much less.	
Ⅵ ─ Ⅶ	A	125.0 km 338 towers (9 points)	△	126.0 km 341 towers (13 points)	△	126.7 km 322 towers (5 points)	◎	121.0 km 327 towers (4 points)	△
	B	(150 m - 490m) 15.0 km 490 m		(150 m - 280m) 15.0 km 280 m		(over 150 m) 0 km 80 m		(150 m - 250m) 3.0 km 250 m	
	C	Distance from the national Road T7 : 2.0 km to 7.0 km. There are few existing roads available. The construction cost of perm. roads with the slope is high.		Distance from the national Road T7 : 2.0 km to 9.0 km. There are few existing roads available. The cost of permanent roads is high.		Distance from the national Road T7 : 0.2 km to 1.0 km. The access roads are available by widening existing roads. The construction cost of permanent roads is cheap.		Distance from the national Road T7 : 0.4 km to 4.0 km. There are few existing roads available. The cost of permanent roads is high.	
	D	(Salt) 18.0 km (Swamp) 2.0 km		(Salt) 18.0 km (Swamp) 2.0 km		(Salt) 19.0 km (Swamp) 1.5 km		(Salt) 15.0 km (Swamp) 2.0 km	
	E	A part of route will pass inside the Forest Protection Area "Ngarama".		——— ———		——— ———		A part of route will pass inside the Forest Protection Area "Ruawa".	
Ⅶ ─ Ⅷ	A	37.0 km 100 towers (3 points)	○	Not applicable		Not applicable		36.4 km 93 towers (2 points)	◎
	B	(over 150 m) 0 km 80 m						(over 150 m) 0 km 70 m	
	C	Distance from the national Road T7 : 2.0 km to 4.0 km. There are few existing roads available. The construction cost of permanent roads will be high.						Distance from the national Road T7 : 0.5 km to 2.0 km. There are few existing roads available. The construction cost of permanent roads is cheap.	
	D	(Salt) 37.0 km (Swamp) 8.0 km						(Salt) 37.0 km (Swamp) 11.5 km	
Recommended Section		Not applicable (Initial Planning only)		Ⅰ─Ⅱ (Substation (1, 2)) Ⅱ─Ⅲ Ⅲ─Ⅳ (Substation (2, 3)) Ⅳ─Ⅴ		0─Ⅰ Ⅵ─Ⅶ		Ⅰ─Ⅱ (Substation (3)) Ⅲ─Ⅳ (Substation (1)) Ⅴ─Ⅵ Ⅶ─Ⅷ	

Source: JICA Study Team



Source: JICA Study Team

Figure 5-22 Optimal Route based on the Result of the First Field Survey

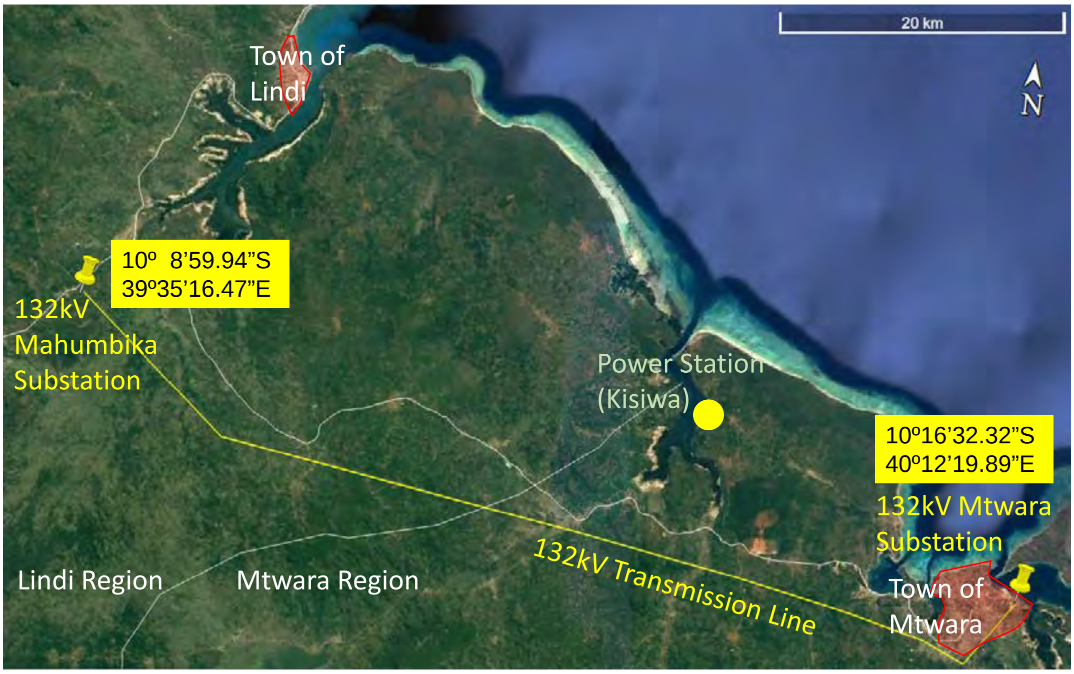
CHAPTER 6

SITE SELECTION FOR SUBSTATION

CHAPTER 6 SITE SELECTION FOR SUBSTATION

6.1 EXISTING SUBSTATIONS

This Chapter reports the results of feasibility study for the site selection of the new 400 kV Mtwara substation and the new 400kV Lindi substation. The new 400kV Somanga substation, is planned by TANESCO and will be constructed under another EPC contract, therefore, the report does not mention about the site selection for the new 400kV Somanga substation. JICA Study Team conducted a site survey of the existing 132kV substations in Mtwara and Lindi areas, because the new 400/132kV substations shall be connected to the existing 132kV substations. In order to reduce the transmission loss and improve the reliability of the transmission system between Mtwara and Lindi, TANESCO constructed a 132 kV transmission line from Mtwara to Mahumbika (near Lindi), and two 132/33 kV substations- one in Mtwara and another in Mahumbika, near Lindi. The location of both substations are shown in Figure 6-1.

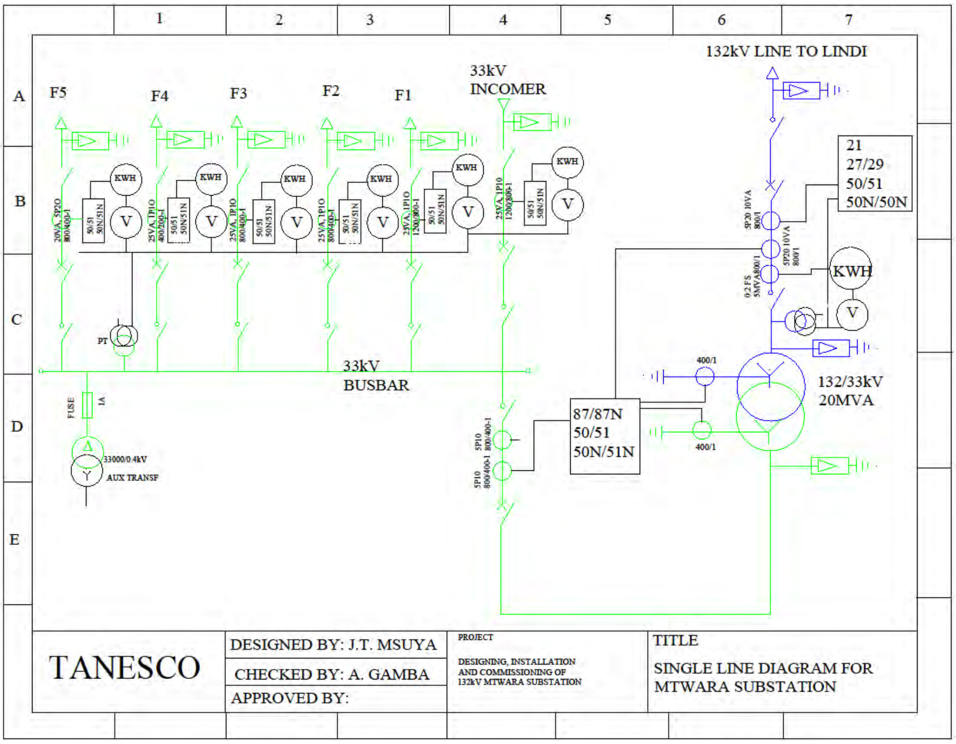


Source: JICA Study Team

Figure 6-1 Location of 132/33 kV Substations

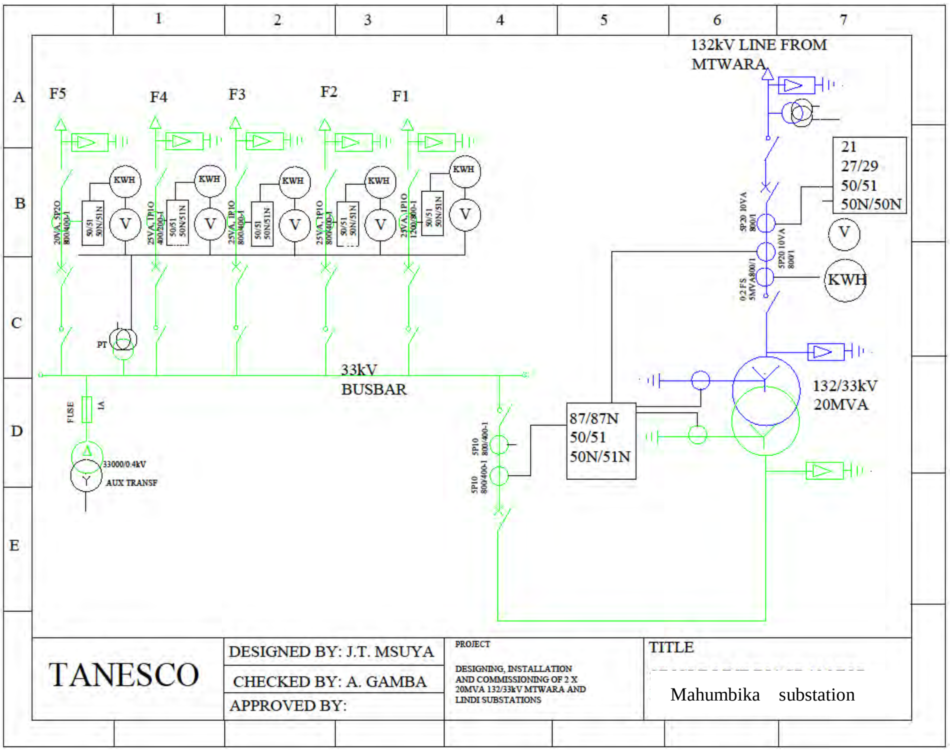
The 132 kV transmission line between the 132kV Mtwara substation and the 132kV Mahumbika substation has only one circuit, and the length of the line is about 80 km. One 132/33 kV transformer of 20 MVA is installed for each substation. The 33 kV bus at the 132kV Mtwara substation has 6 feeders (input from Mtwara gas engine power station × 1, output to the local loads × 5) as shown in Figure 6-2. On the other hand, the 33 kV bus at the Mahumbika substation has 5 feeders (output to the local loads × 5) as shown in Figure 6-3. The photos of the 132kV Mtwara substation are shown in Figure 6-4. In addition, the photos of the 132kV Mahumbika substation are shown in Figure 6-5.

In each substation, TANESCO operates the switching facilities with a computer (microSCADA) and has 2 operators (3 shift system). In addition, TANESCO adopted Gas Circuit Breakers (GCBs) for the 132 kV circuit breakers, and has a spare cylinder of SF6 gas in order to supply the gas to the GCB, by themselves.



Source: TANESCO

Figure 6-2 Single Line Diagram for 132kV Mtwara Substation



Source: TANESCO

Figure 6-3 Single Line Diagram for 132kV Mahumbika Substation

Overview of substation

132/33kV transformer (20MVA)

132kV bus line

33kV bus line

Office building

Control room

Source : JICA Study Team

Figure 6-4 Photos of 132kV Mtwara Substation

132kV transmission line to Mtwara

132/33kV transformer (20MVA)

132kV bus line

33kV bus line

Office building

Control room

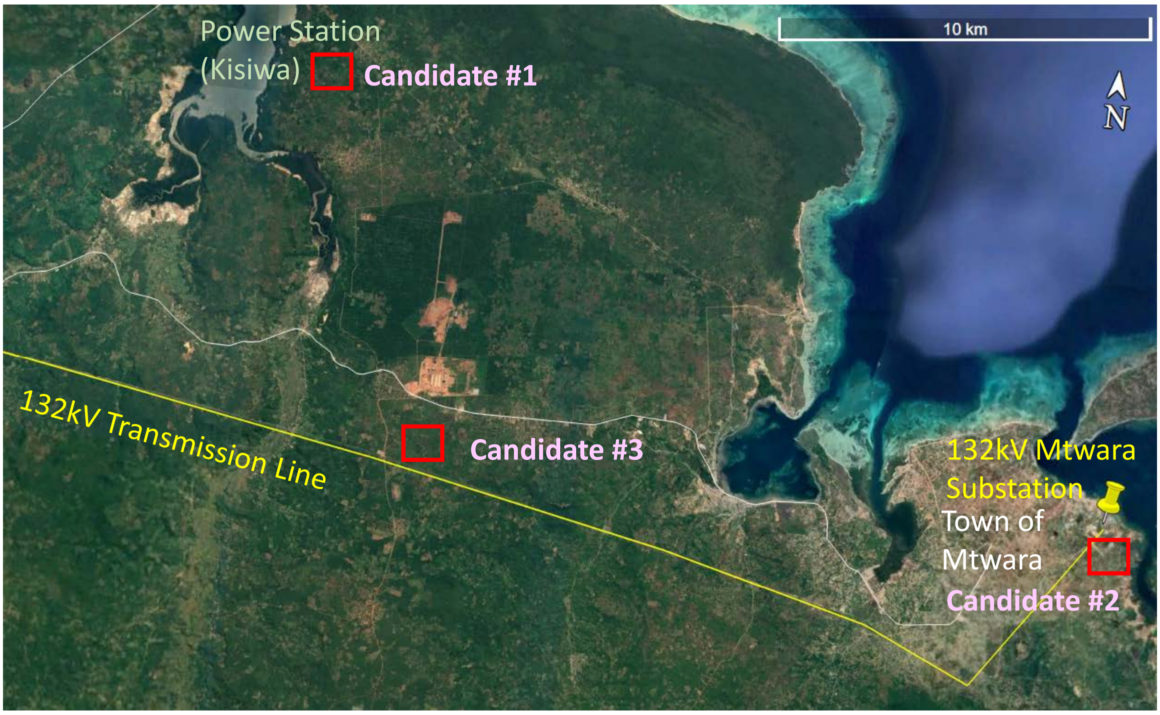
Source : JICA Study Team

Figure 6-5 Photos of 132kV Mahumbika Substation

6.2 New Substations

6.2.1 400KV New Mtwara Substation

As shown in Figure 6-6, JICA Study Team selected three sites as candidate sites for the 400kV New Mtwara substation. The Kisiwa site is one of the candidate sites, where a power station will be constructed.



Source：JICA Study Team

Figure 6-6 Candidate Sites for 400kV New Mtwara Substation #1~#3

As shown in Table 6-1, JICA Study Team evaluated the candidate sites from the following five perspectives, 1) Land acquisition, 2) Construction cost, 3) O&M cost, 4) Local grid linkage, 5) Mozambique linkage. As a result, candidate #1 (inside the Kisiwa site, where the Mtwara GTCC power plant will be constructed) was selected as the optimal candidate, because the site is at the beach, which facilitates easy transportation of heavy equipment. In addition, the negotiation for land acquisition has been completed, and human resource such as O&M staffs will be shared with the Mtwara GTCC power plant.

Table 6-1 Comparison of Candidate Sites for the 400kV New Mtwara Substation

	Candidate #1 (Inside of Kisiwa Site)		Candidate #2 (132kV Mtwara Substation)		Candidate #3 (Branch to Kisiwa Site)	
Land Acquisition	◎	Land has been acquired for power station complex.	×	Located in the town area.	△	Located in the golf course area, according to the Mtwara Master Plan.
Construction Cost	○	Heavy equipment, such as transformer, can be carried by beaching. Countermeasure for sea salt damage is necessary.	△	Land transportation penalty for heavy facilities may be charged. Additional cost for land acquisition is necessary. Countermeasure for sea salt damage is recommended.	△	Same as Candidate #2.
O&M Cost	◎	It may be possible to share resources, such as O&M staffs, with power station	○	O&M staff is necessary for the new substation.	○	Same as Candidate #2.
Local Grid Linkage	△	132kV transmission line from local grid needs to be drawn to the Kisiwa site.	○	Near the existing 132kV local grid	○	Next to the existing 132kV substation.
Mozambique Linkage	△	400kV transmission line from Mozambique needs to be drawn to the Kisiwa site.	○	Compared to Kisiwa site, the distance of the 400kV transmission line to Mozambique is shorter.	○	Same as Candidate #2.

Source: JICA Study Team

It is necessary to consider countermeasures for the sea salt damage, because candidate #1 is located at the seaside. Full-GIS (Gas Insulated Switchgear) substation is generally adopted at the seaside areas to cope with sea salt damage.

As mentioned, one 132kV transmission line between the 132kV Mtwara substation and the 132kV Mahumbika substation, near Lindi already exists. Regarding connection with the local grids, JICA Study Team suggests the joint use (Purple) of transmission line towers, for both the 400kV and 132kV as shown in Figure 6-7. In addition to the joint use of towers, a new 132kV transmission line will be constructed for a few kilometers, to connect the new line with the existing 132kV transmission line (Green line in Figure 6-7). This method minimizes the total space required for transmission lines.

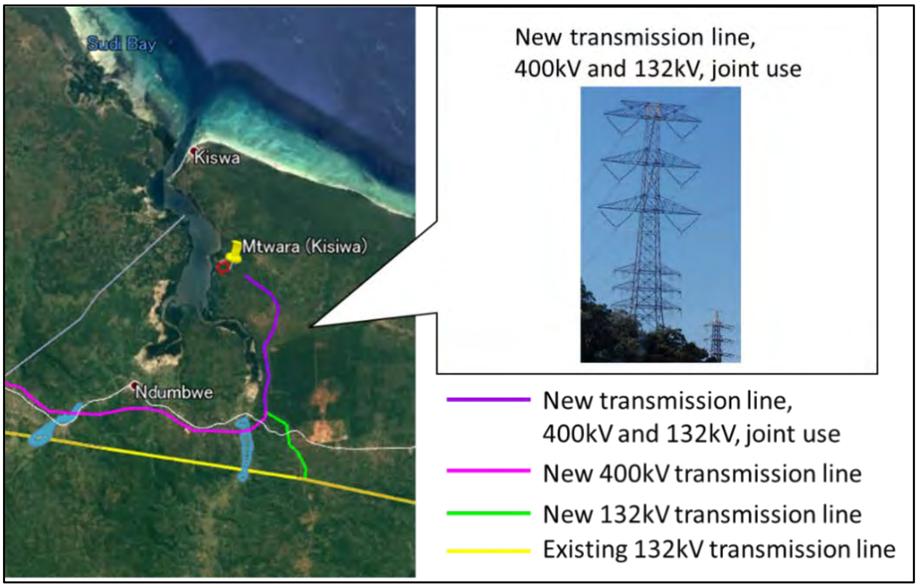
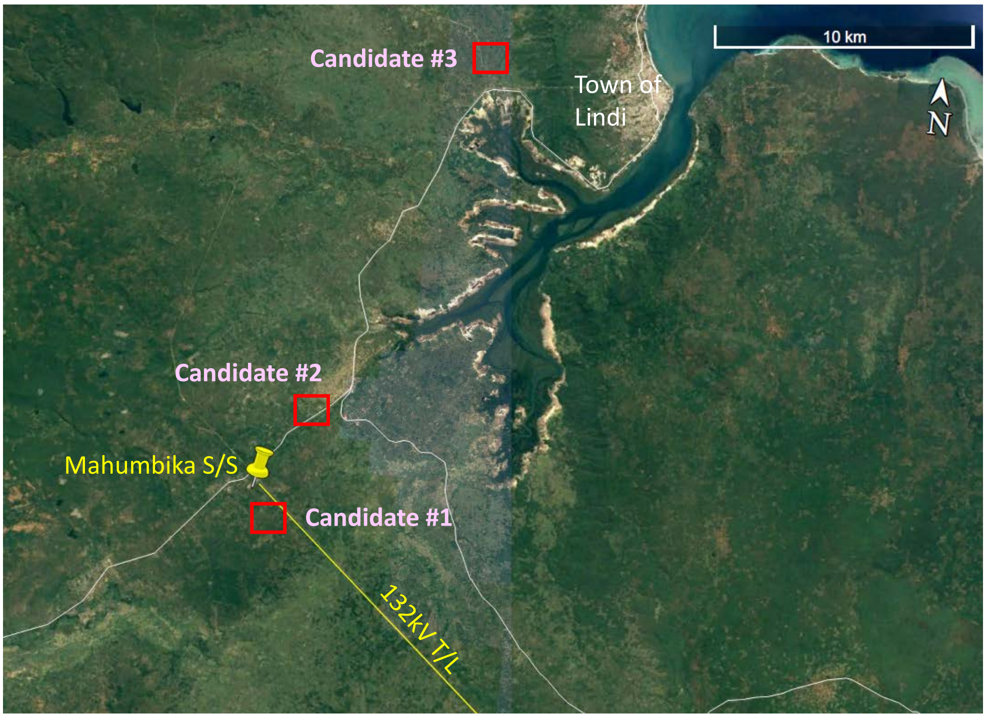


Figure 6-7 Joint Use of Transmission Line from Kisiwa Site

6.2.2 400KV New Lindi Substation

As shown in Figure 6-8, JICA Study Team selected three sites, including the existing 132kV Mahumbika substation, as candidate sites for the 400kV New Lindi substation. Candidate #1 is placed next to the existing 132kV Mahumbika substation. Candidate#2 is near the national road between Mtwara and Lindi, and it is 3km away from the Candidate#1. Candidate#3 is located near the center of Lindi city.



Source: JICA Study Team

Figure 6-8 Candidate Sites for 400kV New Lindi Substation #1~#3

As shown in Table 6-2, JICA Study Team evaluated each candidate site from the following four perspectives, 1) Land acquisition, 2) Construction cost, 3) O&M cost, 4) Local grid linkage. As a result, candidate #1 (adjacent to the 132kV Mahumbika substation for future expansion) was selected as the optimal candidate, because the land acquisition has been completed and also because it is easy to connect to the existing 132kV local grid. In addition, the 400kV New Lindi substation at candidate#1 may be able to share resources, such as O&M staffs, with the existing 132kV Mahumbika substation.

Table 6-2 Comparison of Candidate Sites for the 400kV New Lindi Substation

	Candidate #1 (Mahumbika S/S)		Candidate #2 (Road Branch)		Candidate #3 (Near Lindi town)	
Land Acquisition	◎	Land has been acquired for future expansion of the existing substation.	○	Possible to acquire the land for substation	○	Same as Candidate #2
Construction Cost	◎	Land transportation penalty for heavy equipment may be charged.	○	Land transportation penalty for heavy facilities may be charged. Additional cost for land acquisition is necessary.	○	Same as Candidate #2.
O&M Cost	◎	It may be possible to share resources, such as O&M staffs, with the existing substation.	○	O&M staff is necessary for the new substation.	○	Same as Candidate #2.
Local Grid Linkage	◎	Very close to the existing 132kV local grid.	○	Necessary to construct new 132kV transmission line to Mahumbika S/S.	×	In addition to 400/132kV facilities, new 33kV transmission line shall be needed to supply to Lindi

Source: JICA Study Team

On the other hand, it is necessary to consider countermeasures for land transportation penalty, such as transportation of the special three-phase transformer. JICA Study Team will consider the optimal technological option in order to minimize construction cost and O&M cost.

CHAPTER 7

SITE CONDITION OF THE PROJECT ON LAND, MARINE AND CLIMATES

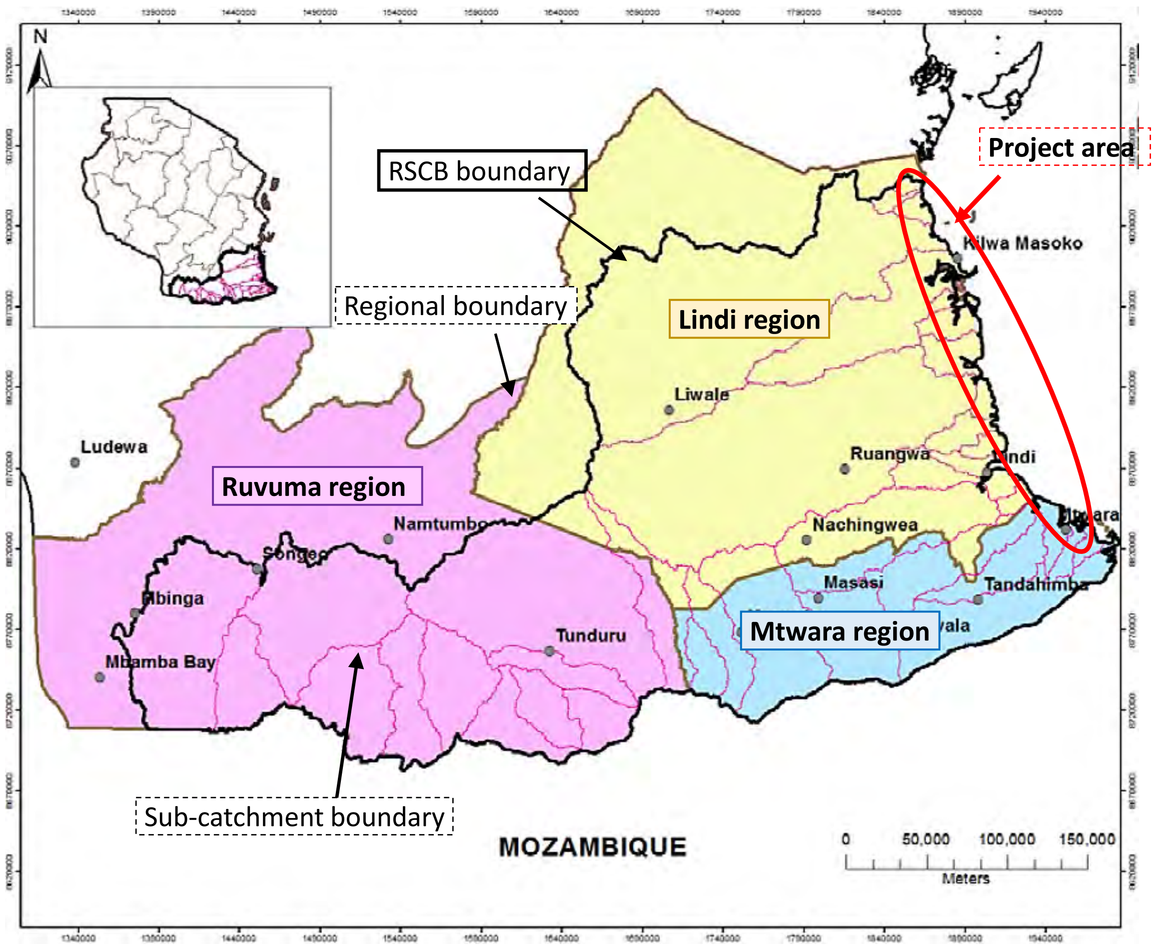
CHAPTER 7 SITE CONDITION OF THE PROJECT ON LAND, MARINE AND CLIMATES

7.1 TOPOGRAPHY

7.1.1 General Topographic Condition of the Project Area

The project area of the proposed Mtwara GTCC power plant, 400kV substations, and 400kV transmission lines is located at the coastal area of Mtwara region and Lindi region, between the Ruvuma River and Southern Coast Basin (RSCB) as shown in Figure 7-1. RSCB is underlain by deeply weathered sedimentary rocks and granites, and as a result, it is relatively flat. The main exception is the elevated sandstone plateau region, which stretches north-south through the eastern area of the Mtwara and Lindi regions, parallel to the Indian Ocean.

The northern part of the RSCB, within the Lindi region, is characterized by hilly, eroded terrain. Close to the coast, the elevation generally remains below 150 m. Several ocean gulfs, extending in to the lands, are also present in the area.



Source: JICA Study Team

Figure 7-1 Ruvuma River and Southern Coast Basin (RSCB) and Region Boundaries

The altitude of the Mtwara coastal area, where the proposed Mtwara GTCC power plant is located, ranges between 0 and 30 meters above the sea level. The undulating topography is made up of a coastal sedimentary zone with a large presence of limestone, with more sandy soils occurring along the coastline. The low-lying areas along the coast are especially vulnerable to flooding during the rainy season. Although the topography consists of rolling hills predominantly, there are a many steep slopes ranging between 11.31 and 18.43 degrees. These slopes will need to be taken into account, when the developmental areas and types are considered.

7.1.2 Topographic Survey of the Kisiwa Site

(1) General Topographic Condition of the Kisiwa Site

The planned 300MW class GTCC Power Plant, the New Mtwara Substation and their related facilities and utilities will be located in the north east part of the Kisiwa Region. The Kisiwa site is comprised of: a part of the shore terrace of the Mambi River, and the area in front of Kisiwa Bay (Sudi Creek). The site will have an area of 160 ha approximately.

As far as the topographic map is concerned, the terrain gradually ascends to the south, and at present, it is densely covered with various trees. It is a rolling terrain with an altitude between 0 to 30 meters above the sea level. The Site is sloping gently downward from south-east to north-west. Small shrubs are flourishing in the mountain site and mangrove forests are formed along the shoreline of the bay except for the tip of the cape which is a sand-covered coastline. The landscape of Kisiwa site is as shown in Figure 7-2.


Source: JICA Study Team

Figure 7-2 Current Landscape of Kisiwa Site

(2) Boundary of Kisiwa Site

The boundary of Kisiwa site was mutually agreed between the Mtwara RAS and TANESCO, it has the following conditions.

a) Along the seashore, the boundary for the power plant area needs to be set at 60 meters away from the high tide level considering the buffering zone

b) On the hill side, the boundary line is defined by connecting the boundary beacons, which have been installed

c) The boundary on the northern and the eastern side will need to be setback by 15 meters for the future road; TANESCO will be responsible for the road development of 15 m width, and the adjacent developer will be responsible for the other half of 15m.

(3) Procedure of the Topographic Survey

Based on the above consideration, it is difficult to conduct a conventional topographic survey due to the cost and time. JICA Study Team decided to conduct a topographic survey using satellite photography.

The work comprises ground survey and production of topographic maps of scale 1:2,500 for an area of approximately 3km^2, covering the Kisiwa site. The survey area is as shown in Figure 7-3.

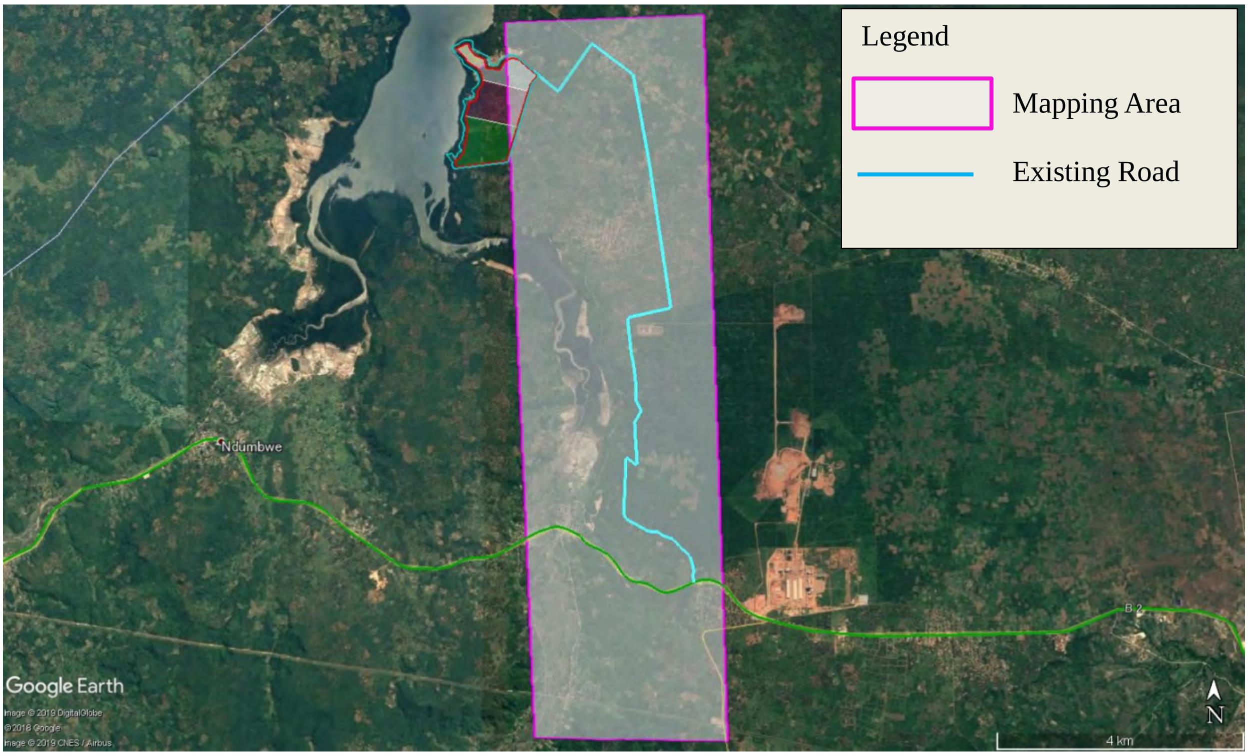
A topographic map, which covers the Kisiwa site, is newly created based on the Digital Elevation Models (DEMs), for which the satellite images were obtained by World View-1 to 3 and Geo Eye-1. The captured area of the satellite image is shown in Figure 7-3 and the topographic mapping specification of the project site is shown in Table 7-1.

In order to improve the accuracy of topographic map of the Kisiwa site, some Ground Control Points (GCPs) were set in the Kisiwa site and a field topographic survey of those points were conducted at the coordinates and elevation. Additionally, in case of certain terrain, which cannot be read from the satellite images, the corrections were made based on the pictures that were taken at the site.

Source: JICA Study Team

Figure 7-3 Topographic Survey of Kisiwa Site

In addition to Kisiwa site, another topographic map is also created by the same method, in order to study the feasibility of additional infrastructures such as access road, gas pipeline and water pipeline. The mapping area is shown in Figure 7-4.



Source: JICA Study Team

Figure 7-4 Topographic Survey of Additional Infrastructures

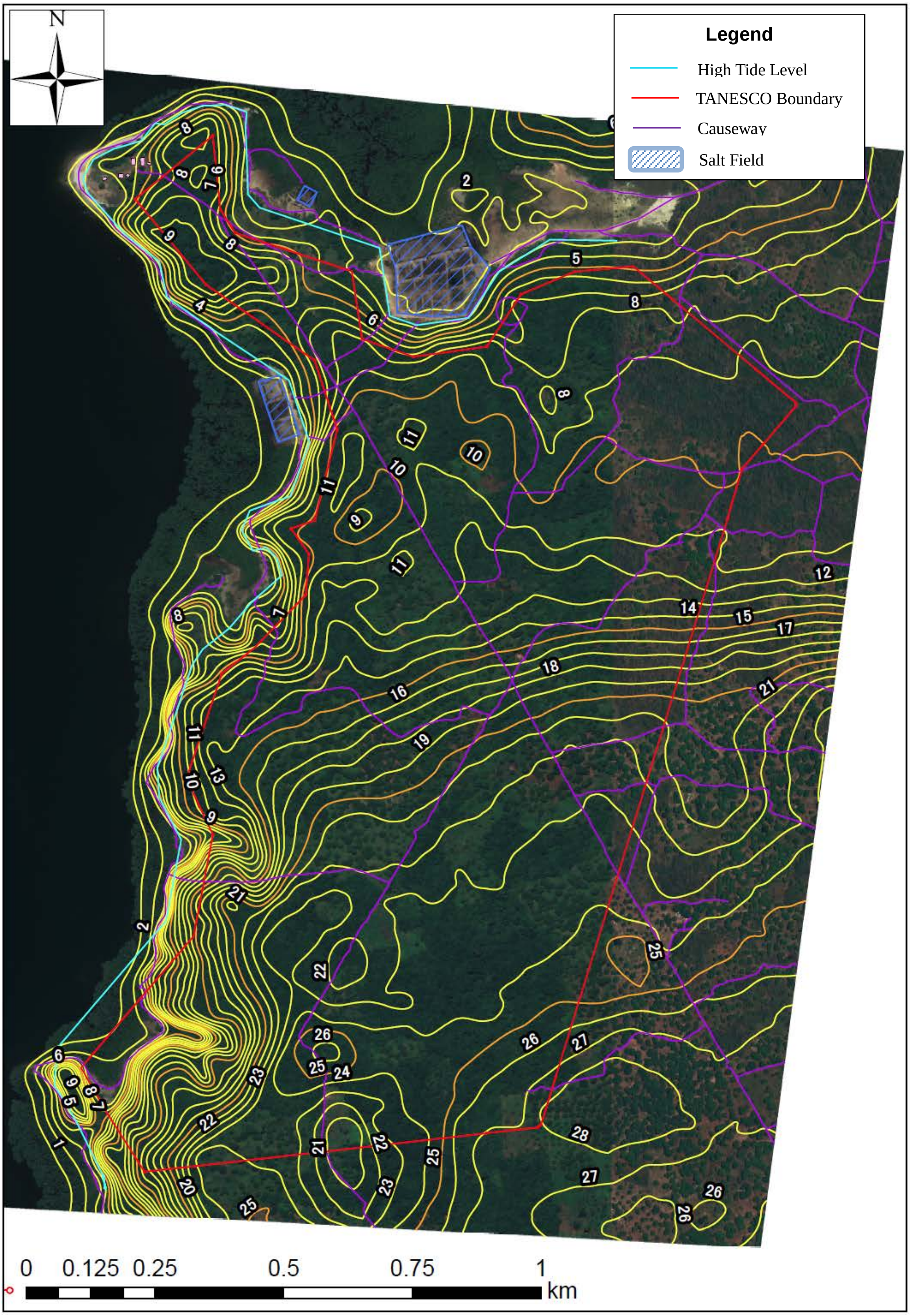
(4) Topographic Map by Satellite Image

Results of the field topographic survey are reflected in the topographic map and is shown Table 7-1 and Figure 7-5 and Figure 7-6, as the final result of topographic survey.

Table 7-1 Specification of Topographic Mapping of Kisiwa Site

No	Product	Purpose of Use	Details	Source
1	Ortho-rectified imagery	Base map to understand the current condition of the area	Seamless mosaic pan-sharpened; Resolution: 50cm; Band: 3 bands true color Captured area: 3km^2 Geographic coordinate system: WGS84	WorldView-2
2	Topographic Data (Digital Terrain Model)	To create contour line	Resolution: 1m	WorldView-1, WorldView-2, WorldView-3, GeoEye-1
3	Terrestrial objects	To integrate into topographic map	Extracted based on extraction criterion (see Table 5 for details)	Ortho-rectified imagery of Product #1
4	Topographic Map	To integrate all data and information into topographic map	Contour interval: 1m	Topographic Data

Source: JICA Study Team



Source: JICA Study Team

Figure 7-5 Topographic Map of Kisiwa Site

Source: JICA Study Team

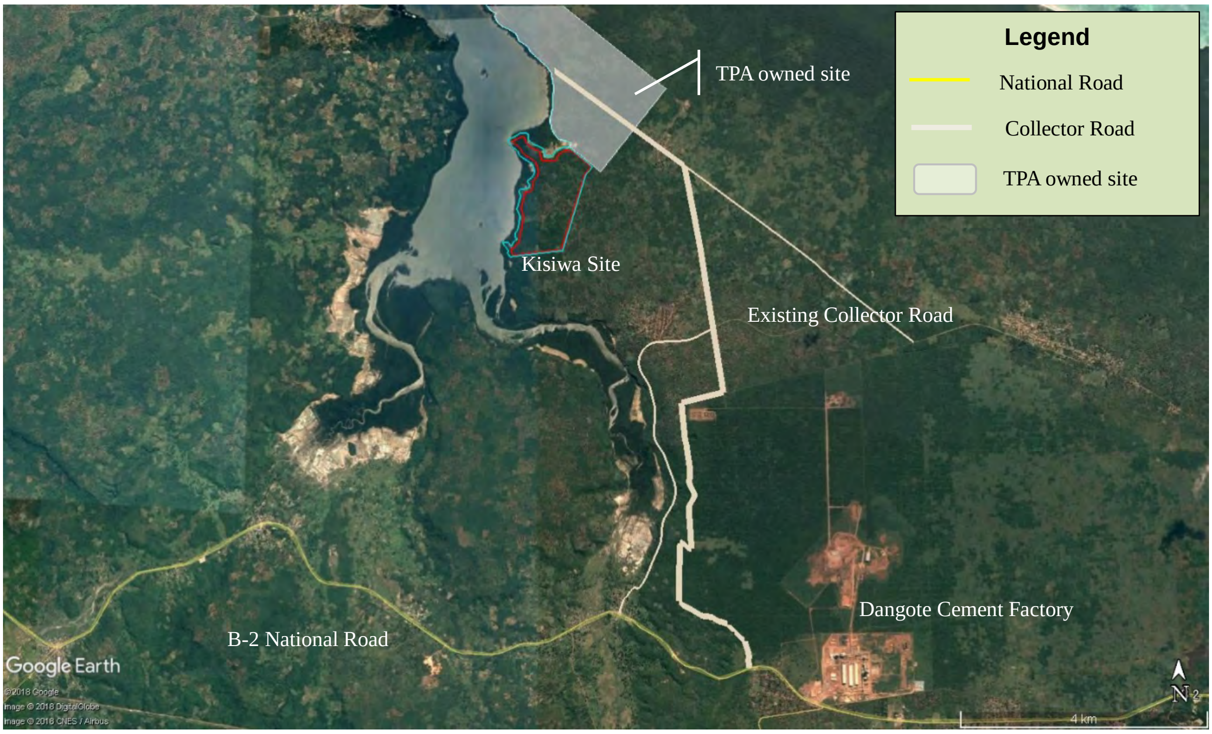
Figure 7-6 Topographic Map of Area around Kisiwa Site

(5) Site Boundary and the Areas Adjacent to the Kisiwa Site

The boundary of Kisiwa site, planned to be owned by TANESCO, is indicated with a red line in Figure 7-5, and TANESCO and Mtwara RAS have mutually agreed upon it. The boundary along the seashore is defined at a setback distance (60 meters) from high tide level. The boundary on the hill side is defined by boundary beacons, and the boundary beacons have been placed to facilitate the construction of boundary ring road of 30 meters width in the future. TANESCO has a plan to develop the Kisiwa site as a power complex in the future.

The site, owned by the Tanzania Ports Authority (TPA), is adjacent to the northern area of Kisiwa site, and it has mangrove forests and abdicated salt fields. The area adjacent to the eastern side of Kisiwa site is planned to be zoned as a residential area in the future.

The Kisiwa site can be accessed through the national road (B-2), which branches near the Dangote Cement factory, and the unpaved roads, which are used by local residents and are used for the transportation of cashew nut. Then, the narrow road, which diverges from the cashew nut collector road and which is being used by local fishermen, reaches the Kisiwa site through the deserted salt fields, which spreads across a long distance of 700 meters approximately.



Source: JICA Study Team

Figure 7-7 Area Adjacent to Kisiwa Site

7.1.3 Topographic and Adjacent Areas of Lindi

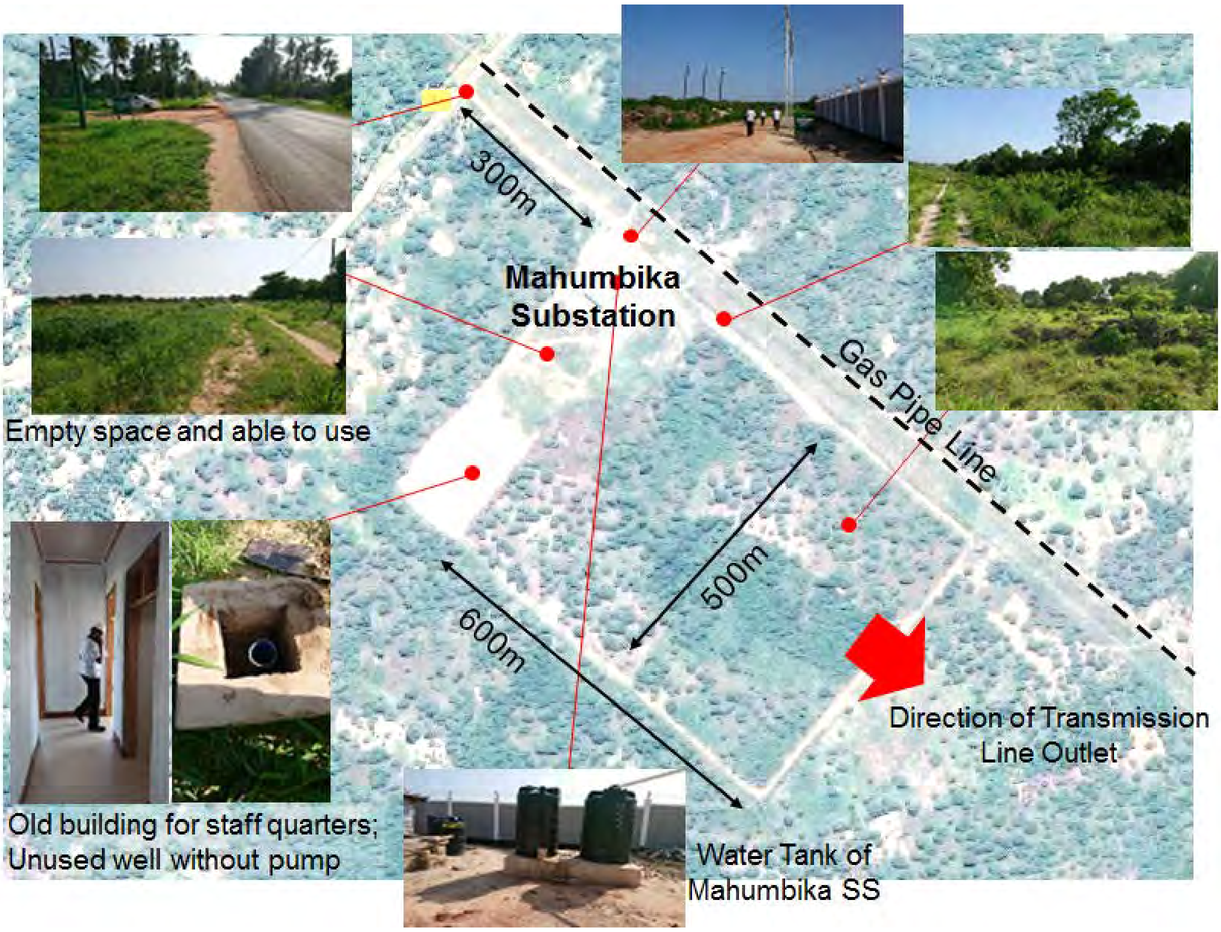
The site for 400kV New Lindi Substation was selected from three (3) candidates from the viewpoint of engineering and surrounding environment as previously described in the Chapter 6. General topographic condition of Lindi is described in Chapter 6, with focus on the area near the 132kV Mahumbika Substation site.

The site for the New Lindi Substation is located to the south of the intersection of national road (B-5) from Lindi to Masasi and the gas pipe line from Mtwara to Dar es Salaam as shown in Figure 7-8, and the 132/33kV Mahumbika Substation is in operation at the northern part of the site. The residential houses are being developed along the national road (B-5) on the western neighborhood of the New Lindi Substation site.

Source: JICA Study Team

Figure 7-8 New Lindi Substation Boundary and Adjacent Areas

Current topographic condition and the landscape of the site is shown in Figure 7-9. The site is mostly a flat landscape and is covered by small shrubs, except the area of the 132kV Mahumbika Substation. It is not necessary to consider the additional effects of sea breeze and soot / dust, since the site of 400kV New Lindi Substation is sufficiently away from the sea (approximately 15 km) and there are no factories around it. However, according to IEC/TS 60815-1, a substation, which can withstand Very Heavy pollution levels, is installed in Tanzania due to dust and low precipitation during dry season.



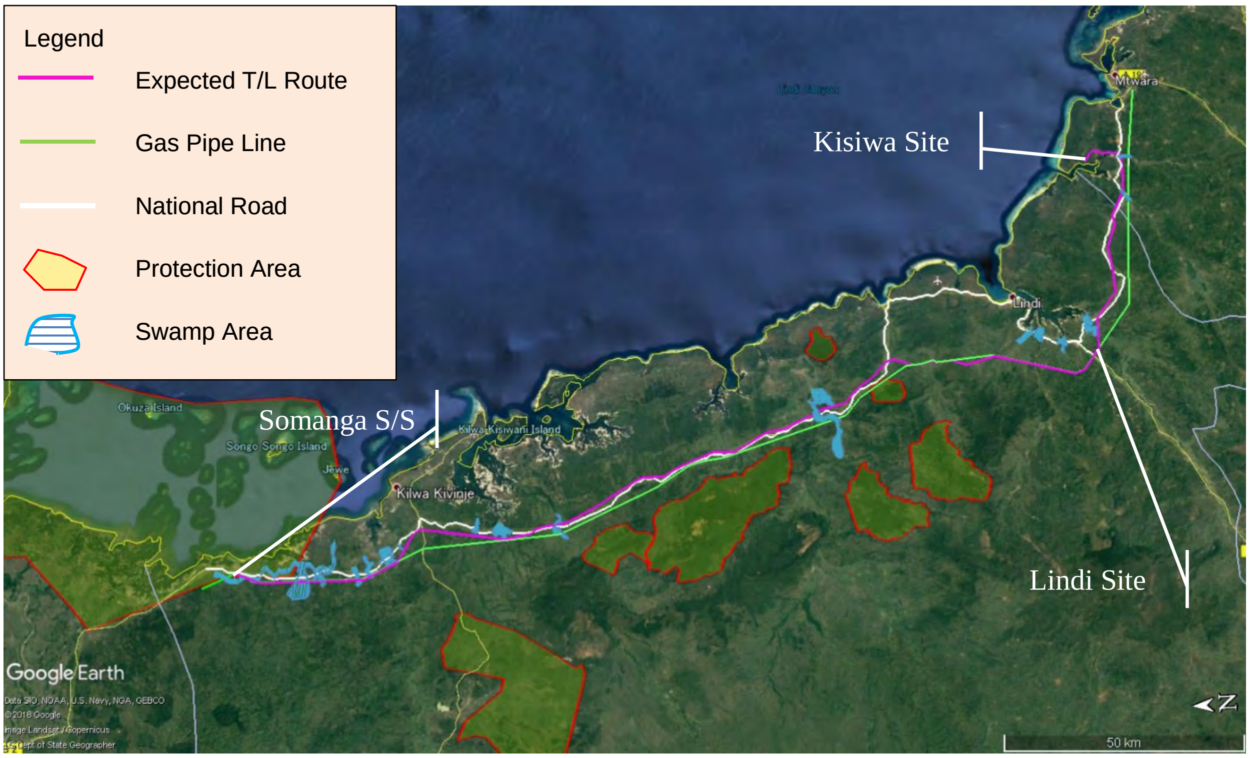
Source: JICA Study Team

Figure 7-9 Current Landscapes of the Lindi Site

7.1.4 General Topographic Condition of Transmission Line

The outline of the proposed route for the 400kV transmission line, between Mtwara and Somanga of about 270 km, is shown in Figure 7-10. Most sections of the route are expected to run close to the major roads between Mtwara and Somanga. The route has a gentle topography without high and/or steep mountains, but there are swamp areas on the expected route of the transmission line, and it also passes close to the protected areas (Figure 7-11).

In addition, a part of the 400kV Somanga Substation Site is located in the protected area of Rufiji-Mafia-Kilwa Ramsar convention. The detailed layout of the 400kV Somanga Substation hasn't been decided yet, therefore when the Detailed Design (DD) is carried out, it is necessary to consider the direction from which the transmission line is connected to the substation and coordinate these matters with TANESCO from the aspect of environment.



Source: JICA Study Team

Figure 7-10 Outline of Transmission Line Route

Condition of swamp (dry season)

Condition of a road

Source: JICA Study Team

Figure 7-11 Current Typical Landscapes of Transmission Line Route

7.2 OCEANOGRAPHY NEAR KISIWA SITE

7.2.1 General Conditions of Shoreline and Offshore

(1) Condition of Shoreline

The undulating topography is made up of a coastal sedimentary zone with a large presence of limestone with sandy soils occurring along the coastline in the Kisiwa site.

The elevated part at the northwestern end of the site is at an altitude of 0 m to 8 m, and it has salt fields scattered in the surroundings, and the sandy beach is used by fishermen for mooring the ship. Mangrove forests along the seashore of the southern area forms a coastal terrace with a height of about 3 meters as shown in Figure 7-12. Mangrove forests are flourishing between coastal line and the high tide level along the shoreline of the Kisiwa site

In accordance with RAS, the areas of salt fields and mangrove forests might be usable for water intake and discharge structures, if the permission of National Environment Management Council (NEMC) can be obtained.

Source: JICA Study Team

Figure 7-12 Coastal Terrace along the Kisiwa Site

(2) Condition of Offshore

During the rainy season, the Mambi River and the Mbuo River have flowed from the upstream of the Kisiwa Bay, but in the dry season there is little inflow from both the rivers.

Seawater with a depth of 2 to 4m continues along the coastline, except for some parts of the offshore sandy beach, located at the northwest end of the Kisiwa site. The seawater seems to be transparent for about 1 m depth.

The tidal current in the Kisiwa Bay was moderate at normal times and was estimated to be about 0 to 0.3 m/s, and the wave height was about 0.5 m to 1 m. There are small islands where mangroves grow, and the islands are submerged during a high tide in the bay.

JICA Study Team did not observe any jellyfish at the end of July, but many jellyfish with 10 to 15 cm diameter were observed in the middle of December. It is presumed that the presence of jellyfish increases during the rainy season, from December to April.

There were a few drifting objects such as floating trash and tree branches. Local fishermen's catch was mainly small fish and crab.

Source: JICA Study Team

Figure 7-13 View of Kisiwa Site from the Kisiwa Bay and Jellyfish on the Beach

7.2.2 Seawater Level

The parameters of the astronomical tide to be considered are the heights of datum level, mean sea level, mean spring high water level and mean spring low water level.

The tide levels referred above are defined as follows,

(1) Mean Sea Level (MSL)
The level of the average sea surface during a certain period shall be referred to as the Mean Sea Level during the period. For practical use, the Mean Sea Level shall be the average sea level of one year.

(2) Chart Datum Level (CDL)
It is the datum level of charts, and is determined as the water level below the mean sea level obtained by the sum of tide amplitudes of the four major tide constituents: M2, S2, K1 and O1.

(3) Mean High Water Springs (MHWS)
Mean water level of the monthly highest water levels appearing within five days from the day of new moon and full moon of the respective months.

(4) Mean Low Water Springs (MLWS)
Mean water level of the monthly lowest water levels appearing within five days from the day of new and full moons of the respective months.

(5) Highest Astronomical Tide (HAT)
For each inspection tide, the highest tide level recorded during the period from the start of observation of the tide level till present

(6) Lowest Astronomical Tide (LAT)
For each inspection tide, the lowest tide level recorded during the period from the start of observation of the tide level till present

Following is a record of tidal level at Mtwara Port that is provided by TPA.

Highest Astronomical Tide (HAT)	4.1 m
Mean High Water Springs (MHWS)	3.6 m
Mean High Water Neaps (MHWN)	2.6 m
Mean Sea Level (MSL)	2.0 m
Mean Low Water Neaps (MLWN)	1.4 m
Mean Low Water Springs (MLWS)	0.4 m
Lowest Astronomical Tide (LAT)	0.0 m

7.2.3 Seawater Temperature

Seawater temperature that was observed by JICA Study Team in September 2017 is shown in Table 7-3 in combination with other indicators related to seawater.

Normally, seawater temperature is lower than the ambient temperature, but it was found that seawater temperature is higher than ambient temperature during the actual site confirmation on 15 December, 2017 as indicated in Table 7-2. This means that heat absorption from the sun exceeds the radiation heat of the atmosphere.

Table 7-2 Result of Seawater Temperature Measurement

No.	Coordinates (Zone 37L)		Time	Ambient temp. (°C)	Seawater temp (°C) Depth				
	E	S			1 m	2 m	3 m	4 m	7 m
1	608088	8874302	11:20	28.0	30.5	30.0	30.0	29.5	29.5
2	608112	8874328	11:38	28.0	31.0	–	–	–	30.0
3	608413	8875058	12:06	28.0	30.0	30.0	30.0	29.0	–
4	608304	8874667	12:21	28.0	31.0	30.0	30.0	–	–

Source: JICA Study Team, measured in December in 2017 (rainy season)

7.2.4 Sea Water Quality

The proposed Mtwara power plant is located close to the Kisiwa Bay (Sudi creek) in Mtwara district. Sea water quality measurement was conducted at three locations in this creek (Mgao, Kisiwa, Namgogori) in September 2017, during the dry season. The measurement locations are as shown in Figure 7-14.

The physico-chemical parameters involved in the seawater monitoring are: in-situ measurements of pH, Dissolved Oxygen (DO), temperature and salinity, and collection of water samples using a Niskin bottle for subsequent laboratory measurements. The physical conditions of the sea water at three locations in the Kisiwa Bay are as shown in Table 7-3.

The result of laboratory measurements of the sampled sea water is as shown in Table 7-4.

Source: JICA Study Team

Figure 7-14 Three Locations for Sea Water Sampling in Kisiwa Bay (Mgao, Kisiwa, Namgogori)

Table 7-3 Physical Condition of Sea Water in Kisiwa Bay (Mgao, Kisiwa, Namgogori)

Site (sampling depth from the surface)	Temperature degree C	Salinity ‰	DO mg/l	pH	Conductivity ms/cm^3
Namgogori (1m)	28.03	36.98	2.76	8.44	55.84
Namgogori (5m)	27.98	37.03	2.90	8.44	55.88
Kisiwa (1m)	27.80	36.75	3.45	8.49	55.51
Kisiwa (5m)	27.70	36.83	2.97	8.47	55.62
Mgao (1m)	27.59	36.43	3.11	8.31	55.09
Mgao (5m)	27.54	36.42	2.96	8.47	55.07

Source: JICA Study Team, measured in September in 2017 (dry season)

Table 7-4 Sea Water Quality at the Three Locations in Kisiwa Bay (Mgao, Kisiwa, Namgogori)

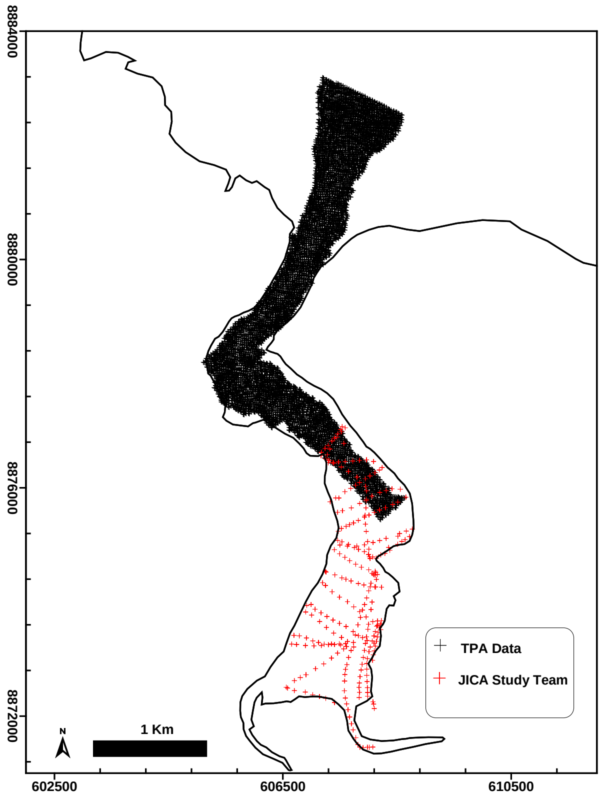
Site (sampling depth from the surface)	Chlorophyll	TSS	Oil and Grease	COD	Free Chlorine	Mineral Oil and Grease	Total colliforms	Fecal colliforms	E-Coli
	ug/ml	g/l	mg/l	mg/l	mg/l	mg/l	cfu/100ml	cfu/100ml	cfu/100ml
Namgogori (1m)	0.267	0.0304	0.090	328.8	0.60	0.085	19	N.D	N.D
Namgogori (5m)	0.255	0.0310	0.201	328.3	0.58	0.185	22	10	3
Kisiwa (1m)	0.243	0.0298	0.020	419.5	0.88	0.015	N.D	N.D	N.D
Kisiwa (5m)	0.256	0.0285	2.053	729.6	1.16	1.845	12	5	2
Mgao (1m)	0.233	0.0308	0.489	328.8	0.60	0.665	11	N.D	N.D
Mgao (5m)	0.277	0.0290	1.192	255.4	0.62	1.065	14	3	N.D

Note: N.D = Not detected

Source: JICA Study Team, measured in September in 2017 (dry season)

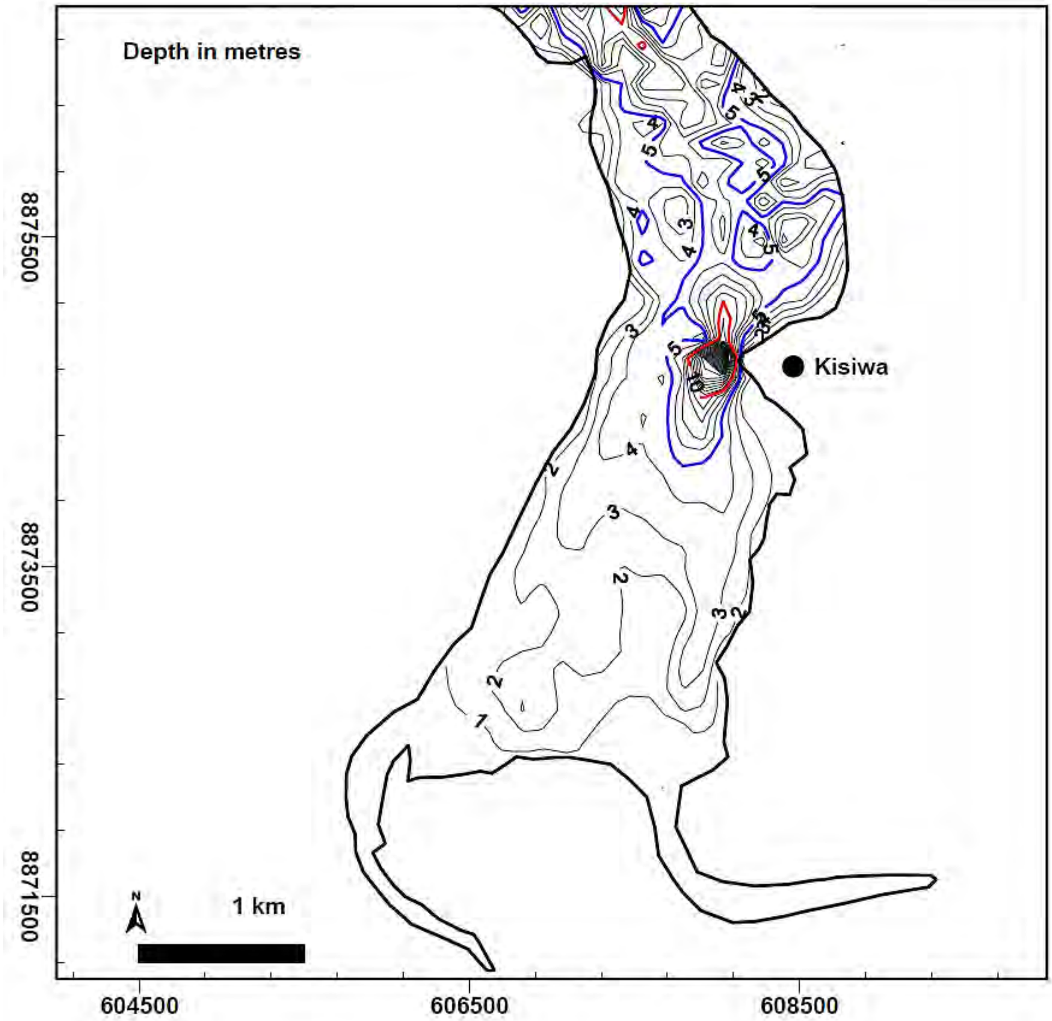
7.2.5 Bathymetry Survey (Kisiwa Bay)

The bathymetric survey was undertaken for the area of the tidal creek that was not previously surveyed by the TPA as shown in Figure 7-15. The sounding measurements were conducted using a hand-held echo sounder, held along evenly spaced sounding lines (designed to cross the channel). The distance between the sounding lines was about 50m and the distance between sounding points along each transect was about 25m or less. The positions of the sounding points were recorded using a hand-held GPS, where the depth, geographic position and time were recorded simultaneously to allow subsequent correction of the data for the tides. Based on the result of the bathymetric survey, the sea bottom topography of the southern parts of Kisiwa Bay is shown in Figure 7-16.



Source: JICA Study Team

Figure 7-15 Kisiwa Bay Sounding Points measured by TPA (black symbols) and JICA Study Team (red symbols)



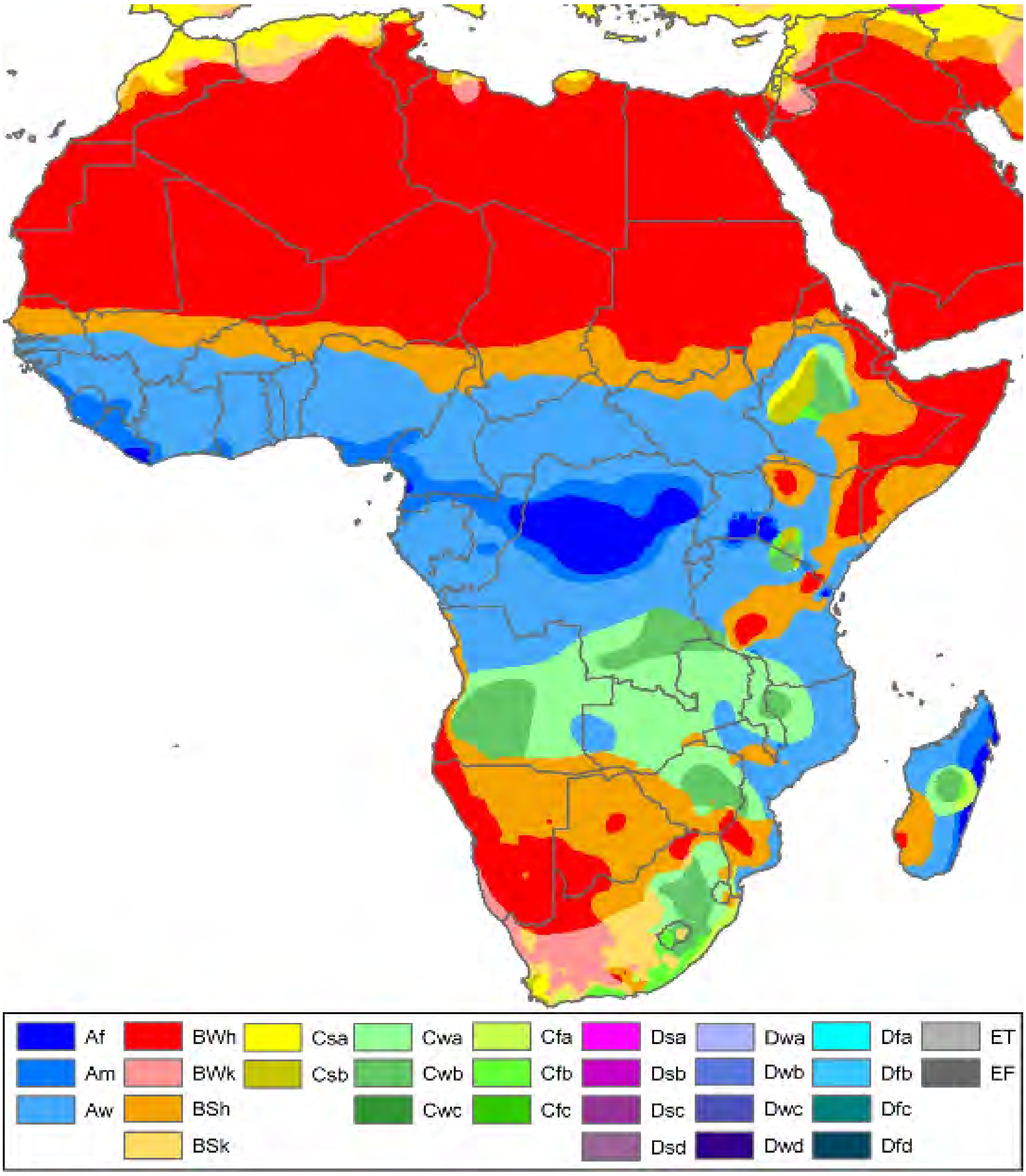
Note that the 5 and 10 m contours are indicated in blue and red colors, respectively. Source: JICA Study Team

Figure 7-16 Sea Bottom Topography of the Southern Parts of Kisiwa Bay

7.3 METEOROLOGY AND CLIMATE

7.3.1 General Meteorology of Tanzania

The climate of Mtwara and the other project area are categorized as tropical savanna climate (Aw) by the Koppen-Geiger climate classification as shown in Figure 7-17. This climate zone (Aw) indicates that the region has tropical wet and dry climate, with a precipitation- less than 60 mm (2.4 in) during the driest month, and of a total annual precipitation- less than 4%. The period between January and April has a good deal of rainfall, and the period between June and December has very little rainfall. The average annual temperature in Dar es Salaam is 26.2°C. The annual precipitation is about 1,089 mm.



Source: Hydrology and Earth System Sciences: "Updated world map of the Köppen-Geiger climate classification"

Figure 7-17 Koppen-Geiger Climate Classification of Africa

The meteorological information of Kisiwa site was obtained from the data of the Mtwara meteorological observation station (Latitude 10°21', Longitude 40°11', Altitude 370 FT/113), located near the Mtwara airport. This data was provided by Tanzania Meteorological Agency (TMA). However, the quantity of data is not sufficient to analyze and decide the basic design. In addition, documents and data were collected through the Internet and details are described below.

Source: JICA Study Team

Figure 7-18 Mtwara Meteorological Observation Station

7.3.2 Precipitation

(1) Record of Precipitation

JICA Study Team obtained meteorological data of Mtwara meteorological observation station for the years 2005 to 2016, however, data of daily and hourly precipitation are not available with TMA. Therefore, daily rainfall data for 2014 to 2016 was obtained through the website of Tutiempo Network, S.L (URL: https://en.tutiempo.net/climate), to complement the existing data.

The rainfall in Mtwara is concentrated from November/December to April/May as shown in the Figure 7-19, accounting for about 70% of total annual rainfall. The rainfall is at its peak in January, however, it may occasionally be at its peak in February or March. The amount of total annual precipitation tends to vary with altitude. Especially, it rarely rains from June to September in this region. Annual maximum rainfall is 1,406.5 mm, recorded in the year 2006, and the minimum is 643.6 mm, recorded in 2012. Monthly maximum rainfall is 505.5 mm, recorded in January, 2013; and minimum is 0 mm, recorded in June and July 2009 and July 2016. The average rainfall is between 800mm to 1,100 mm per annum.

In the Mtwara Master Plan 2015-2035, the following is described; “there is a significant amount of rainfall experienced once in every 10 years, where a rainfall of approximately 155mm per hour is experienced. These storms, however, do not last very long and within one hour of the start of the storm, only 65mm rain per hour is experienced” and “(a) significant rainfall intensity once in every two years where approximately 110mm rainfall per hour is experienced at the beginning of the storm, and approximately 45mm rain after 1 hour”.

Based on information from TMA head office, the historical record of extreme rainfall for Mtwara are as shown in Table 7-6. In the case of December 2017, the Mtwara town was flooded.

Table 7-5 Total Monthly Rainfall Data

(Unit: mm, TR : Trace Rainfall less than 0.05mm)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2005	187.1	50.8	224.5	107.8	116	2.6	0.1	TR	15.1	8.8	1.4	39.6	753.8
2006	109.2	168.5	251.4	256.9	78.9	13	42	55	7.1	51.5	62	311	1406.5
2007	50.8	232	122.8	193.3	29.8	3.3	12	17.1	20.5	41.2	13.5	17.1	753.4
2008	200.4	234.7	200.2	156	35.8	22	2.9	0.4	10.3	150	45.6	72.2	1130.5
2009	14.9	332	173.4	65.5	56.4	0	0	7.9	0.6	40.2	33.3	75.6	799.8
2010	168.2	310.1	203.3	339	95.3	12	1.8	2	0.9	4.5	6.9	86.2	1230.2
2011	35.4	371.6	187.8	194.6	98.5	35	2.7	0.8	38.6	13.8	91.9	154	1224.7
2012	179.7	78.9	165.4	70.1	54.8	6.3	14.3	3.9	1.2	15.1	9.8	44.1	643.6
2013	505.5	60.6	327.1	45.5	15.9	0.6	1.7	TR	36.2	4.4	22.6	136.5	1156.6
2014	65.9	304.6	239.7	194.7	32.0	13.2	0.4	3.3	5.9	0.5	80.5	113.0	1053.7
2015	321.8	96.4	303.3	63.0	86.3	0.8	4.0	1.1	0.2	20.2	35.7	139.3	1072.1
2016	494.1	230.8	274.3	282.4	5.0	3.5	0.0	0.2	7.0	42.8	14.3	23.1	1377.5
Mean	194.4	205.9	222.8	164.1	58.7	9.4	6.8	7.6	12.0	32.8	34.8	101.0	1050.2

Source: Tanzania Meteorological Agency

Table 7-6 Historical Record of Extreme Rainfall in Mtwara (1953-2017)

	Amount of precipitation in 24 hours	Date
1st	232.7mm (in 24hrs)	26/March/1978
2nd	210.8mm (in 24hrs)	27/March/1978
3rd	202.6mm (in 24hrs)	10/December/2017
4th	199.6mm (in 24hrs)	13/January/1953

Source: Tanzania Meteorological Agency

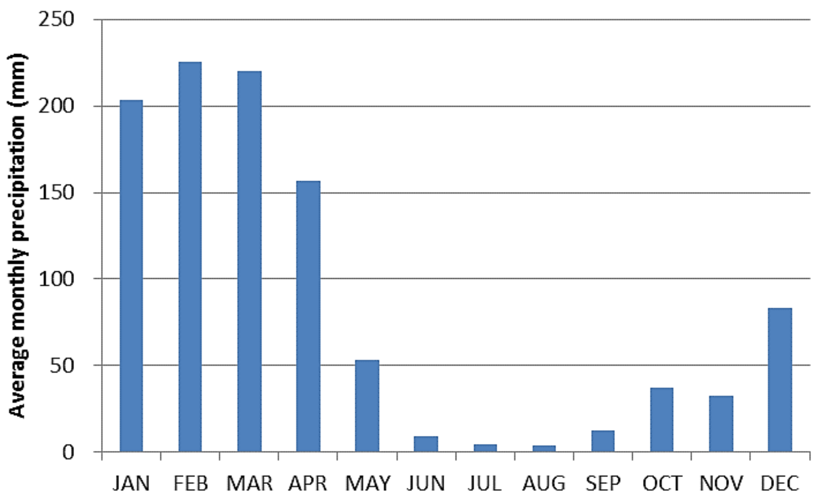


Figure 7-19 Average Monthly Precipitation at Mtwara Meteorological Station 2007-2016

Average monthly rainfall is calculated for the period between 2007 and 2016.

(2) Design Rainfall Intensity

Following the Design Guideline of Thermal and Nuclear Power Plant Civil Engineering Structures (Japan Electric Power Civil Engineering Association, 1996), design of drainage system of power generation site is done by applying 10-year rainfall probability and intensity. And the capacity of drainage facility is determined by runoff volume, which is estimated from catchment area, rainfall intensity and runoff factor.

Based on the daily precipitation data at Mtwara from 2012 to 2017 (Source: Tutiempo Network, S.L), rainfall probability (rainfall intensity) is calculated by Iwai's method, which is a statistical method using the rainfall records as shown in Table 7-7. The daily rainfall of 10 years return period is set as 252mm for the design.

Table 7-7 Probable Daily Maximum Rainfall at Mtwara

Period (Year)	Daily Rainfall (mm)
200	599.33
100	512.25
50	429.65
30	371.11
20	325.89
15	295.03
10	251.13
7	212.75
5	177.14
3	122.50
2	75.46

Source: JICA Study Team

7.3.3 Ambient Temperature

The data of highest and lowest ambient temperature for 5 years from 2014 to 2018 were available, and are shown below.

According to the observation results of the monthly average highest ambient temperature for 5 years, the average highest temperature is 32.4°C in April and the average lowest temperature is 18.3°C in August. The highest temperature of 33.6°C was recorded in April 2015, and the lowest temperature of 16.8°C was recorder in August 2016.

The highest and lowest yearly average of ambient temperatures in Mtwara are 31.0°C and 21.4°C. Therefore, the overall average temperature is 26.2°C.

Table 7-8 Monthly Average of Highest Ambient Temperature

(Unit:°C)

Year	2014	2015	2016	2017	2018	Average
Jan	31.4	30.1	31.0	30.7	31.4	30.9
Feb	30.9	30.1	29.0	30.5	31.4	30.4
Mar	31.1	31.6	31.8	29.9	32.2	31.3
Apr	32.4	33.6	32.4	33.2	30.5	32.4
May	30.5	31.3	30.8	31.1	31.0	30.9
Jun	30.0	30.6	30.4	30.3	31.0	30.5
Jul	30.5	30.6	30.0	28.6	30.6	30.0
Aug	31.9	30.6	30.4	30.6	30.9	30.9
Sep	30.7	30.2	30.5	29.4	29.0	30.0
Oct	31.6	31.1	30.5	31.7	30.4	31.1
Nov	33.0	31.5	31.0	32.2	30.9	31.7
Dec	30.4	30.1	32.1	31.9	33.5	31.6
Average	31.2	30.9	30.8	30.8	31.1	31.0

Source: Tanzania Meteorological Agency

Table 7-9 Monthly Average of Lowest Ambient Temperature

(Unit : °C)

Year	2014	2015	2016	2017	2018	Average
Jan	24.3	24.6	23.8	23.8	23.0	23.9
Feb	20.7	22.5	24.0	21.6	25.0	22.8
Mar	22.4	22.1	23.7	22.5	23.2	22.8
Apr	22.1	22.2	23.5	23.0	23.0	22.8
May	20.9	20.7	21.3	21.2	21.8	21.2
Jun	20.8	20.5	20.0	22.5	21.4	21.0
Jul	18.8	19.0	17.8	19.9	19.7	19.0
Aug	19.3	17.6	16.8	18.8	19.0	18.3
Sep	18.7	17.6	19.1	20.0	19.3	18.9
Oct	20.5	22.4	19.6	21.0	18.9	20.5
Nov	22.2	24.3	21.5	22.5	18.3	21.8
Dec	24.5	24.8	23.4	23.5	23.1	23.8
Average	21.2	21.5	21.2	21.7	21.3	21.4

Source: Tanzania Meteorological Agency

7.3.4 Relative Humidity

The data of the highest and lowest relative humidity for 10 years from 2007 to 2016 were available, and are shown below.

According to the observation results of monthly average highest relative humidity for 10 years, the average highest relative humidity is 96.4% in March, and the average lowest humidity is 50.6% in August. The highest relative humidity of 99% was recorded in July 2010, July and August 2011, and the lowest relative humidity of 45% was recorder in August 2009.

Relative humidity varies between 87 percent in March and 79 percent in October. Temperatures and humidity decrease inland.

Table 7-10 Monthly Average of Highest Relative Humidity

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
Jan	93	96	89	94	96	97	97	91	92	96	94.1
Feb	96	96	95	96	98	92	95	95	92	96	95.1
Mar	97	97	97	96	97	96	96	96	95	97	96.4
Apr	97	98	94	97	97	95	95	96	95	97	96.1
May	96	96	97	97	98	97	94	94	95	93	95.7
Jun	94	96	96	97	98	96	93	93	93	96	95.2
Jul	94	96	96	99	98	94	94	93	95	94	95.3
Aug	96	97	96	97	99	97	93	95	95	96	96.1
Sep	97	98	97	98	99	97	93	95	95	92	96.1
Oct	97	97	97	97	98	96	94	94	96	96	96.2
Nov	96	98	96	96	96	95	94	95	95	96	95.7
Dec	97	96	96	94	97	96	93	93	95	95	95.2
Mean	95.8	96.8	95.5	96.5	97.6	95.7	94.3	94.2	94.4	95.3	

Source: Tanzania Meteorological Agency

Table 7-11 Monthly Average of Lowest Humidity

(Unit: %)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
Jan	67	70	61	68	65	75	73	68	73	71	69.1
Feb	72	67	70	68	69	73	73	71	66	72	70.1
Mar	66	63	68	67	67	65	65	71	69	70	67.1
Apr	48	64	57	69	66	66	63	68	65	69	63.5
May	61	59	59	63	65	55	56	60	62	55	59.5
Jun	51	52	49	62	61	54	50	55	51	54	53.9
Jul	48	53	50	60	55	50	52	49	48	50	51.5
Aug	51	48	45	48	62	50	52	53	47	50	50.6
Sep	51	58	51	49	65	51	55	52	50	53	53.5
Oct	57	57	55	50	64	50	54	53	54	55	54.9
Nov	58	60	56	57	55	53	56	58	54	58	56.5
Dec	57	69	60	60	62	59	60	64	66	60	61.7
Mean	57.3	60.0	56.8	60.1	63.0	58.4	59.1	60.2	58.8	59.8	

Source: Tanzania Meteorological Agency

7.3.5 Wind

The predominant wind direction is from the south and the average wind speed varies between 10 and 20 knots (5.14 m/s to 10.28 m/s) per month.

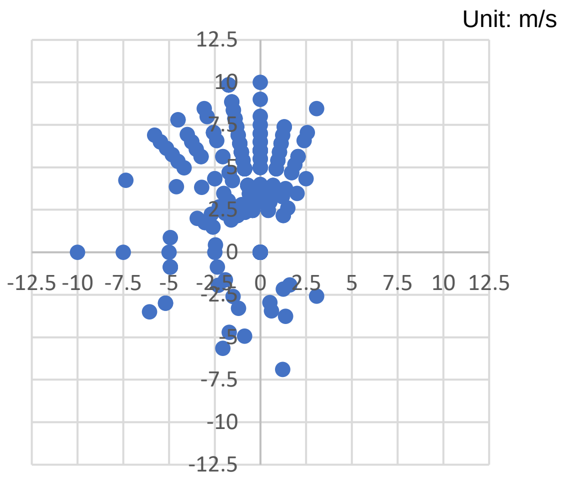
Based on the observation results of wind direction and wind speed of 3 hours intervals in the year of 2016, a diagram showing wind direction and frequency of wind speed (wind rose) is created as shown in Figure 7-20.

The wind direction is indicated by 36 directions, and is displayed at 10 degrees intervals as follows;
In January and February, winds from the northeast and northwest concentrate and the flow of wind from the south direction is very less.
In March, there is an even flow of winds from all directions.
From April to August, winds from the south and east are recorded mainly.
In September, the flow of wind from the west direction is less, the wind blows mainly from the east direction.
From October to December, the wind blows from the east and north.

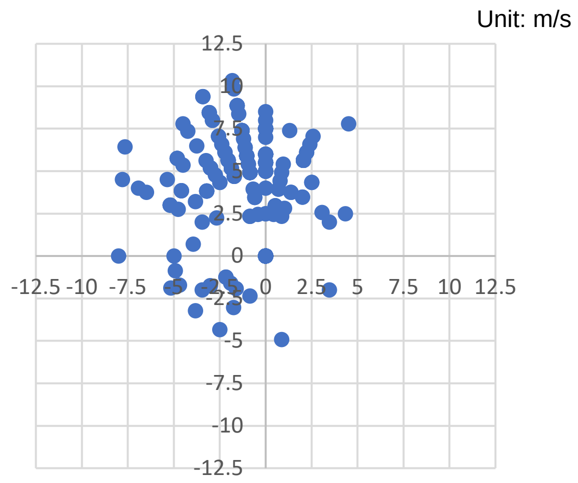
JICA Study Team can conclude that the wind from the north direction mainly blows in the rainy season, and the wind from the south direction mainly blows in the dry season.

The fastest wind speed throughout the year of 2015 was 25 knots (about 15.4 m/s) in February, but there was no cyclone in Mtwara district.

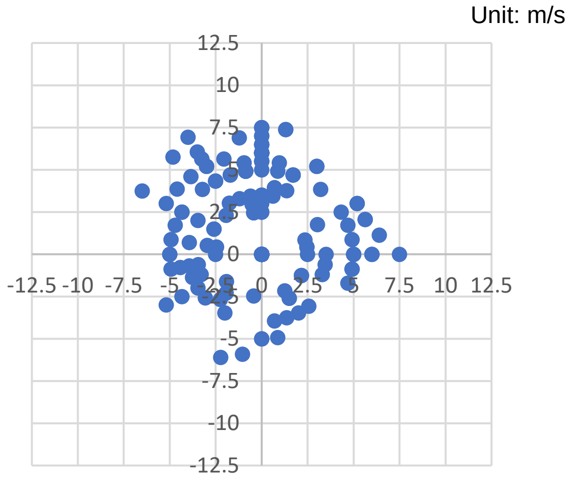
WIND SPEED AND DIRECTION in January 2016



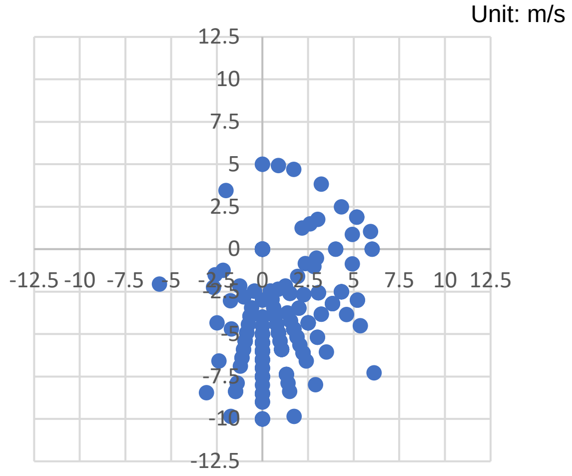
WIND SPEED AND DIRECTION in February 2016



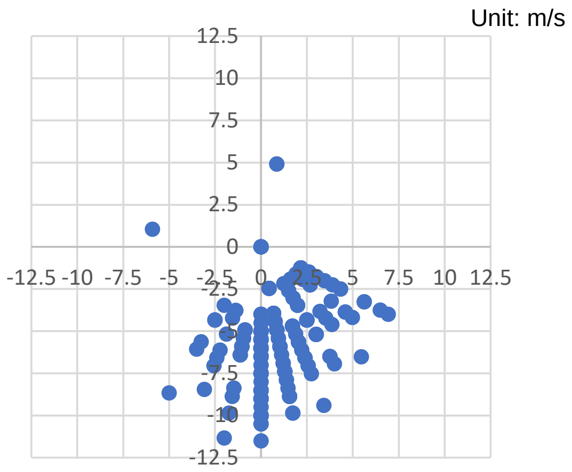
WIND SPEED AND DIRECTION in March 2016



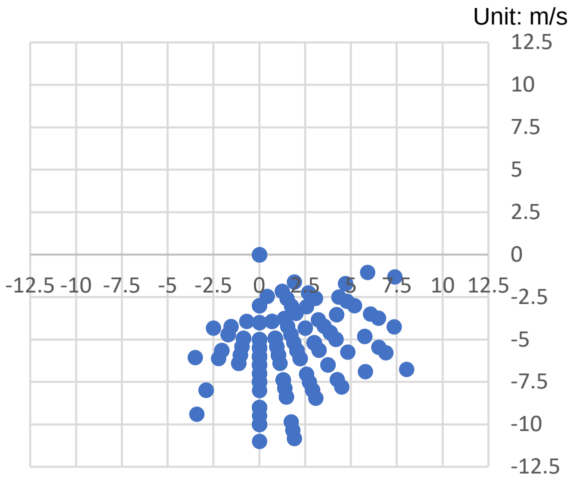
WIND SPEED AND DIRECTION in April 2016

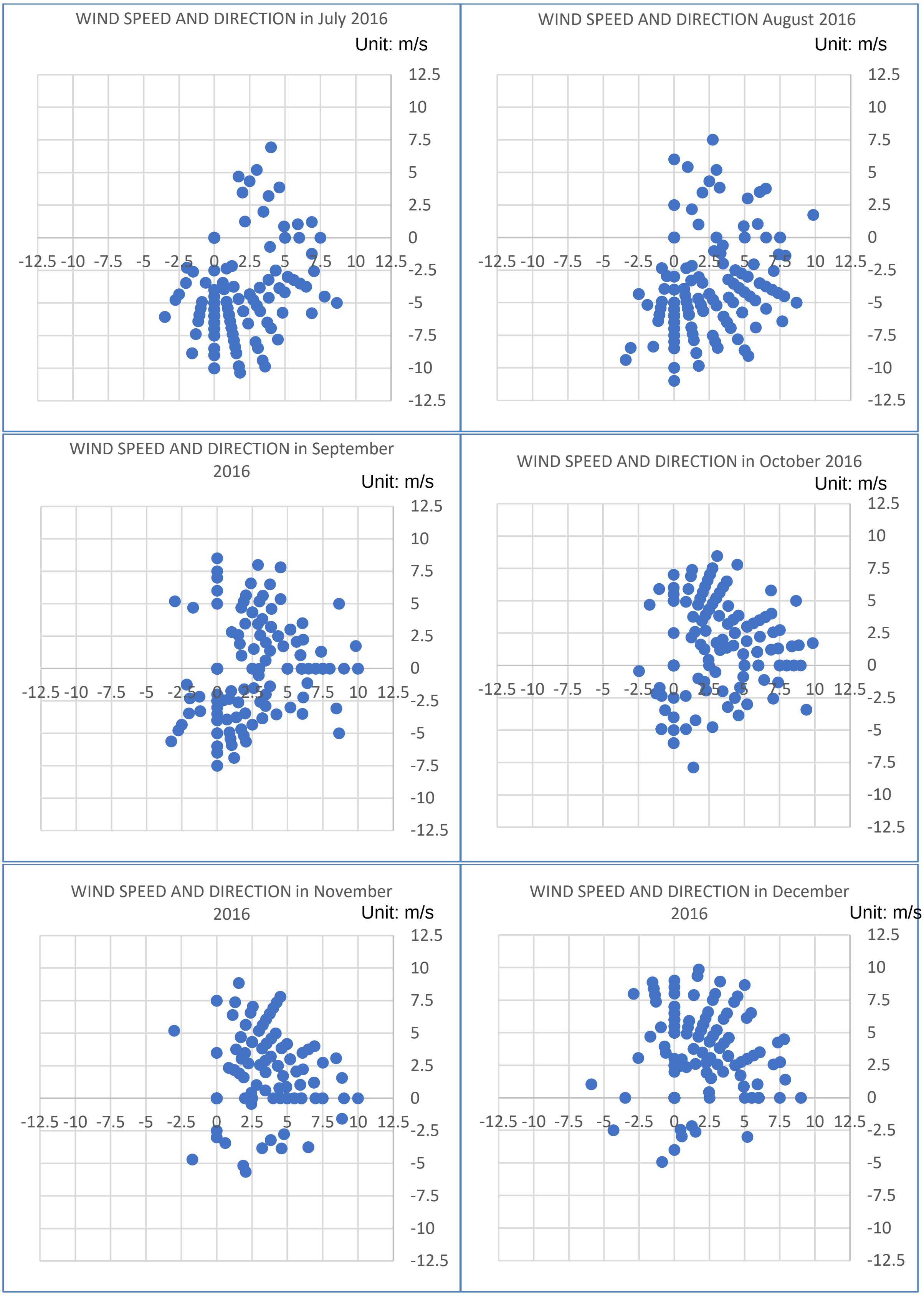


WIND SPEED AND DIRECTION in May 2016



WIND SPEED AND DIRECTION in June 2016





Source: Tanzania Meteorological Agency

Figure 7-20 Wind Speed and Directions

7.3.6 Future Climate

(1) Future climate:

Recent studies on climate change in Tanzania show that there will be an increase in extreme weather events, mainly associated with intense, frequent and unpredictable flooding, drought and tropical storms. Rainfall has also become scarce and unpredictable. According to the regional level climate change projections published by the TMA in 2015 and the Second National Communication (SNC) developed by the Vice President Office (VPO) in 2014, the projected changes in air temperature and rainfall in Mtwara and Lindi area for the year 2025 and 2050 are as shown in Table 7-12. In Mtwara and Lindi, the amount of rainfall in wet season is expected to increase both in 2025 and 2050, expecting the rising risk of flood in the flood prone areas.

Table 7-12 Projected Change in Temperature and Rainfall by 2050 in Mtwara and Lindi

	Season	Projected change by 2025	Projected change by 2050
Temperature change in degrees	Annual mean change	+ 0.64 degree (TMA,2015)	+1.39 to +1.62 degree (SNC, 2014) +1.71 degree (TMA,2015)
	Dec-Jan-Feb season	+0.64 to +0.67 degree (TMA,2015)	+1.45 to +1.56 degree (SNC, 2014) +1.43 to +1.45 degree (TMA,2015)
	Mar-Apr-May season	n/a	+1.45 to +1.60 degree (SNC, 2014)
	Jun-Jul-Aug season	n/a	+1.32 to +1.66 degree (SNC, 2014)
Rainfall change in %	Annual mean change	+1.1 % (TMA,2015)	-7.0 to +3.1% (SNC, 2014) -1.9 % (TMA,2015)
	Dec-Jan-Feb season	+3.6% (TMA,2015)	+6.7 to +9.9% (SNC, 2014) +8.1% (TMA,2015)
	Mar-Apr-May season	-1.3% (TMA,2015)	-0.5 to +4.2% (SNC, 2014) -2.9% (TMA,2015)
	Jun-Jul-Aug season	n/a	-10.3 to 7.2% (SNC, 2014)
	Sep-Oct-Nov season	-7.1% to -2.6% (TMA,2015)	-15.8% to -5.8% (TMA,2015)

Source: Climate Change Projections for Tanzania (Tanzania Meteorological Agency); TMA, 2015
The Second National Communication of Tanzania (Vice President Office); SNC, 2014

The projections of future climate for Tanzania suggest an intensification of seasonal rainfall – i.e. the wet season getting wetter and the dry season getting drier – and warmer temperatures across all seasons, which translate into an increase in Potential Evapotranspiration (PET). PET is expected to increase in the range of 2% to 5% in the 2020s and 2030s.

(2) Sea level and Sea water temperature change:

Along the coast of Tanzania, the only tide gauge station, which has long term records of sea level data, is the Zanzibar tide gauge. The sea level measurements from this tide gauge reveal that the long-term dataset is characterized by both annual and decadal variability[1].

The average sea level anomaly in the first phase (1984-1994) is about +21.37 mm above the long

1 Implementation of Concrete Adaptation Measures to Reduce Vulnerability of Livelihoods and Economy of Coastal Communities of Tanzania, Vice President's Office (VPO), 2016

term mean of 1984-2011. This phase is followed by a second phase (1994-2004) of low sea levels (mean anomaly = -20.08 mm), and later the high sea levels (mean anomaly = +25.08 mm) bounced back in the third phase (2004-2011) to a value slightly above the original level. This indicates that it is a two cyclic change, characterized by a declining sea level trend from 1984 to 2000, followed by a rising sea level trend after 2000. Analyses of the mean, maximum and minimum monthly sea surface temperature data are also characterized by rising trends, particularly during the warm season- December to April. According to Mwandosya[2], who assessed the vulnerability of Tanzanian coastline caused by sea level change, two sea-level rise scenarios of 0.5 m and 1.0 m have been assumed for a period of a century.

2 Mwandosya, M.J., Nyenzi, B.S. & Luhanga, M.L.(1998) The Assessment of Vulnerability and Adaptation to Climate Change Impacts. Centre for Energy, Environment, Science and Technology. Dar es Salaam

7.4 TERRESTRIAL NATURAL CONDITIONS

7.4.1 Natural Disasters

Because of the low land utilization rate of the project area including the Kisiwa site and the lower population density, natural disasters such as earthquake, cyclone, drought, extreme rainfall, lightning strike and flood have rarely been reported in the past.

According to EM-DAT, a disaster database, there are 41 events of natural disasters, (except for epidemic and insect infestation) which occurred in Tanzania in the past 20 years, and the list is shown in Table 7-13.

Table 7-13 History of Natural Disaster in Tanzania - Past 20 Years (1988-2017)

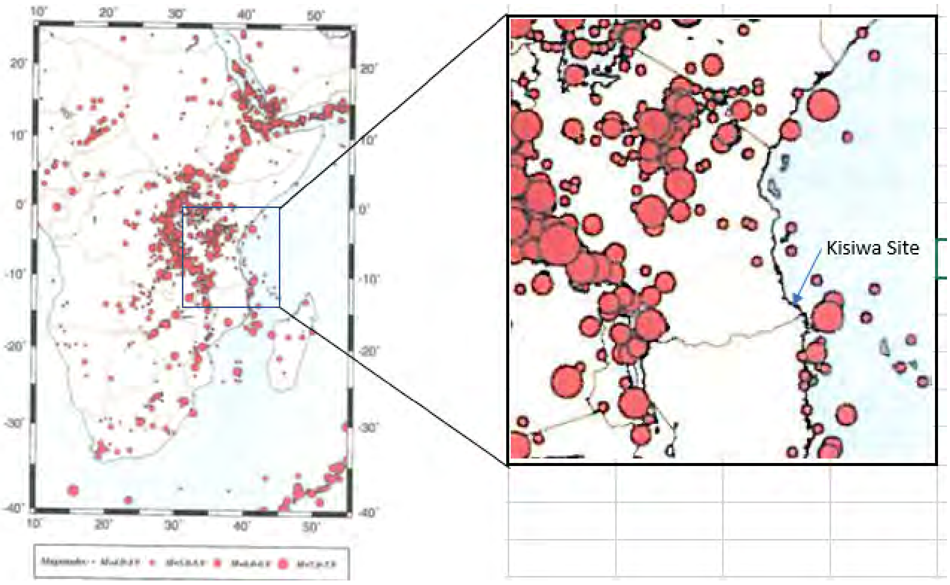
Year	Disaster type	Number of People					Total damage ('000 US$)
		Total deaths	Injured	Affected	Homeless	Total affected	
1988	Drought	0	0	11000	0	11,000	0
1988	Flood	0	0	6,500	0	6,500	0
1989	Flood	10		141,056		141,056	
1990	Flood	189		142,000	20,868	162,868	280
1991	Drought			800,000		800,000	
1993	Flood	54	30	201,513	280	201,823	3,510
1994	Flood	31			7,000	7,000	
1994	Storm	4			2,500	2,500	
1995	Flood	3		1,850	20,000	21,850	
1996	Drought			3,000,000		3,000,000	
1997	Flood	83		8,028	2,104	10,132	
1997	Wildfire						
1998	Flood	61		4,600		4,600	
2000	Earthquake	1	6	750	35	791	
2000	Flood	36	17		1,800	1,817	
2001	Earthquake				700	700	
2001	Flood	5			200	200	
2001	Landslide	13			150	150	
2002	Earthquake	2			2,000	2,000	
2002	Flood	9		1,200		1,200	
2003	Drought			1,900,000		1,900,000	
2003	Flood			2,000		2,000	
2004	Drought			254,000		254,000	
2004	Earthquake	10					
2005	Earthquake	2		5,000		5,000	
2005	Flood	1		10,548		10,548	
2006	Drought			3,700,000		3,700,000	
2006	Flood		28		21,500	21,528	
2008	Flood	73	15	7,500	1,942	9,457	
2008	Storm		7	670		677	
2009	Flood	38		50,000		50,000	
2009	Storm			605		605	
2011	Drought			1,000,000		1,000,000	
2011	Flood	37	200	59,000	6,776	65,976	
2012	Flood	10					
2014	Flood	31		40,000		40,000	2,000
2015	Flood	12			5,000	5,000	
2015	Storm	47	112	5,000		5,112	
2016	Earthquake	17	440	139,161		139,601	458,000
2016	Flood	16		126,342	13,933	140,275	
2017	Flood	7					

Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

(1) Seismic Condition

As confirmed at the Mtwara meteorological observation station, the official has not heard of any damage due to the occurrence of an earthquake, and there were no records concerning the earthquake.

Figure 7-21 shows the location of earthquakes with a magnitude 4.0 or higher, which occurred in Eastern Africa and South Africa between 627 and 1994. Earthquakes occurred frequently along the East Africa Rift Valley, but there is no record of earthquake occurring around the Kisiwa site.



Source: Seismic Hazard assessment in Eastern and Southern Africa 1999

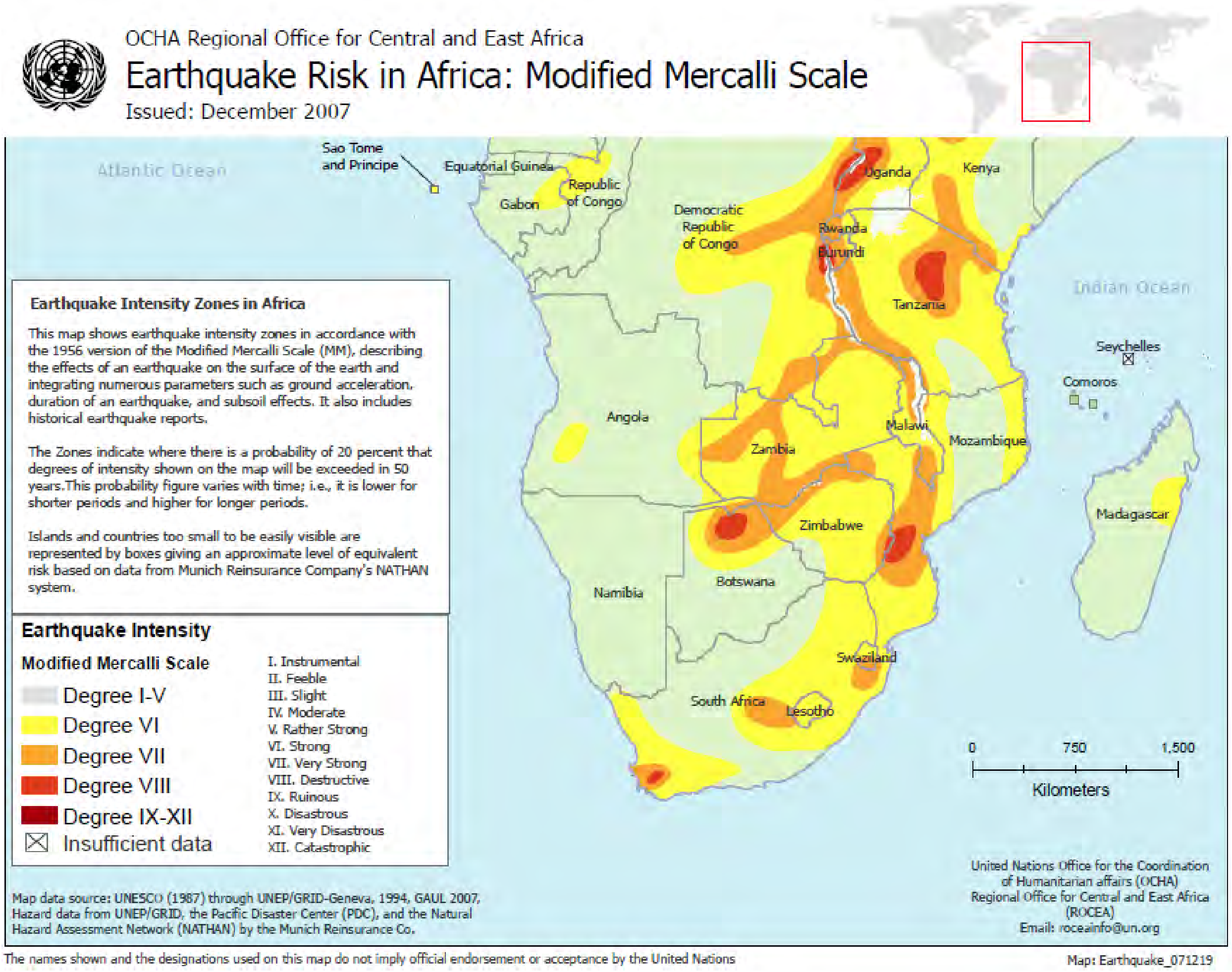
Figure 7-21 Seismic Hazard Record of East and South Africa

Africa's seismic hazard map is shown in Figure 7-22. This was created by the Office for the Coordination of Humanitarian Affairs (OCHA), regional office for Central and East Africa. According to the map, Kisiwa and the project site belong to degree VI and the corresponding velocity is 8.1 – 16 cm/s, and the acceleration is 0.092 – 0.18 Gal based on the modified Mercalli scale, which was developed by the United States Geological Survey (USGS), and is shown in Table 7-14.

Table 7-14 Modified Mercalli Scale

Instrumental Intensity	Acceleration (Gal)	Velocity (cm/s)	Perceived shaking	Potential damage
I	**< 0.0017**	< 0.1	Not felt	None
II–III	**0.0017 – 0.014**	0.1 – 1.1	Weak	None
IV	**0.014 – 0.039**	1.1 – 3.4	Light	None
V	**0.039 – 0.092**	3.4 – 8.1	Moderate	Very light
VI	**0.092 – 0.18**	**8.1 – 16**	Strong	Light
VII	0.18 – 0.34	**16 – 31**	Very strong	Moderate
VIII	0.34 – 0.65	**31 – 60**	Severe	Moderate to heavy
IX	0.65 – 1.24	**60 – 116**	Violent	Heavy
X+	> 1.24	**> 116**	Extreme	Very heavy

Source: USGS



Source: OCHA (December, 2007)

Figure 7-22 Seismic Intensity

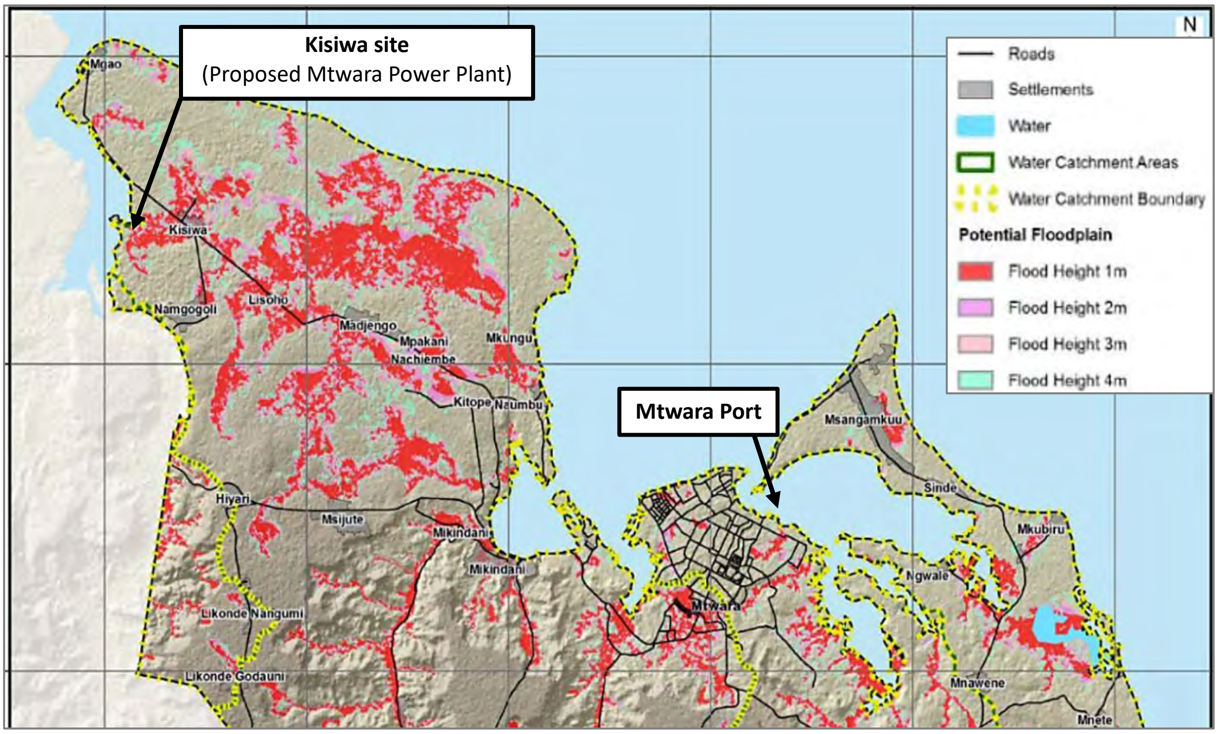
(2) Flood

Storm-water management is a critical issue for the overall planned area of the Mtwara Master Plan[3]. As a whole, the area experiences regular flood. This situation has been caused by the natural topographic setting of this area. Most of the flooding areas fall below sea level. Due to the topographical nature of the planned area, it receives water from many rivers, streams, and valleys. Another reason for flooding is the high water table in many parts of Mtwara. The potential flood risk areas are shown in Figure 7-23.

In Mtwara, currently, the most prevalent risk is flooding because of the followings factors:

- a combination of considerable rainfall events;
- a topography that includes many low-lying areas or basins;
- a coastline which is low and prone to coastal flooding from storm surges combined with high tides;
- lack of adequate storm water management provisions; and
- The construction of housing within floodplains and basins.

3 Mtwara Master Plan 2015-2035, Ministry of Lands, Housing and Human Settlement Development, 2017



Source: Mtwara Master Plan

Figure 7-23 Flood Plains in and around the Proposed Mtwara Power Plant Site in Mtwara

(3) Debris Flow

Based on the past records of natural disasters for the project's surrounding area, it can be noted that a debris flow disaster caused by torrential rain occurred in the beginning of April 1990. The national road B5 Lindi - Masasi route was damaged at two (2) places due to this debris flow. One superstructure of the Nanganga Bridge was washed away by flood, and the river bed was eroded and sunk by more than 10 meters depth, in the upstream of the bridge. The other area to be damages, was the Mkwara sandy area, which was buried by debris flow.

Although the project's surrounding area is not a steep terrain and most of area form gradual slopes, the probability of occurrence of debris flow disasters should be considered, during the implementation of design and construction work of transmission line and site development.

(Source: Debris Flow Disaster on Road in Tanzania, Tetsuya Kubota, 1992)

Source: JICA Study Team

Figure 7-24 Location Map of Debris Flow Disasters

7.4.2 Surface Water and Groundwater

(1) Surface Water

The region of Mtwara falls within the Ruvuma River and the southern coast basins. Furthermore, the proposed Mtwara power plant at the Kisiwa site is located in the Mambi sub-basin as shown in Table 7-15. The Mambi sub-basin is divided into six sub-catchments (Mnazi, Nachenjere, Mikindani, Mbuo, Mambi, Madangwa). The annual total flow in Mambi sub-basin is estimated to be 401 Mm3/year. Among these sub-catchments, Mbuo and Mambi sub-catchments are the major sub-catchments related to the Project. The closest perennial river is the Ruvuma River, which is located approximately 40 km to the south, along the border of Tanzania and Mozambique. The remaining rivers of the coastal Mtwara area and tributaries are non-perennial.

Table 7-15 Mambi Sub-basin and its Sub-catchments

Sub-Basin	Area (km^2)	Annual total flow (Mm^3/year)	Mean Annual Runoff (mm/year)	Sub-Catchment	Area (km^2)	Mean Annual Rainfall (mm)	Mean Annual Runoff (mm)
Mambi	5,258	401	76	Mnazi	251	984	72
				Nachenjere	326	1,004	81
				Mikindani	492	1,032	105
				Mbuo	1,405	990	87
				Mambi	2,523	959	70
				Madangwa	261	1,008	86

Source: Integrated Water Resources Management and Development Plan for the Ruvuma River and Southern Coast Basin, Ministry of Water, 2013

The quality of the surface water at the four locations, indicated in Figure 7-25 (A: Lukuledi river, B: Mbwemkuru river, C: Mavuji river, D: Matandu river), is shown in Table 7-16.

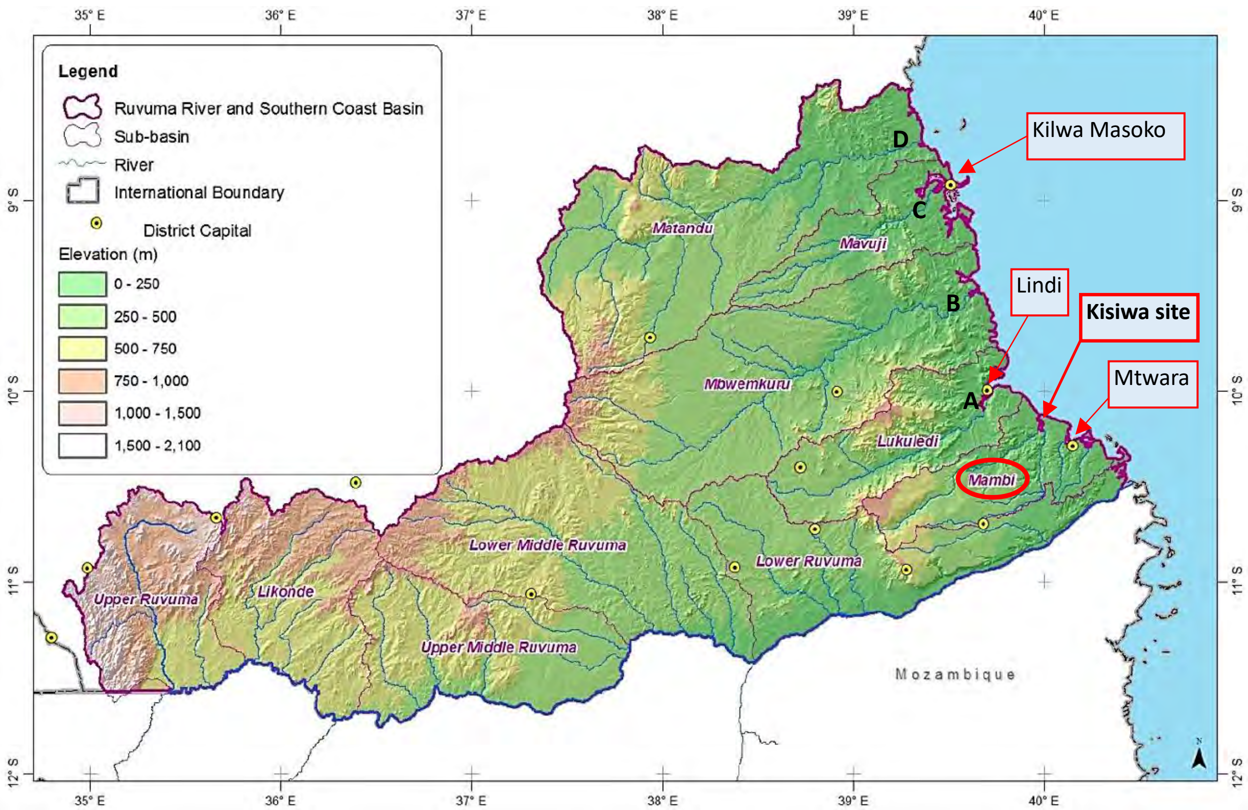


Figure 7-25 River Network and Sub-basins in Ruvuma River and Southern Coast Basin

Source: Integrated Water Resources Management and Development Plan for the Ruvuma River and Southern Coast Basin, Ministry of Water, 2013

Table 7-16 Surface Water Quality in the Coastal Area of Lindi Region and Mtwara Region

Parameter	**Standards**		**A: Lukuledi river** (Mkwaya bridge)		**B:Mbwemkuru river** (Mbwemkuru bridge)		**C: Mavuji river** (Mavuji bridge)		**D: Matandu river** (Matandu bridge)	
	Tanzania	WHO	Nov/2009	Jan/2010	Nov/2009	Jan/2010	Jan/2010	Dec/2011	Nov/2009	Jan/2010
pH	6.5-9.2	6.5-8.5	7.6	7.6	8.2	7.2	7.1	8.2	7.9	7.0
EC(μs/cm)	2000		490.0	876.0	640.0	173.8	143.0	250.0	705.0	144.0
TDS(mg/l)		500	143.0	438.0	138.0	86.9	71.5	116.4	133.0	72.0
Salinity	200-600		n/a	n/a	n/a	n/a	n/a	0.1	n/a	n/a
Turbidity (NTU)	0-30	0-15	8.5	T.T	2.0	T.T	T.T	6.0	5.5	T.T
Total Hard. (mg/l)	600	500	45.5	110.5	87.5	43.5	40.0	37.0	94.0	40.5
Ca (mg/l)	300	200	15.2	31.2	22.4	8.0	8.4	n/a	28.5	9.2
Mg (mg/l)	100	150	8.5	17.4	14.5	8.2	7.2	n/a	15.9	1.1
Fe (mg/l)	0-1.0	0-0.3	0.1	0.1	0.1	2.6	2.5	0.1	0.1	2.6
Mn (mg/l)	0-0.5	0-0.1	0.2	0.2	0.2	0.1	0.2	0.0	0.3	0.3
SO4 (mg/l)	600	400	12.0	44.0	29.0	20.0	0.0	2.0	41.0	0.0
Cl^- (mg/l)	800	250	135.2	207.7	158.8	23.4	19.1	31.9	124.1	20.6
Alk. (mg/l)	500	500	45.5	48.0	92.0	34.0	40.0	40.0	96.0	46.0
NO3 (mg/l)	10-75	0-30	0.3	0.1	0.0	4.6	6.5	0.4	0.0	9.1
F (mg/l)	0-8.0	0-1.5	0.5	0.3	0.3	0.0	0.0	0.2	0.2	0.0

Source: Integrated Water Resources Management and Development Plan for the Ruvuma River and Southern Coast Basin, Ministry of Water, 2013

(2) Groundwater

Both shallow and deep groundwater are found in the coastal zone and in the river sediment zones of Lindi region and Mtwara region. It appears due to the large fluctuation in the water table, and contributes to the relatively large number of seasonally insufficient or dry wells. Groundwater in this sedimentary zone generally lies so deep that the use of boreholes is not viable. Furthermore, alluvial deposits can be found in river valleys along the narrow coastal zone. Alluvial sediments exist in pockets in the coastal zones, predominantly in river valleys leading to the ocean. Significant quantity of groundwater is found in these sedimentary deposits, and they may be accessible via hand dug wells for rural water supply. For example, the Mtawanya aquifer near Mtwara, Mikindani; the sedimentary deposits in Lindi; and the deposits near Kilwa. During rainfall, the shallow groundwater increase rapidly in these sediments. Fluctuations of the groundwater level at deep groundwater observation sites are small and slow e.g. at Mikindani, rise in the groundwater level starts only at the end of the rainy season. This is likely to correlate with the recharge moving down from the plateaus into the river valleys.

The groundwater quality in this coastal zone will not be as good as the inland aquifers, as the primary aquifers are at the lower end of the catchment. With increasing proximity to the coast, the groundwater is likely to become more saline, especially in the case of deep groundwater.

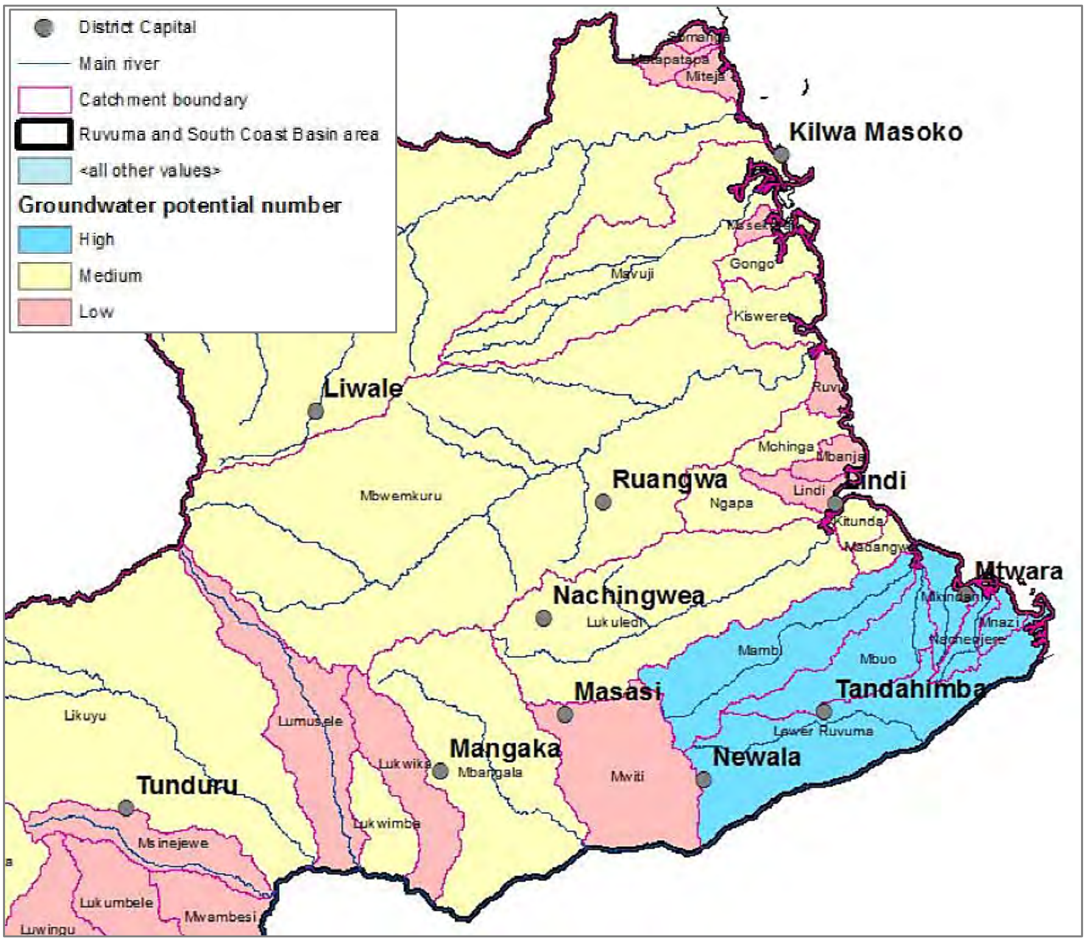


Figure 7-26 Groundwater Potential in the Coastal Area of Lindi Region and Mtwara Region

Source: Integrated Water Resources Management and Development Plan for the Ruvuma River and Southern Coast Basin, Ministry of Water, 2013

As previously described in Section 4.2.4-Water Supply to Kisiwa site, water for the new GTCC project in Mtwara is planned to be supplied from wells near the Mbuo River. It is necessary to confirm the water quality for the GTCC power plant including the feed-water of steam turbine.

JICA Study Team collected water samples from a well and a tap as shown in Figure 7-27. Since the existing wells (#1, #2 and #3) were covered and it was not possible to collect samples from these well, the water samples were taken from the upstream well located 2 km south of the above-mentioned wells and the water outlet in the Kisiwa Village. Existing wells and southern well (point F) are located in the same catchment area of Mbuo River, so it seems that the water quality of these wells are similar. According to the interview with MTUWASA, the technique applied for water purification is limited and the quality of supplied water is almost same as the water from the wells.

E. Tap Water of Kisiwa Village

F. Upstream of Mbuo River

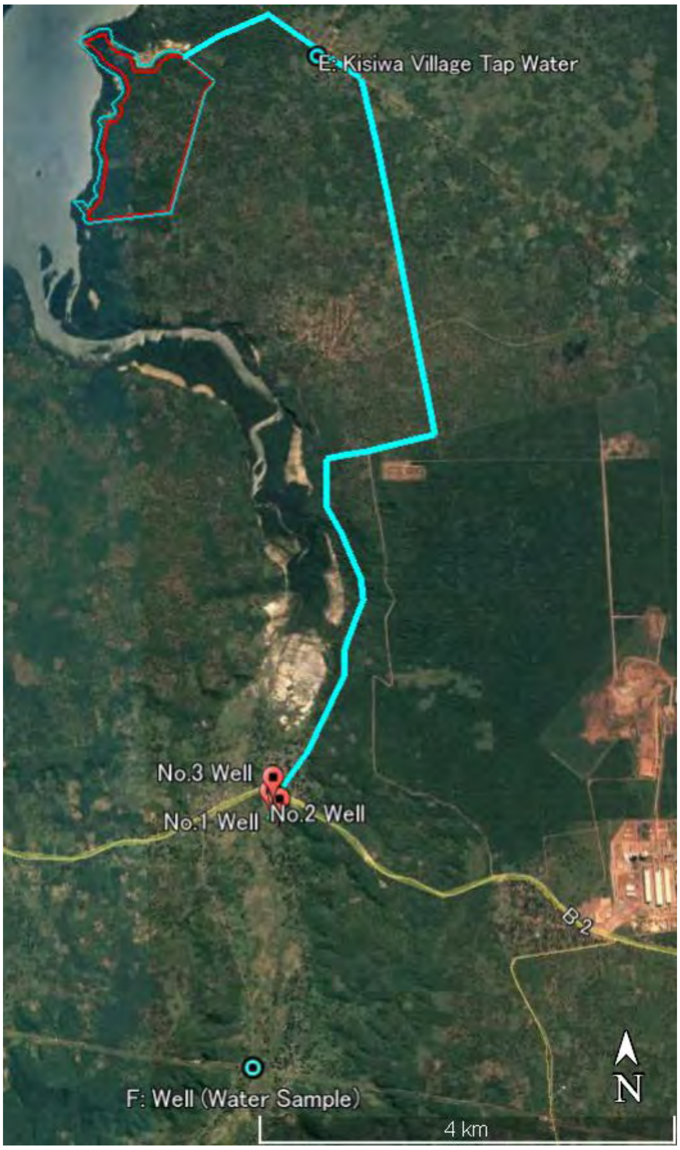


Figure 7-27 Location of Wells and Water Sampling

Source: JICA Study Team

The result of water quality analysis is shown in Table 7-17. According to the analysis results, all parameters meet the standards of Tanzania drinking water supplies and the WHO guidelines for drinking-water quality. In addition, the high values of chlorides (Cl^-) and sodium (Na^+) indicate groundwater contamination by seawater. However the conventional water treatment facility that is considered in the Chapter 4, can eliminate salt for this level of saltwater concentration.

Table 7-17 Groundwater Quality in the Mtwara Region

Parameter	Standards		E: Kisiwa (Mtwara Rural)	F: MBUO (Mtwara Rural)
	Tanzania	WHO	Mar/2018	Mar/2018
pH	6.5-9.2	6.5-8.5	7.61	7.35
EC(μs/cm)	2000		1241	598
TDS(mg/l)		500	683	242
Turbidity (NTU)	0-30	0-15	9	11
Total Hard (mg/l)	600	500	174.83	83.18
Ca (mg/l)	300	200	49.4	28.4
Mg (mg/l)	100	150	12.5	2.98
Fe (mg/l)	0-1.0	0-0.3	0.02	0
Mn (mg/l)	0-0.5	0-0.1	0.016	0.06
SO4 (mg/l)	600	400	8	2
Cl^- (mg/l)	800	250	385.67	106.23
Alk. (mg/l)	500	500	80.0	76.0
NO3 (mg/l)	10-75	0-30	4.8	6.9
F (mg/l)	0-8.0	0-1.5	0	0
Na (mg/l)	250	200	46	184
K (mg/l)	100	-	28.39	35.95
Temperature (°C)	35.0 (Highest)		30.2	30.8

Source: JICA Study Team

7.5 GEOLOGY

7.5.1 Geological Condition in the Kisiwa Site

(1) Onshore Geological Condition

a) Borehole Location for Geological Survey

Heavy equipment such as GT/ ST and 400kV substation are planned at the Kisiwa site, therefore geological survey with boreholes drilling was conducted in this area. GT and ST is planned at the northwest part of Kisiwa site, and the 400kV new substation is planned in the central part of the north end, and about 500 m from the coast. As far as the topographic map is concerned, the terrain gradually ascends to south and at present, it is densely covered with various trees.

Table 7-18 and Figure 7-28 show the location of boreholes at the Kisiwa site. The basis for choosing each point are as follows: 1) Accessibility is good for carrying out borehole survey, 2) It is a reference for the expected arrangement of power generation facilities and the finish height of the ground and 3) It is useful for estimating the surrounding geological ground condition.

Table 7-18 Coordinates of Boreholes in the Kisiwa Site

Borehole	Coordinate (UTM)	
	Easting	Northing
D-4	608521	8874281
D-5	608741	8873988
D-6	609092	8873438

Source: JICA Study Team

Source: JICA Study Team

Figure 7-28 Borehole Location of Kisiwa Site

b) Regional Geology

a. Terrain Features

The Kisiwa site is located on the east shore of Kisiwa Bay, where mangrove forest cover the marine shallows and the sand hills rise at EL.10 meters approximately. From the wide view, it can be noted that the terrain around the project site is mostly a flat land, but a total of six marine terraces can be recognized, and dried-up gullies named ‘wadi’ incise these terraces deeply. When viewed from the highest elevation, it can be noted that the marine terraces form flat lands or have very gentle slopes at EL.270 – 300m, EL.210 – 240m, EL.150 - 170m, EL.60 – 120m, EL.20 - 40m and EL.10 - 13m in this region. These terraces seem to reflect the coastal benches or abrasion platforms, which were a part of coral colonies in the distant past, and they showed up on the land surface due to the intermittent drop in sea water level during the glacial age. The general geo-structure around the project site is terrace benches with coral limestone and relatively thin sediments, which are derived from river or ocean currents that overlay the benches. Actually limestone outcrops are exposed on coastal cliffs or gully walls, and parts of them are exploited as quarry mainly for the cement material.

b. Geological Conditions around the Site

The Kisiwa site includes four geological compositions such as, the lowest land on the bay shore which is submerged constantly by ocean tides, the lowest terraces (Te1) at EL. 10-13m, the next terrace (Te2) at EL. 20 – 40m and the coral limestone as basement (see Figure 7-29). As shown in Figure 7-29, the drilling survey studied the underground conditions of the site and it confirms that Te1 consists of silty sand (S1), gravelly sand mixed with clay (SG) and soft clayey sand (Cl1) are present at the bottom; these sediments are stacked up on a hard clay layer (Cl2) or coral limestone (Lm) at the drilling holes of D-4 and D-5. Drilling at D-6 ascertains an elevation difference of approx. 20m between the top surfaces of limestone of D-5 and D-6. Therefore the drilling hole of D-6 is certainly located on higher terrace (Te2) than Te1. The coral platform of Te2 is thinly overlaid by loose sandy sediments. According to the detailed contour map, the land surface gradually rises southward, beginning at EL.13m up to 30m, hence it seems that the ancient ocean cliff of limestones on Te2 is possibly buried under the sandy sediments along the contour line of EL.13m.

c) Engineering Geology

a. Physical and Mechanical Properties of Foundation

As a part of field drilling works in the project site, the Standard Penetration Test (SPT) at 1.5m intervals for all boreholes was carried out, and the disturbed soils collected by SPT were subjected to laboratory tests. Soil compositions and the range of N-values in each soil/rock layer of the site are summarized below,

[Layer]	[Thickness]	[Composition]	[N-Values]
S1	5 – 10 m	Silty sand	< 10
SG	Approx.10 m	Gravelly sand mixed with clay	20 - 30
Cl1	Approx.5 m	Clayey sand mixed with gravel	< 10
Cl2	Approx.5 m	Hard clay with gravel	> 50
Lm	> 35m	Coral limestone thinly intercalated with compacted clay, sand and gravel	> 50 (Basically not penetrated)

Horizontal borehole loading test is a test to check the horizontal strength of the ground and the purpose is to obtain the horizontal deformation characteristics of the ground. Deformation coefficient, yield pressure and ultimate pressure of the ground can be obtained from the wall pressure and the displacement of the wall surface by applying the gas pressure or hydraulic pressure in the direction perpendicular to the wall surface of the borehole. This test was conducted by Menard Pressure meter in accordance with ASTM D 4719-07, to obtain the information of geotechnical parameters at Kisiwa Site and Lindi Site.

As per the result, deformation coefficient was about twice the limit pressure, which is lower than the theoretical value. The reason considered for this is that sufficient strength could not be measured, because the borehole wall was loose for some reason. Test result is shown in Table 7-19

Table 7-19 Test Result Summary for Horizontal Borehole Loading Test

Test Results	Test interval		Pressiometer modulus E: **(kPa)**	Ultimate pressure PL: **(kPa)**	Ratio E/PL:	Yield pressure PF: **(kPa)**	Ratio PL/PF:
	From (m)	To (m)					
BH 01 D4)	3	3.5	963.5	670.4	1.4	380.4	1.8
	3.5	4.00	1,109.1	508.0	2.2	280.4	1.8
BH 02 D5	1	2	1,297.4	753.0	1.7	291.7	2.6
	3	4	1,680.8	781.2	2.2	380.4	2.1
	2	3	1,127.1	678.0	1.11	277.9	3.8
BH3 D6	3.5	4	1,334.2	721.0	1.15	330.4	3.1
	2.5	3.5	1,824.9	731.2	2.5	382.9	1.9
BH04 D7	3.5	4.5	1,529.0	702.1	2.2	340.9	2.1

Source: JICA Study Team

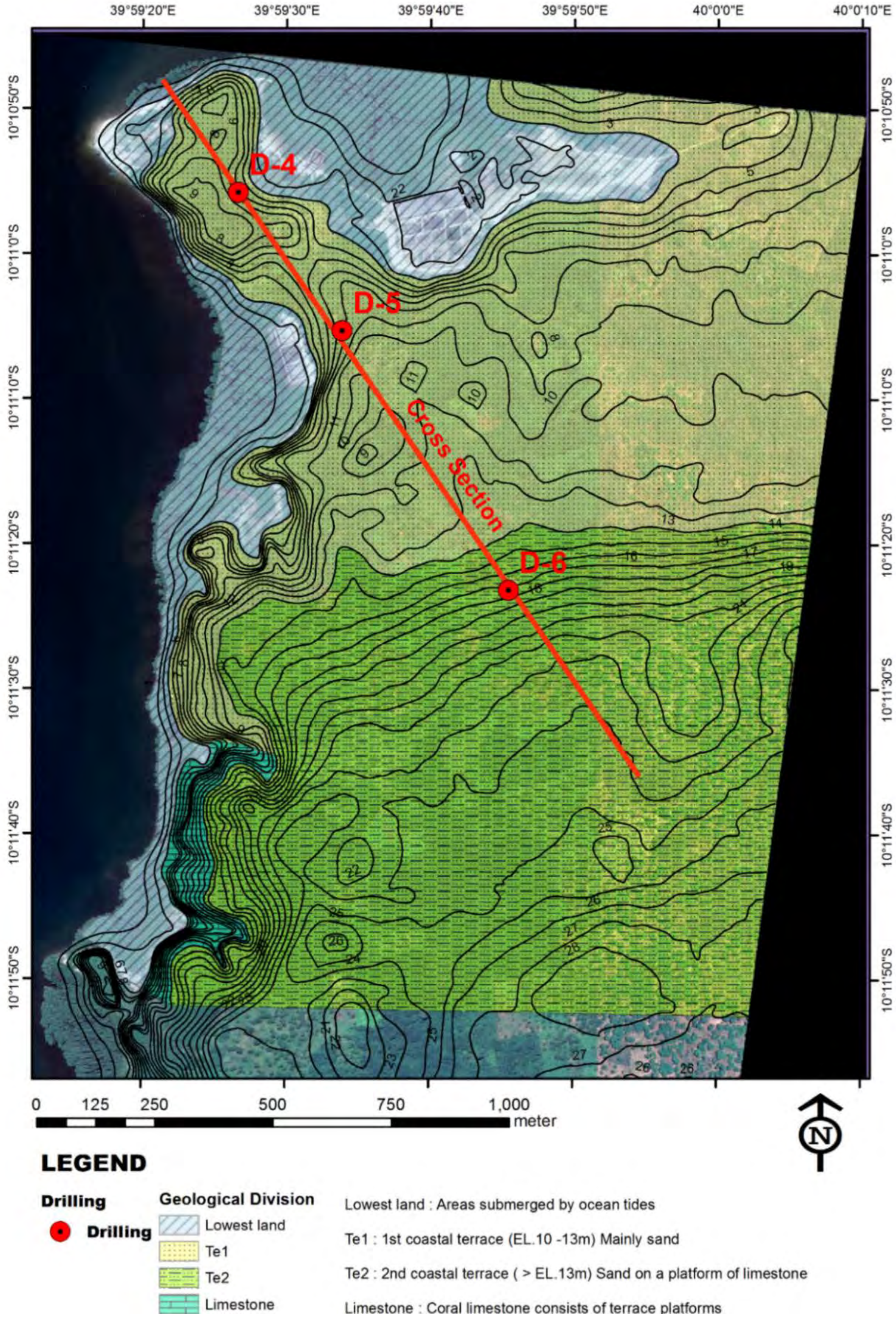
The deformation coefficient (E) is predicted by the empirical formula of (E) = 700 N-Value. When this formula is adopted, the horizontal deformation coefficient is estimated to be 5000 to 7000 kPa from the result of standard penetration test at a depth of 4 m from the ground surface. Therefore, it is highly recommended that additional investigations of the horizontal borehole loading test be carried out at the next step (basic design stage).

b. Geotechnical Consideration

Coral limestone which is composed in the platforms of terraces (Te1 and Te2) tolerates the loading weight of any structure in the Project. Basically piles have to reach up to the depth of limestone. It seems that the hard clay layer (Cl2) was formed at the same geological age as the limestone at the bottom floor of Te1, and it has been compacted sufficiently, therefore, the Cl2 layer is can receive the load of thermal power plant facilities. The Cl1 layer is not thick and is buried under sea level. It mainly consists of soft clay, thus it should be avoided as the pile foundation of any facility.

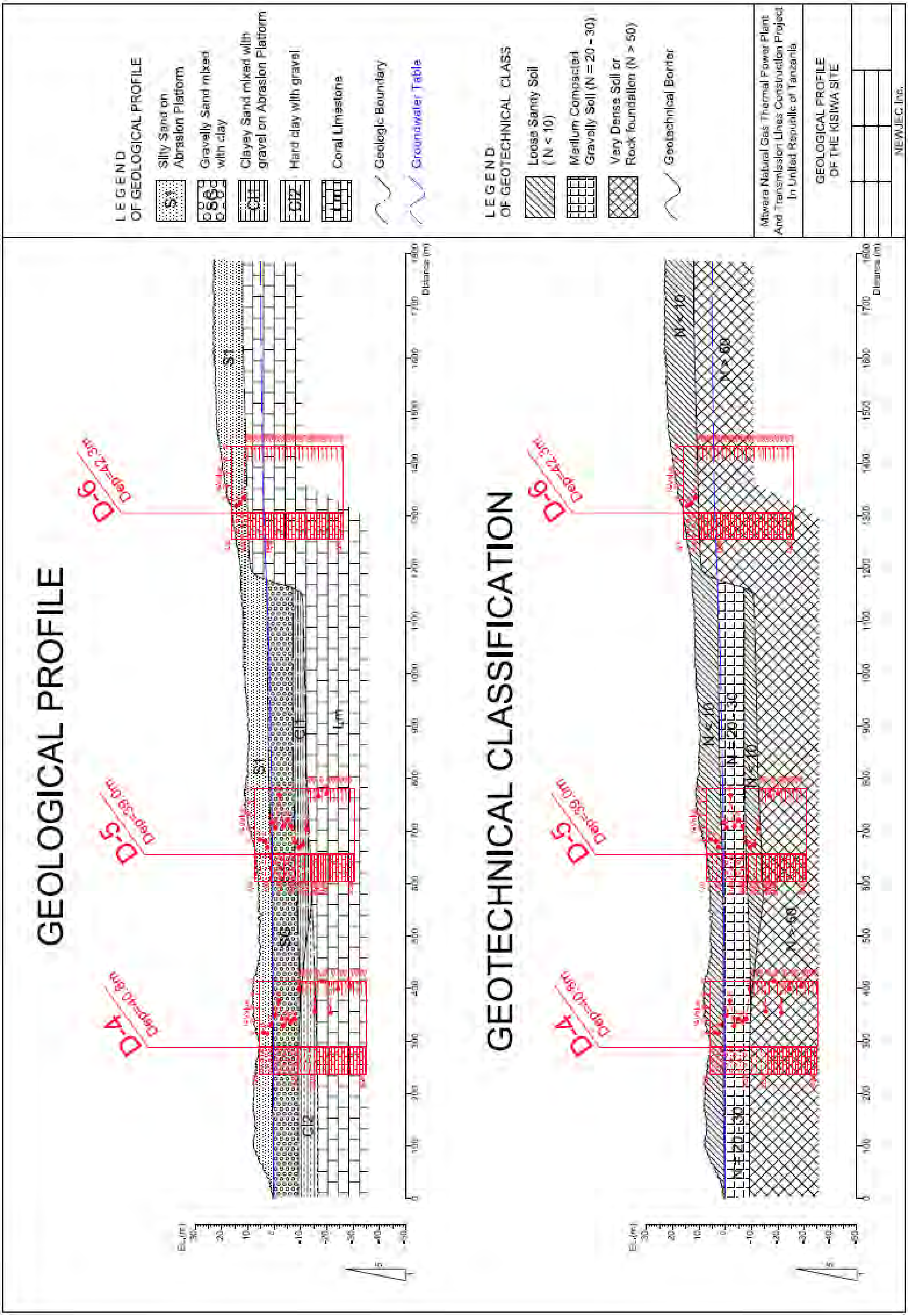
The SG layer is below sea level and it is entirely submerged by groundwater. If the open excavation reaches the layer, a large amount of seepage should be taken into consideration. Most of facilities can be directly placed on the SG layer, but, specifically, the foundation of crucial facilities such as gas turbines and steam turbine requires a more reliable layer than the SG layer. The top layer, namely the S1, may be capable of directly bearing the foundation of light facilities. As necessary, SPT with borehole drilling should be carried out to check geotechnical condition at the place of each building in the project implementation stage.

Generally, the Kisiwa site, where the power plant and other heavy equipment will be installed, has a relatively favorable geological condition according to the result of geological survey.



Source: JICA Study Team

Figure 7-29 Geological Compositions around the Kisiwa Site



Source: JICA Study Team

Figure 7-30 Geological Profile in the Kisiwa Site

(2) Offshore Geological Condition

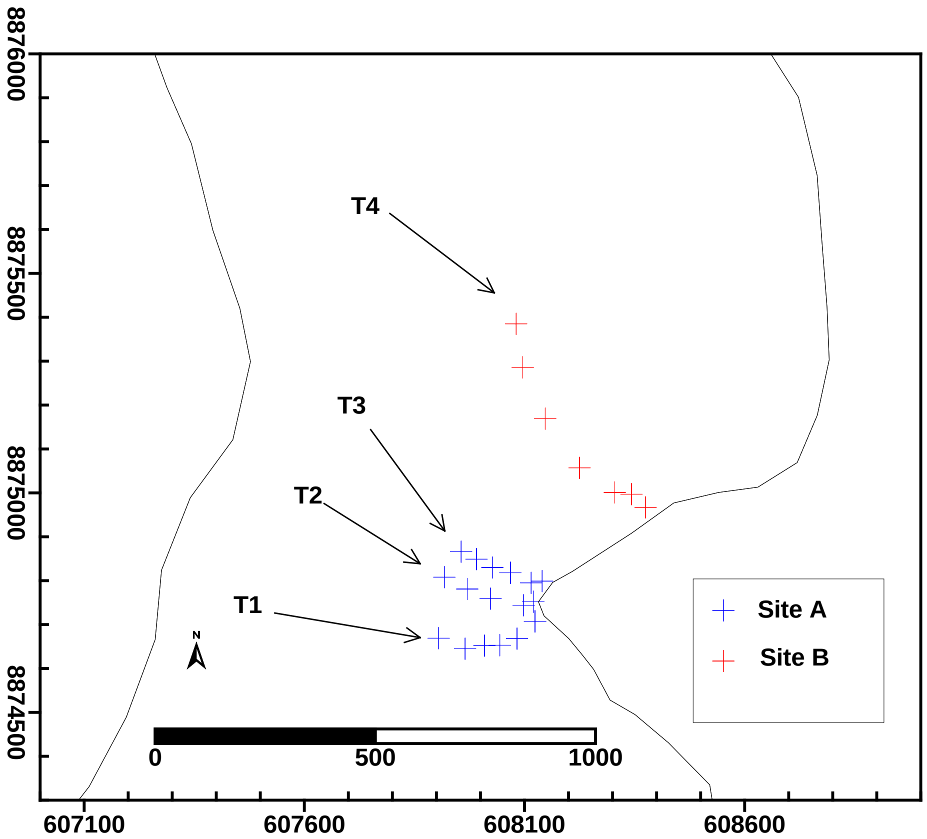
a) Purpose of the Study

The purpose of the seafloor survey is to comprehend the geological conditions of the seafloor surface required for the basic design of the marine structures, and obtaining the information necessary for estimating the movement mechanism of the drift sand. Since the distribution characteristics of sediments are considered to indicate the result of drift sedimentation phenomenon, it is possible to estimate the drifting direction and sources.

Area of the seafloor survey is shown in Figure 7-31 and Figure 7-33. Site A (indicated in blue "x") in Figure 7 30 is expected to be installed with a cooling water intake, as it is in front of the sandy beach, where the local fishermen are currently landing their catch. The area is approximately 160 × 60 meters, and eighteen (18) points were investigated in T1, T2 and T3, which are marked with a blue "x". In addition, Site B, where the discharge channel is expected to be installed, was investigated at seven (7) points, and is marked with a red "x". Measurement points are named as following: from T1a to T1f, T2a to T2f, T3a to T3f, and T4a to T4g in order, from beach to sea.

Source: JICA Study Team

Figure 7-31 Locations of Seafloor Survey (Wider Area)



Source: JICA Study Team

Figure 7-32 Locations of Seafloor Survey (Detailed)

b) Results of Survey

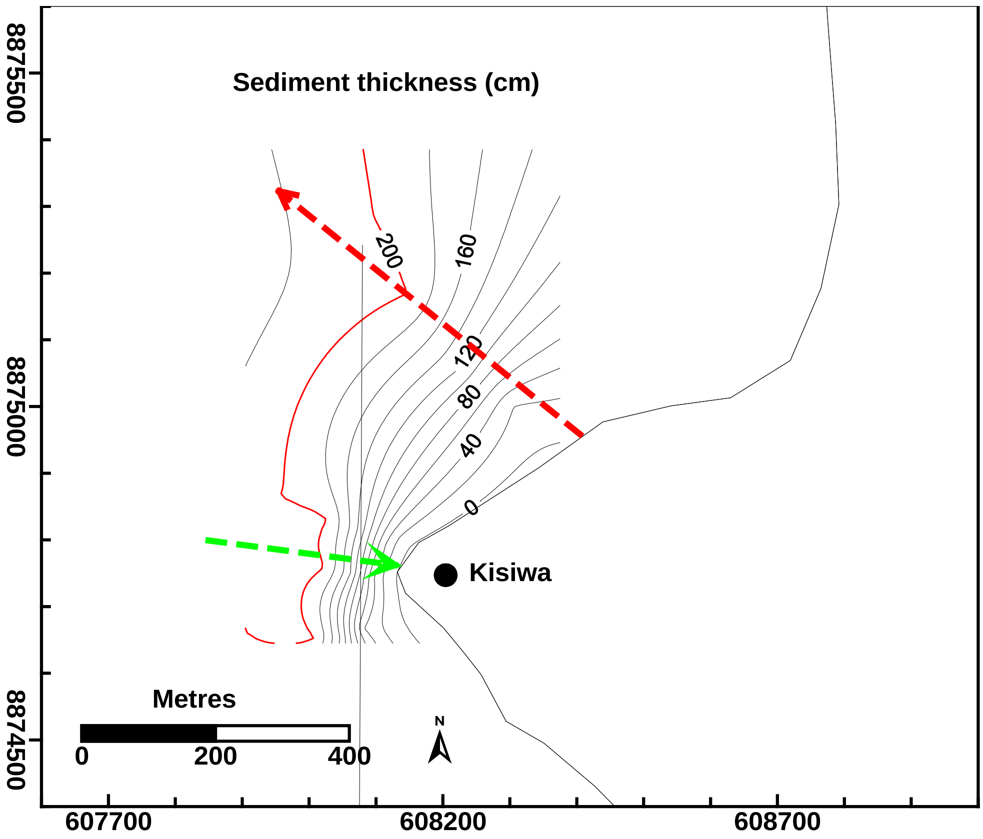
The sediment thickness was measured by the divers at different sampling sites and the results are presented in Table 7-20, and is also summarized in Figure 7-33. The results presented in Table 7-20 show that all the three outermost points at each transect had sediment thickness exceeding 2m, while the other three points located closer to the shoreline had sediment thickness varying between 0 and 1.5m. The results presented in Figure 7-33 show that the 200cm contour which is roughly located at about 7-8 m depth is relatively away from the shore (about 400m) at the water discharge structure location, and is much closer to the shoreline (about 200 m) at the water intake structure location.

Table 7-20 Sediment Thickness on the Sea Bottom at the Kisiwa Site

(Unit: cm)

SITE A (Area of Water Intake)						SITE B (Area of Water Discharge)	
Site No.	Thickness	Site No.	Thickness	Site No.	Thickness	Site No.	Thickness
T1-a	8	T2-a	9	T3-a	10	T4-a	6
T1-b	39	T2-b	38	T3-b	40	T4-b	16
T1-c	145	T2-c	148	T3-c	149	T4-c	20
T1-d	>200	T2-d	>200	T3-d	>200	T4-e	>200
T1-e	>200	T2-e	>200	T3-e	>200	T4-f	>200
T1-f	>200	T2-f	>200	T3-f	>200	T4-g	>200

Source: JICA Study Team



Source: JICA Study Team

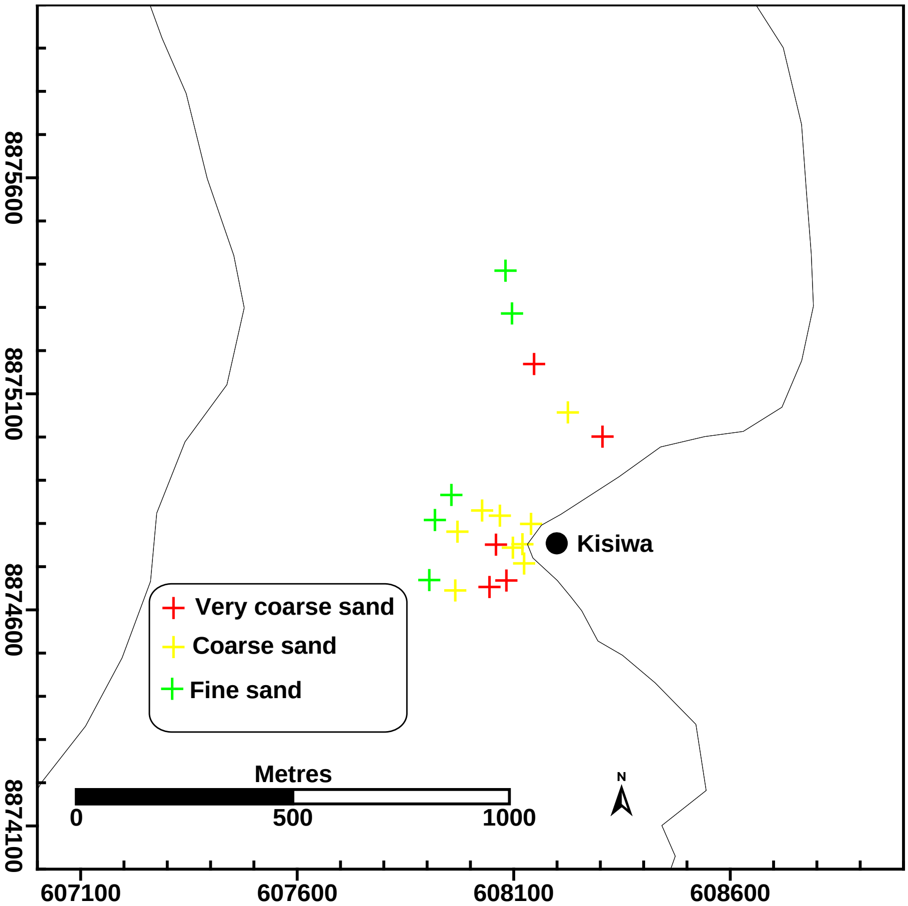
Figure 7-33 Sea Bottom Contour Map

Note; *1: Red contour line marks the boundary between the shallow water areas, where the sediment thickness is below 200cm, and the deeper areas, where the sediment thickness is more than 200cm.

*2: Red and green arrows show the location of the water intake and discharge structure

Summary of sieving analyses of sea floor is shown in the maps of Figure 7-34. The mean grain size of the sediments varied from very coarse sand (5 samples), coarse sand (10 samples) and fine sand (5 samples). The coarse sand and very coarse sand were generally located on the shallow parts (less than 5m depth) of the investigated sites, and fine sediments were located at the outermost samples at relatively higher depths.

The sorting of the sediments varied from poorly sorted (18 samples) to very poorly sorted (2 samples). The two poorly sorted samples were located in the intertidal area along the first transect (T1).



Source: JICA Study Team

Figure 7-34 Sand Size Categories/Classes at the Kisiwa Offshore

The nature of the sea bottom was not clearly discernible, because of the poor visibility of the sea bottom at the outermost parts of all the Transects. However, based on the results of sediment analyses by sieving, the sea bottom sediments are expected to be fine sand. From the outermost points to the intertidal areas, the sea bottom sediments varied from fine sands to coarse sand/very coarse sand and this was consistent with the sieving analyses, and the sea bottom on the intertidal areas was also characterized by the presence of biogenic fragments/shells and sand ripples. Figure 7-35 shows the sediments composed of very coarse sand, enriched with pebbles and shell fragments.

Source: JICA Study Team

Figure 7-35 Sea Bottom Photograph at T-2f

The study revealed that the sediments of investigated area are dominated by siliciclastic sediments (i.e. sediments derived from the land). The siliciclastic components in the sediments were estimated to be 60-70%, while the biogenic constituents varied between 30-40%. The biogenic proportion in the sediments tended to be higher towards Site B. Most of the siliciclastic sediments are introduced into the Kisiwa Bay by the river discharges, through the head of the Creek at Namgogori, and most of the biogenic constituents are introduced into the Creek from the north through the mouth of the Creek at Mgao. The observed categories of sand sediments suggest that the area is characterized by high energy environment. Furthermore, the observed high proportion of siliciclastic input could be one of the major limiting factors for the observed low biodiversity and absence of corals in the investigated area. Increased sedimentation from land-derived sediment sources cause a physical change in the sea water quality with detrimental effects to the health of some of the carbonate producers such as the corals.

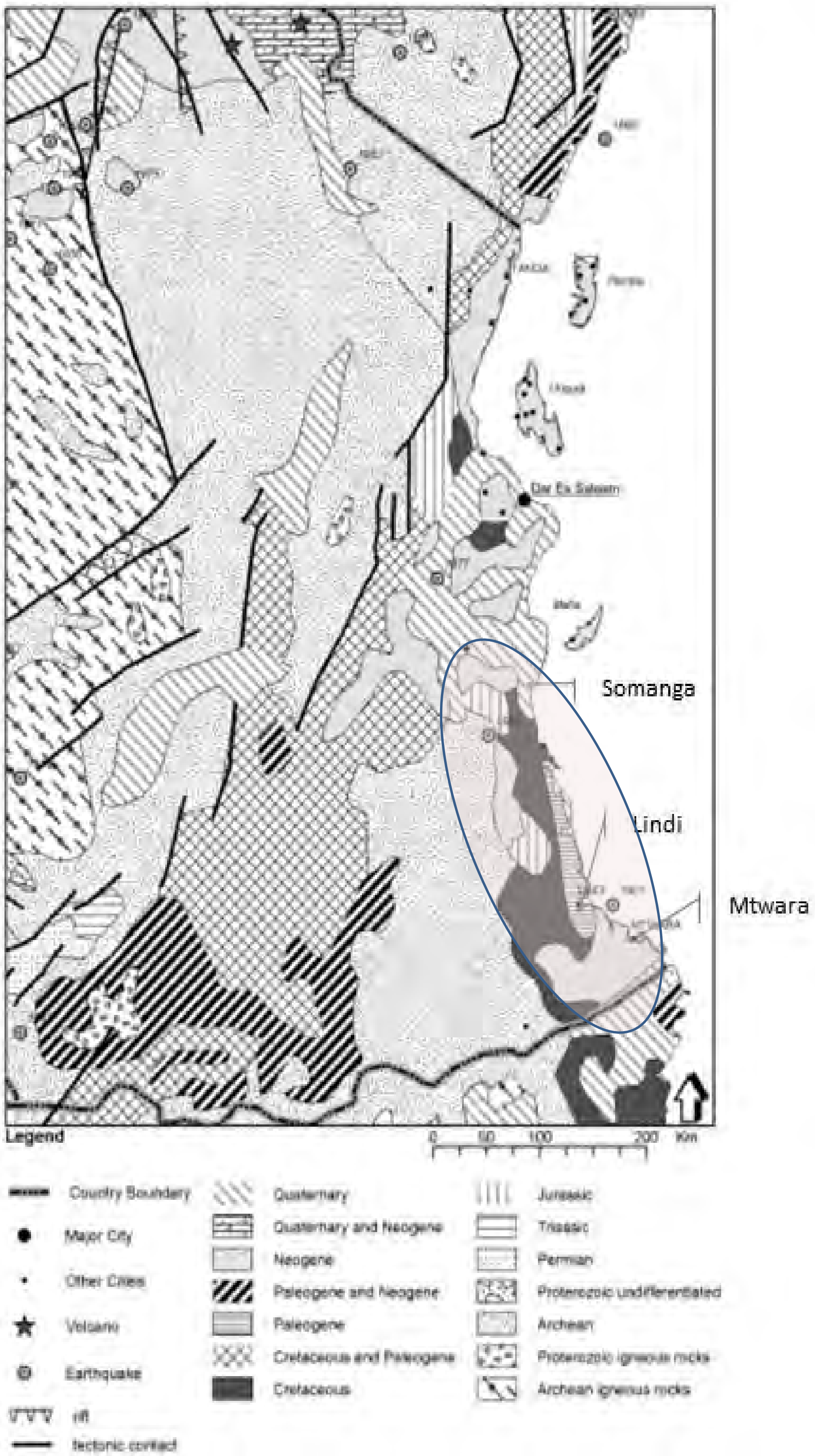
Sorting of the sediments reflects that the overall size variation of the particles was influenced by the variation in energy of the depositing medium. Analyses of the sorting distribution of the sediments revealed that the investigated sediments were either poorly sorted or very poorly sorted, suggesting that there was high variation in the energy of the depositing medium, leading to the deposition of coarse and fine particles in the same sample. This could also explain why corals are not common in the area, despite the fact that the area is characterized by high energy environment.

According to the result of the survey, the bathymetric feature of the place, where the water discharge structure is planned to be installed, is shallow, and the depth of the structure is approximately 4 meters, hence, it is relatively easy to install water discharge structure. On the other hand, the bathymetric feature around the water intake structure, rapidly deepens at the sea. Top of the water intake facility is approximately 10 meters deep and the deepest part is 18 meters below sea level, therefore, temporary works and construction scheme are important for the smooth implementation.

7.5.2 Geological Condition at Substation and Transmission Line

(1) General Geological Condition along the Coastal Zone

According to the Eastern Africa Atlas of Coastal Resources, published by the United Nations Environment Programme (UNEP) 2001, Tanzania is primarily underlain by rocks of igneous metamorphic origin, part of the crystalline complex that makes up part of the interior of Africa. Intense structural movements are observed in a variety of rock types. Geology of the area between Mtwara, Lindi and Somanga consists of quaternary, neogene, paleogene and cretaceous as shown in Figure 7-36.



Source: Eastern Africa Atlas of Coastal Resources (UNEP, 2001)

Figure 7-36 Geological Map of the Coastal Tanzania

(2) Purpose of Geological Survey and Borehole Locations

The geological survey and laboratory test are conducted to identify and categorize geological conditions along the route of transmission line of the Project for structural foundations, and to make the necessary structural design for the study. This geological survey and laboratory test includes standard penetration test, water level monitoring, sampling and laboratory test. Based on the result of this geological survey, the basic design of towers for transmission lines and substations are outlined in the following chapter.

The expected site for the New Lindi Substation has already been acquired by TANESCO and the site is almost flat with plants and trees. As shown in Figure 7-38, a borehole named as “D-7” was drilled near the southeast boundary of the New Lindi Substation site.

As shown in Figure 7-37, four (4) geological survey points were selected along the national road and the expected transmission line route shall be connecting Mtwara and Somanga with easy accessibility, taking into consideration the geology of the surrounding area. Boreholes are named as “D-8” to “D-11” from south to north. Coordinates and characteristics of the borehole are shown in Table 7-21. Borehole location of D-8 and D-11 were determined on estimating that those places have comparatively soft ground.

Table 7-21 Location of Boreholes in the Lindi Site and along the T/L Route

Borehole	Coordinate (UTM)		Remarks
	Easting	Northing	Soil Classification
D-7	564941	8877937	Site for New Lindi Substation 6km from Mnazi Mmoja
			Neogene
D-8	597075	8868562	1km from village Centre
			Paleogene Lowland, supposed to be soft ground
D-9	564017	8906048	16km from Mitengi Junction, on the road to Lindi
			Paleogene
D-10	550139	8947442	2 km from Kiranjeranje town, on the road to Nanjilinji
			Cretaceous
D-11	527745	9051619	1km from Miteja Centre
			Quaternary Swamp Area during rainy season

Source: JICA Study Team

Source: JICA Study Team

Figure 7-37 Location of Geological Survey for Transmission Line and Substation

Source: JICA Study Team

Figure 7-38 Borehole Location of 400kV New Lindi Substation

(3) Result of the Survey

a) Physiography

The planned transmission line of 400kV is approximately 270km long, from the Mtwara GTCC power plant to the 400kV Somanga Substation, and it runs mainly on gentle hill areas with elevation ranging between EL.10 - 300m. These hills consist of coastal terraces made of limestone and thin sediments. On the other hand, the transmission line route passes several hill valleys which may have relatively thick river deposits.

b) Estimation of Engineering Basement for Towers and Substation

In this study, five (5) exploratory drillings of D-7 to D-11 were conducted on the transmission line and at the site of the New Lindi Substation. In Table 7-22, the depths of engineering basement with N-values along the transmission line route are summarized taking into consideration the drilling data and topographic features. Sections of the route, are based on the classification of Section 5.2, and are shown in the Figure 7-37.

In accordance with the SPT, the N-values at the borehole locations of D-9, D-10 and D11 are over 50, above the depth of 20 meters, and the N-value of D-8 has been below 50, until depth of 20 meters. The result of survey shows that most of the transmission line route is planned on well stiff ground, however some part are planned on the weaker grounds. Weaker ground is expected to appear in some sections, but it is limited.

In addition to the above condition, foundation of transmission towers shall take into consideration the geology of covering soil. According to the survey result, geology of shallow part of D-8 is identified as clay and D-11 is mostly sand. Thus, foundation in these weaker locations are estimated to be in the range of standard design of transmission towers. Based on the survey, the basic design of transmission tower foundations is done in the Chapter 8.

Table 7-22 Depths of Engineering Basement with N-Values for Tower Foundation

T/L route section		Threshold depth of N-Value (Lithology of shallow layer)	
Section	Borehole	N > 10	N > 30
Section I - II	D-8	Range in 5 – 10m (Clay)	Deeper than 10m
Section II - III	D-7 (Lindi S/S)	Range in 5 – 10m (Sand)	Deeper than 10m
Sec. III – IV *3		-	-
Sec. IV – V - VI	D-9	Shallower than 1m (Sand and Limestone)	Range in 1 – 5m
Sec. VI - VII	D-10	Shallower than 1m (Sand)	Range in 1 – 5m
Sec. VII - VIII	D-11	Range in 1 - 5m (Sand)	Range in 5 – 10m

*3: Geological conditions of Section II- II seems to be good due to hilly area.

c) Recommendation for further study

Only five drilling have been carried out for geotechnical investigation on the long transmission line route, including the site of substation in the study. Therefore, it is difficult to estimate the adequate foundation level along the transmission line route. SPT with borehole, including Dutch cone penetration test, should be carried out to check geotechnical condition at the place of each tower during the project implementation stage.

When the detail design of transmission line’s towers is carried out, special attention should be given to parts with weaker ground, especially, the swamps areas, rivers and low-lying lands.

CHAPTER 8

BASIC DESIGN OF POWER PLANT, TRANSMISSION LINE AND SUBSTATIONS

CHAPTER 8 BASIC DESIGN OF POWER PLANT, TRANSMISSION LINE AND SUBSTATIONS

8.1 BASIC DESIGN OF POWER PLANT FACILITIES

8.1.1 Design Philosophy

(1) Project Outline

The planned GTCC will be installed at Kisiwa site in the Mtwara region. The net power output will be about 300 MW.

1) The average atmosphere temperature is estimated to be 26.2°C.

2) Fuel gas will be supplied by TPDC.

3) Fresh water will be supplied by MTUWASA.

4) As for the cooling system of the steam turbine condenser, JICA Study Team evaluated the technology and economics of cooling systems. As a result, it is recommended to use the seawater-cooled condenser.

5) Power output from each generator shall be supplied to 400kV New Mtwara substation.

(2) Operation Requirements

The main components and their auxiliaries shall be designed to ensure that start-up and long-term operation are achieved with minimum troubles, throughout the design life of the new plant. Adequate redundancies for auxiliary facilities and equipment shall be taken to achieve high availability. The main components and their auxiliaries shall be designed to enable start up and to reach full load by pushing a single start button. The entire plant shall be suitable for continuous power load operation. All facilities shall comply with Tanzanian rules and regulations such as the Tanzanian Grid Code (GC).

1) Plant Requirements

The new plant shall have high efficiency and reliability. The new plant shall be designed to withstand the continuous annual operation in this specification.

2) Start-up Time Schedule Requirements

The start-up time shall be as short as possible. The new plant shall be designed to meet such a start-up time as specified in the following table.

The start-up time for GTCC shall be defined as the time from pushing the start button to the full load conditions, provided that a condenser vacuum level is established and the new plant is ready for start. The start-up time for simple cycle (GT) shall be defined as the time required from ignition to full load. The time for air purging of GT exhaust line and synchronization shall be excluded.

Table 8-1 Requirement for Unit Starting Time in Each Mode

Type of Start-up	Time as GTCC (min.) ※1	Time as Simple Cycle (min.)※2
Cold start after stop of more than 36 hours	Max. 240	Max. 25
Warm start after stop of less than 36 hours	Max. 180	Max. 25
Hot start after stop of less than 8 hours	Max. 120	Max. 25
Very hot start after stop of less than 1 hour	Max. 60	Max. 25

※1. The time from pushing the start button to the full load.
※2. The time from the ignition to full load.

Source: JICA Study Team

3) Service Life Time

The new plant and the associated equipment shall be designed and constructed for the service time as specified below:

Minimum service time = 25 years
Equivalent service hours = 188,121 hours on a full load basis
($24 \times 365 \times 25 \times 0.859$, 0.859: capacity factor)

The new plant shall be designed for a continuous load operation with 7,972 actual operating hours per year on the basis of around full load. The hours necessary for the starting up and shutting down cycle are not included in the above operating hours. Throughout the service time, the new plant and the associated equipment shall continue to be operated with high efficiency, high reliability and excellent economy.

4) Start-up and Shutdown Operation

The start-up and shut down operation of the new plant shall be performed automatically from the Central Control Room (CCR) of the plant.

Full supervisory and control functions shall be provided for the safe, reliable and efficient operation of the new plant.

The new plant shall be capable of being auto-synchronized and initial-loaded from the CCR.

5) Compliance with the GC

All generators connected to the grid system shall comply with the GC. For example, frequency variation, ability to perform island operation, black start capability, etc. must comply with the GC.

(3) Control and Operation, Maintenance Philosophy

1) Command from GCC

Based on the information from TANESCO, Grid Control Center (GCC) directs start up/shut down of generators, and increase/decrease of generation output by means of telephonic communication. But in the future, GCC will install Automatic Generation Control (AGC) system and GCC will instruct increase/decrease of generation output using the SCADA. So far, there is no need to install AGC system at Mtwara GTCC. When the AGC system is installed at GCC in the future, modification is necessary at Mtwara GTCC.

2) Plant Automation

The start-up/shut down sequential control and the protection of the new plant shall be fully automated, so that operators at the CCR can supervise the overall new plant. However, the start-up/shut down control sequence shall include break points to allow the operator to intervene and provide normal assistance, as needed.

The start-up/loading procedures, including draining and venting of the new plant, shall be selectable and controlled automatically depending upon the status of the new plant such as very hot, hot, warm, or cold.

3) Plant Operation

The CCR shall be located in the new administration building, next to the new plant. In addition, the Distributed Control System (DCS) with the data logging system shall be installed, so that the output can be automatically controlled to respond to the power demand. In order to ensure the reliability of the control system, the Central Processing Unit (CPU) shall duplicate the configuration using the standby redundant system. The Liquid Crystal Display (LCD) to monitor the operation conditions, and keyboard panels with mouse to operate the plant shall be installed in the CCR. By adopting these facilities, the operation of the plant will be easier and the reliability of the plant monitoring will be higher. The switching operation of the generator circuit breakers and the step-up transformer circuit breakers shall also be performed from the DCS in the CCR. On the other hand, the switching operation of the other circuit breakers in 400kV New Mtwara substation shall be performed from the other CCR in the substation.

4) Under and Over Frequency Operation

Comprehensive system studies for the new generators will be necessary to ascertain the dynamic behavior of the system, depending on their position in the network. System frequency variations shall be agreed upon with the system operator. According to the GC and the guideline of system frequency variations; each synchronized generator needs to comply with the following. Each generator shall be able to operate continuously without tripping in the range of 48.5 to 51.0 Hz. For the other frequency ranges, the time limitation of operation shall be designed by the manufacturer.

5) Ability to Island and Black Start Capability

According to the GC, the 300MW class of units are required to have the ability of island operation. Therefore, the power plant studied in this project shall have the ability to perform island operation in case of the load disconnection. The black start capability is also required depending on the result of consultation with the system operator. Based on the request from TANESCO and the specification of a similar plant Kinyerezi II, JICA Study Team considers that it is necessary to use the black start generator for this project.

6) Plant Maintenance Interval

Among the main facilities of GTCC, the GT has the highest failure rate, and its maintenance level greatly affects the operation rate of the entire plant.

The high temperature parts of the GT, which are exposed to gases of 1,000 degrees or more, are prone to serious deterioration and damage. Therefore, manufacturers have set forth the expected life for each type of these high temperature parts and the recommended inspection intervals of the GT. Normally, it is necessary to inspect, repair, and replace these high temperature parts in accordance with the inspection interval until the service life is reached. For reference, the inspection interval of a typical heavy duty GT is shown below.

Type of Inspection	Inspection Interval/ EOH
Hot Gas Path Inspection	24,000 hour
Major Inspection	48,000 hour

* These data is based on base load operation.

** Combustor Inspection is included in Hot Gas Path Inspection and Major Inspection. Combustor Inspection is not carried out alone, in case of base load operation.

7) Examination of the LTSA

Among the main facilities of GTCC, GT has the highest failure rate, and its maintenance level greatly affects the operation rate (capacity factor) of the entire plant.

The high temperature parts of a GT, which are exposed to gases of 1,000°C or more, are seriously deteriorated and damaged during operation. Therefore, manufacturers have set the expected life for each of these high temperature parts and the recommended inspection intervals of the GT. Normally, it is necessary to inspect, repair, and replace these high temperature parts in accordance with the inspection interval until the service life is reached.

Because the high temperature parts of GT are made from super alloy materials of high heat resistance, special techniques and special facilities are required for the repair of these parts. Therefore, most users order GT manufacturer or other repair company to repair them.

a) Characteristics of GT long-term maintenance contract

In the operation of GTCC, it is common to sign long-term maintenance contracts such as LTSA, by which each GT manufacturing company performs maintenance for a certain period of time. The contract term is generally set for one cycle up to major inspection.

The characteristics of the LTSA (an example) are summarized in Table 8-2.

Table 8-2 Characteristics of the LTSA (an example)

	LTSA	Individual Order
Management of inspections, repairs, replacements for high temperature parts	Packaged management GT manufacturing company	Management by user
Stationed engineer (option)	Available	Not available
Payment of inspections, repairs, replacement costs for high temperature parts	Package price and payment of a set price each month. The same level as or less than total price of individual orderings. Supplier covers for unexpected repairs and replacements (excluding the case of user responsibility)	Payment of price for repairs and replacements at each inspection. User is charged for unexpected repairs and replacements

Source: JICA Study Team

In the case of LTSA, the supplier collectively manages the necessary scope and timing of inspection, repair and replacement of high temperature parts, instead of the user.

Furthermore, in the case of LTSA, the cost of inspection, repair and replacement of high temperature parts can be included in a package price. Since LTSA price is determined at the time of contract, it makes possible to stably manage expenses during operation by leveling variable costs with large fluctuations due to unexpected repair and replacement of the high temperature parts, for example.

b) Introduction of the LTSA into this Project

As described in Section 9.2.3, since the LTSA would greatly contribute to the stabilization of the power plant operation cost and company management, it is a preferable process from the viewpoint of financing planning. And TANESCO also requires to adopt an LTSA in this Project. Therefore, JICA Study Team recommends for this Project an inclusion of LTSA initial package for 6 year period that will start from COD.

c) Examination of the RMS

In the operation of GTCC, it is also recommended adopting Remote Monitoring System (RMS) to improve the operational conditions. RMS provides a service to monitor the operation status of the plant in real time at a remote monitoring center of the supplier by installation of a remote monitoring system. This service will provide the user with notifications of anomaly during the plant operation and support the trouble shooting when a trouble occurs. As a result, this service can contribute to improve the operation rate.

8) Difference between LTSA and Spare Parts as Initial Cost

i) LTSA covers GT and GT auxiliary.

ii) Spare parts as initial cost do not include parts in the LTSA supply scope. Spare parts include such as ST auxiliary spare parts like valve, packing etc., and do not include consumable.

These spare parts need to be prepared before COD.

8.1.2 Study of Basic Technical Issues

(1) Expected Performance of Tanzania GTCC

1) Candidate Models of GTCC

As examined in Chapter 4, there are four models with a rated capacity of around 300 MW.

From the viewpoint of operating experience, the GTs of these four Original Equipment Manufacturers (OEMs) mature with much operating experience, and are deemed to be suitable for the project. The OEM companies of GT and the model of GTCC are shown below:

Name of OEM for GT	Model of GTCC
MHPS	H-100 × 2 units × 1 block
IHI (GE)	LM6000 PF+ × 2 units × 2 blocks
SIEMENS	SGT-800 × 2 units × 2 blocks
GE	6F.03 × 2 units × 1 block

2) GTCC Performance Data on ISO Conditions

In the 2019 GTW Handbook, performance data of the above GTCCs models are described as the ISO conditions (101.33 kPa, 15°C, 60% RH) of natural gas. Necessary conditions other than ambient temperature and pressure are not specified. The performance data of the three GTCC models are described below:

Table 8-3　GTCC Performance Data - ISO Conditions

Model of GTCC	Plant Output (MW)	Plant Efficiency (%)
H-100	346.0 (Gross[※1]) 339.4 (Net[※2])[※3]	58.0 (Gross[※1]) 56.9 (Net[※2])[※3]
LM6000 PF+	270.0 (Net[※2])	55.3 (Net[※2])
SGT-800	326.2 (Net[※2])	58.6 (Net[※2])
6F.03	272.0 (Net[※2])	57.4 (Net[※2])

※1. Output of power generation end
※2. Output of power transmission end
※3. Estimated by JICA Study Team

Source: 2019 GTW Handbook

And the exhaust gas NOx emission value of each GTCC is described below.

Table 8-4　NOx Emission Value of each GTCC

Model of GTCC	NOx Emission Value (ppm)
H-100	9
LM6000 PF+	<25
SGT-800	≤ 20
6F.03	15

Source: JICA Study Team

3) Calculation Results of GTCC Heat Balance on Unfired Conditions

Performances of the three GTCC models in rated and maximum capacity based on the site conditions must be predicted to specify the performance requirements of the plant in the bidding documents. For this purpose, the heat balances at the rated and maximum capacity based on the site conditions are calculated, using the GT performance data of ISO conditions specified in the 2019 GTW Handbook, as shown below:

Table 8-5 Performance of Applicable GT Model

Model of Gas Turbine	H-100	LM6000 PF+	SGT-800	6F.03
ISO Base Rating (MW)	116.5	51.4	57.0	88.0
Efficiency (%)	38.3	41.7	40.1	36.8
Pressure Ratio	18.0	32.9	21.8	16.4
Mass Flow (kg/s)	296	136	137	219
Exhaust Gas Temp (°C)	586	492	565	622

Source: 2019 GTW Handbook

The net specific energy (lower heating value) of the natural gas is assumed to be 47,198 kJ/kg. This value is calculated from the fuel gas data received by TPDC. Based on the wide experience of dealing with this type of data, JICA Study Team corrected the performance data of the above GTs based on the site, inlet and exhaust conditions, in accordance with the various correction factors. The changes of inlet and exhaust pressure loss for the combined cycle configuration are also predicted. The preliminary site conditions are designated as shown in the table below, based on the site survey results:

Type of Site Condition	Rated Value
Dry Bulb Temperature (°C)	26.2
Relative Humidity (%)	76.5
Wet Bulb Temperature (°C)	22.6
Barometric Pressure (kPa)	101.3 (consider the level of HHWL+1.3m)

Based on a request from TANESCO, dry bulb temperature is set to 26.2°C using the TMA's daily temperature data of 5 years - from 2014 to 2018.

The GT's maximum capacity widely changes depending on the site ambient conditions (especially ambient dry bulb temperature). To determine the installation capacities of electrical and auxiliary equipment, the site ambient conditions for the GT's maximum capacity must be specified.

According to the records of over past 20 years of Mtwara, the lowest temperature is estimated to be +12.2°C. And the relative humidity at +12.2°C was measured to be 94%. From the viewpoint of effective use of power generation facility, 12.2°C is considered to be the lowest air temperature. Therefore, the installation capacities of electrical and auxiliary equipment shall be determined to meet the operating performances of GTs and the bottoming system at the ambient dry bulb temperature of 12.2°C. The relative humidity at the ambient temperature is 94%.

The seawater temperature in Kisiwa site is estimated based on the actual measurement result in this Study. The seawater temperature was measured during rainy season and dry season. Based on the measured temperatures of each season and considering the ratio of period between rainy seasons and dry seasons, the average seawater temperature is estimated to be 30.4°C.

Auxiliary power requirements, including the step-up transformers under the steady state conditions at 100% load of the plant, must be taken into account to obtain the plant net power output.

(2) Exhaust Gas Bypass System

In the case of a multi-shaft GTCC, the exhaust gas bypass system is usually equipped for a simple cycle operation due to many factors which may cause the bottoming system not to operate. This system will also be required when the GT power package of the topping system must be put into commercial operation in advance, separately from the bottoming system due to any impending power demand, such as in the Tanzania case. For this purpose, bypass stacks and dampers must be equipped in the high temperature gas stream between the GT exhaust system and the heat recovery steam generator. This system must cope with high temperatures around 500 to 550°C. Therefore, the system has the advantage of contributing to flexible operation, although the plant cost gets higher with lower operational reliability. Besides, performance loss may occur due to the leakage of GT exhaust gas into the atmosphere. Such issues are studied below.

1) Operational Flexibility

In case the GTCC has the exhaust gas bypass system, the plant can be transferred to a simple cycle operation without power failure when any trouble occurs in the bottoming system. The overall plant downtime can be reduced because the inspections and repairs to the bottoming cycle can be undertaken while operating the GT. As stated above, the operational flexibility of the plant shall be limited if it does not have the exhaust gas bypass system.

There is no difference between plants with and without the exhaust gas bypass system as far as the start-up generation capability of the plant is concerned.

2) Operational Reliability

Diverter or flap type dampers are normally utilized for GT applications with heat recovery steam generators and are exposed to above 500 to 550°C exhaust gas.

The damper shall be designed in such a way that they can be stably, smoothly and quickly operated, and shall maintain the minimal gas leakage loss over the lifetime of the plant. It appears to be rather difficult to design a damper, which can operate under such severe conditions. However, many dampers of the GTCCs are successfully operated today all over the world.

In order to use the exhaust gas bypass system, the following equipment and work are additionally required:

- A bypass stack with a silencer (depending upon environment protection requirements)
- A diverter damper
- A guillotine damper (for maintenance of the bottoming system during the simple cycle operation)
- Longer transition gas ducts and expansion joints
- Related site assembly, erection and civil work
- Other related costs such as shipping, management and commissioning

3) Phased Construction

If the exhaust gas bypass system is used, all construction works can be phased. This system will enable the operation of GT to start earlier. Separated construction sequences are usually adopted to meet the rapidly increasing power demand. The completion schedule of the phased construction plan is longer than the single phase construction plan, while the commercial operation of the GT can start earlier. The outline of construction schedule is shown below.

[Commercial operation of GTCC]

If the exhaust gas bypass system is used, start time of the entire GTCC commercial operation will be delayed by 1 to 2 months.

[Partial commercial operation of the GT/generator package]

If the exhaust gas bypass system is not used, it is impossible to perform partial commercial operation of the GT/generator package.

If the exhaust gas bypass system is used, it is possible to start partial commercial operation of the GT/generator package before 7 to 8 months of commercial operation of the GTCC without bypass system.

This advantage is to be evaluated by the plant purchaser depending upon the extent of power supply demand.

4) Performance

If the bypass system is installed, both the plant power output and efficiency will be slightly lower in comparison with the plants having no bypass system. Based on the estimation of JICA Study Team, the plant efficiency drops by about 0.1% (relative) in simple cycle operation and about 0.04% (abs) in combined cycle operation.

5) Other Viewpoints

A larger footprint area is required for the installation of the bypass system. In the case of H-100 GTs, an additional 10m length would be required.

On the contrary, in case a silencer is installed in the bypass stack, the steady and the proper function of silencer for the plant lifetime should be given attention, as it is exposed to high temperatures and high velocity of gas. Additional deliberate maintenance work is required to maintain the exhaust gas bypass system in a good condition so that it can be reliably used whenever it is necessary. Even though there are many GTCCs using exhaust gas bypass facilities worldwide.

6) Study Summary

As stated above, the operational flexibility of the plant will be enhanced with the adoption of the exhaust gas bypass system. And TANESCO has requested the use of exhaust gas bypass system due to the above merit. So, JICA Study Team finally recommends installing the exhaust gas bypass system for this project.

(3) Auxiliary Boiler

1) Necessity

In the case of a multi-shaft GTCC without a standalone auxiliary boiler, the GT can be started up along with the Heat Recovery Steam Generator (HRSG), independent of the steam turbine/generator. After a certain period of time, the necessary steam for start-up will become available from its own HRSG and then the steam turbine/generator can be started up under its own steam. However, the HRSG will be started up with a higher oxygen concentration in the HRSG inlet feed water than under normal operating conditions because, the start-up is without the gland sealing of the steam turbine.

The gland sealing of the steam turbine can be supplied from external sources before the GT and HRSG are operated. When the necessary steam for start-up becomes available from the external sources, the steam turbine/generator can be started up without any loss of time and the HRSG can be started up within the permissible oxygen concentration in the HRSG inlet feed water.

If a standalone auxiliary boiler is applied to this project, the tender shall recommend the specifications for a standalone auxiliary boiler.

2) Owner Requirement

The HRSG and auxiliary equipment will enable the shortest start-up time with the adoption of the auxiliary boiler.

However TANESCO supposes base load operation of Mtwara GTCC, and to meet this operation strategy, they do not require an auxiliary boiler.

(4) Gas Turbine and Steam Turbine Buildings

The GT and steam turbine buildings will protect the facilities from rain, wind and salt from the sea, and prevent facility deterioration due to rust, etc., and enable personnel to carry out the maintenance and management work without any disturbance from climate.

However, the buildings will need to have air-conditioning, fire-resistance and other facilities, and the related maintenance costs.

A review of the GT and steam turbine buildings is conducted, and the characteristics of the GT and steam turbine facilities with or without buildings are shown in the table below:

Table 8-6 GT and Steam Turbine Facilities With and Without Building

Review Items	Without Building	With Building
Building Facility	Base	• Building • Electrical wiring, air-conditioning facility, lighting, etc. • Overhead traveling crane • Fire/ smoke sensors • Fire protection facility
Building Facility Costs	Base	High
Running Costs	Base	High • Periodical inspection of overhead traveling crane, fire protection facility, etc.
Operability	Base	Good • No influence from wind, rain and sea water
Maintainability	Base • Need to prepare a crane for every work. • Bad workability at night. • Repair work may be impossible due to bad weather. • Not workable if flooding and submergence occur.	Good • Repair work is always possible in the case of problems, as an overhead traveling crane will be installed. • Workable at night. • No influence from the weather.
Equipment Facility	Base	✓ Rust can be prevented from seawater, etc.
Noise	Base	Small
Facility Reliability	Base	High

Source: JICA Study Team

1) Gas Turbine Building

Outdoor GT power generators are packaged, and there are many working examples in the world. The existing Kinyerezi I GT, which is also an outdoor type, is maintained in a good condition. The GT is covered with a compartment, having sufficient durability against the weather. Plant output and efficiency are impacted a little by rain, etc. For the GT power generator, from the viewpoint of extensive experience and economics, an outdoor type without a GT building is recommended.

2) Steam Turbine Building

The output and efficiency of a steam turbine are influenced by the steam temperature and pressure.

To maintain the steam temperature and pressure, thick thermal insulating materials are applied to the casing and the piping. The penetration of rainwater and seawater inside the insulating materials lowers the steam temperature and pressure, and also deteriorates the thermal insulating materials, steam turbine casing, piping, valves and other components. To maintain the steam turbine in a good condition for a long period of time, the casing, piping and valves need to be protected from the effects of water. Therefore, it is recommended to cover the steam turbine with the building or the enclosure.

In addition to the above, the enclosure type has been adopted for the Kinyerezi II power plant, and TANESCO requests the enclosure type for this project.

8.1.3 Plant Design Considerations

(1) Design Conditions

The GTCC shall be designed in accordance with the below-listed design conditions:

Table 8-7 Design Conditions

Design air temperature (dry-bulb) / relative humidity (performance guarantee point)	26.2℃/ 76.5%
Design minimum air temperature (dry-bulb) / relative humidity (generator maximum capacity point)	12.2℃/94%
Minimum/ maximum relative humidity	100%/30%
Minimum air temperature (dry-bulb) / maximum air temperature (dry-bulb)	12.2℃/35.9℃
Atmospheric pressure	101.3 kPa
Altitude	5.4 m
Seismic criterion	21~44 gal
Wind-resistant design (instantaneous maximum wind speed)	25knots
Annual average precipitation	3 mm/day
Maximum rainfall rate	232.7 mm/day
Snow load	0 kg/m^2

Source: JICA Study Team

(2) Standards and Criteria

1) Mechanical, Electrical and Control Devices and Equipment

Except for the items specially required in Tanzania, the GTCC shall be designed in conformity with the following international standards and criteria:

Japanese Industrial Standards (JIS)
US standards (ASME, ASTM, etc.)
IEC standards
ISO standards
British Standards (BS)
German standards (DIN)

JICA Study Team with TANESCO confirmed that the above standards and criteria are enough for the design of GTCC.

2) Engineering and Construction Work

Except for the case where specific standards and criteria shall be applied, engineering, designing and construction works shall be in conformity with the related standards and criteria of Tanzania.

(3) Site Layout

JICA Study Team studies the layout of the 300MW × 2blocks GTCC power plant. Figure 8-1 shows the typical GTCC layout plan of 2-on-1× 1 block. And Figure 8-2 shows the typical GTCC layout plan of 2-on-1× 2 blocks. Regarding the future expansion of 300MW GTCC power plant, the hot spot area with a temperature rise of 3°C from the baseline temperature is observed even in the mid-depth. In addition, the surface area with the 3°C rise is observed in a much larger area. Based on our environmental assessment, it is difficult to decide whether seawater cooling type for the 2nd GTCC can be adopted or not. After the 1st 300MW GTCC power plant starts commercial operation, the survey of actual discharge seawater condition is to be conducted. And in the figures, access roads are indicated by gray lines. The width of this access road is planned to be 10m considering the loading and transportation of huge heavy equipment.

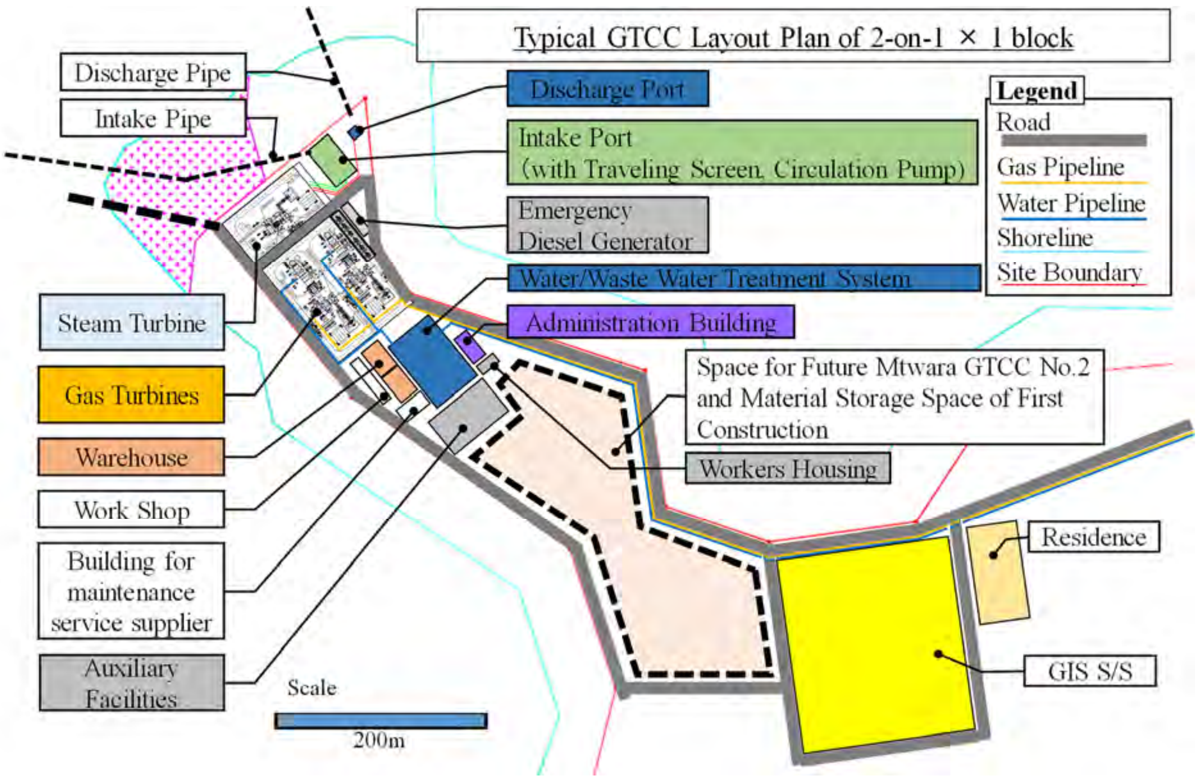
The study considers the following layout restrictions clarified through site investigation.

- For the power plant facilities excluding the intake and discharge cooling water facilities, a setback of 60 m from the coastline is considered as the environmental buffer zone.
- Minimize deforestation of mangrove forests
- Minimize intake and discharge cooling water facilities to reduce construction cost
- Avoid installing the power plant facilities in the salt fields, as they were prone to damage from storm surges in the past
- Avoid the area of ancestral cemetery

In addition, based on the assumption that the seawater cooled condenser is adopted, the location of the power plant should be selected in such a way that it is as close as possible to the intake facility, in order to reduce the power consumption of the circulating water pump.

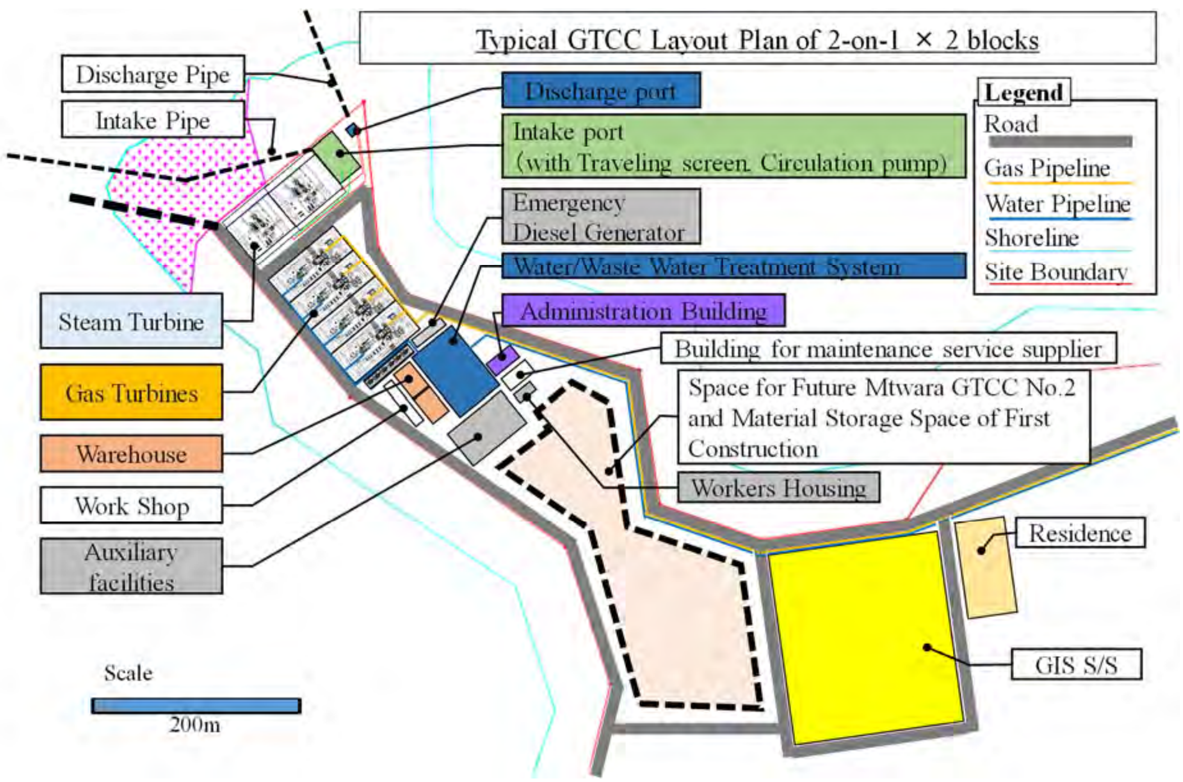
Assuming that the generation facilities are installed in the northwest part of the site, and the transmission line comes from the east part of the site, it is preferable that the switching facilities are located on the eastern part of the site, where the distance from the generation facility and the connecting point of the transmission line is short. JICA Study Team confirmed actual site conditions based on the layout plan indicated in Figure 8-1, because there is no big difference when compared to the other two types.

As a result, no critical issues are found in terms of layout plan.



Source: JICA Study Team

Figure 8-1 Preliminary GTCC Layout Plan (1 Block)



Source: JICA Study Team

Figure 8-2 Preliminary GTCC Layout Plan (2Blocks)

(4) Gas Turbine

1) Gas Turbine

The basic design functions required for the GT which will be employed for this project are described hereinafter. The GT shall be an open cycle heavy duty or an aero-derivative type. The GT shall be supplied from an original equipment manufacturer. In order to start power generation in a short-term, in response to the strong power demand, this GTCC shall be equipped with the exhaust gas bypass system.

The candidate GTs for this project are shown below:

Name of OEM	Type of Model
MHPS	H-100
IHI (GE)	LM6000 PF+
SIEMENS	SGT-800
GE	6F.03

The GT shall have an advance design to meet the NOx emission requirement for the operation of specified natural gas.

The GT design shall have a minimum number of bearings, and shall be located on a steel frame or on adequate steel structures and concrete foundation, sized for the transient maximum transmittal torque imposed on the shaft, in case of any short circuit of the generator and out-of-phase synchronization. The power output shall be taken out at the cold end of the shaft.

2) GT Inlet Air Cooling System

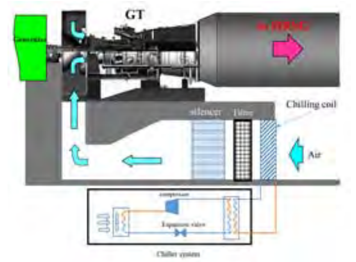
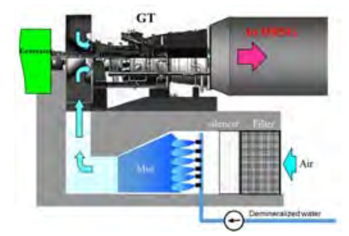
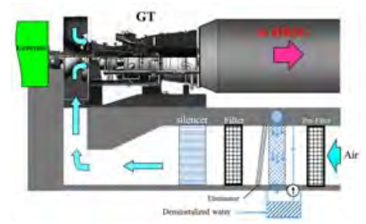
The GT may be equipped with the inlet air cooling system to increase the GT power output. There are mainly three types of inlet air cooling system, namely, evaporative type, fogging type and chiller type.

In the case of the chiller type, the intake air is cooled by the heat exchanger installed in the intake duct. In the case of the fogging type, demineralized water is sprayed from the nozzle installed in the intake duct. In the case of the evaporative type, demineralized water flows down inside the equipment installed in the downstream of the intake air filter. The intake air is cooled by utilizing the latent heat of evaporation. Unlike the chiller type, if we choose the fogging type or the evaporative type, relative humidity rises because of the amount of moisture contained in the inlet. The features of each type are shown in Table 8-8.

According to climate data recorded for the past over 20 years at Mtwara district, the highest temperature is 35.9°C. And the average humidity for the past five years is 76.5%. Both of the evaporative types are not suitable for this project due to the surrounding condition of high humidity. On the other hand, the GT inlet ambient temperature can be decreased more by utilizing the chiller cooling system. It is possible to decrease the GT inlet ambient temperature by more than 15°C with the chiller cooling system.

If a larger increase of the GT output is required, the chiller type is suitable. However, this type will require a huge initial cost and installation area. The adoption of this type is not consider in the Project.

Table 8-8 Features of Inlet Air Cooling System

	Chiller	Fogging	Evaporative Cooling
Type	Air cooling coil located in the inlet air duct room cools intake air by supplying cold water from chiller system.	The water droplets evaporate quickly, and inlet air is cooled.	Install the eliminator in the downstream of the intake air filter and let the demineralized water flow down. The intake air is cooled by falling water evaporation.
Configuration			
Advantage	• Relatively high increase of the gas turbine output • Air can be cooled regardless of humidity	• Low auxiliary power consumption • Low installation and operation cost • Installation required area is small	• Low auxiliary power consumption • Construction equipment is simple and easy to operate • Relatively low water consumption
Disadvantage	• High installation cost • High auxiliary power consumption	• Effect is lower in humid climates • Relatively low increase in the gas turbine output	• Effect is lower in humid climates • There is intake pressure loss even when not in use • Relatively it has the lowest increase in the gas turbine output (Because of low evaporation efficiency compare with fogging type)

Source: JICA Study Team

(5) Heat Recovery Steam Generator

HRSG is the facility that supplies steam to the steam turbine, which is generated by recovering the residual heat of the exhaust gas of the gas turbine. HRSG is classified into several categories. The classification is shown in the table below.

Table 8-9 Classification of HRSG Category

Exhaust Gas Flow Direction	Fluid Circulation Method	Reheating	Pressure
Horizontal Gas Flow Type /Vertical Gas Flow Type	Natural Circulation / Forced Circulation	Non-Reheating Type / Reheating Type	Single-Pressure Type / Multiple-Pressure Type

Source: JICA Study Team

Among these categories, the type of HRSG is selected according to the plant design conditions, gas turbine specifications, steam turbine, site space, placement conditions, etc. In addition, denitration facility is generally incorporated as an environmental countermeasure.

1) Exhaust Gas Flow Direction

The boiler main body is classified into vertical type and the horizontal type depending on the direction of gas flow. Regarding the exhaust gas flow direction of HRSG, in the case of adopting the same type as gas turbine, the degree of performance is almost same for both the vertical type and the horizontal type.

The horizontal type HRSG can get circulating force from the difference in fluid density caused by the heat transfer tubes vertically arranged, so the natural circulation is adopted for this type. For the vertical type, the heat transfer tubes are horizontally arranged, so there is either a natural circulation (circulating force is secured by a drum height) or a forced circulation (boiler water is forcibly circulated by pump). The features of each type are shown below.

Table 8-10 Exhaust Gas Flow Direction Comparisons

Description	Vertical Gas Flow Type	Horizontal Gas Flow Type
Installation Area	Base	Large
Height of HRSG	Base	Low
Scaffold for Internal Inspection	Unnecessary	Necessary
Support of Heat Transfer Tube	Suspension Type	Bottom Support or Top Support
Circulation System	Natural or Forced Circulation	Natural or Forced Circulation
Operability	Base	Same
Equipment Cost	Base	A little lower
Operation Cost	Base	Same

Source: JICA Study Team

2) Fluid Circulation Method

HRSG can be of natural or forced circulation type. In natural circulation units, the thermal head differential between water and steam-water mixture is responsible for the circulation through the system.

In forced circulation units, Boiler Circulating Pumps (BCPs) circulate the steam-water mixture through the tubes of the evaporator to and from the drum.

Advantages of the forced circulation design, are their quick warm/ hot start up capabilities.

However, natural circulation designs do not need circulation pumps to maintain the circulation of steam-water mixture through the evaporator tubes. Therefore, operating costs and concerns about pump failure or maintenance can be eliminated. The probability of using natural circulation type HRSGs is higher, because of the absence of critical rotating equipment such as the circulation pumps.

There is no difference in cold start up time because much of the time is spent on heating the metal and the water of the evaporator module in the transient heat up phase. This process is nearly the same, whether it is a natural or a forced type. In summary, both natural and forced circulations HRSGs are widely used in the industry, while the natural circulation design has some merits over the forced circulation design as discussed above. Hence the natural circulation type HRSG is proposed for this project.

3) Reheating / Pressure

The HRSG can be of, single-pressure type with single steam pressure level or multiple-pressure type with two or more steam pressure levels. And an additional reheater can be used to implement the reheating/ multiple-pressure type.

Although the multiple-pressure type is a more complicated system, and is more expensive than the single-pressure type, the heat recovery efficiency of the gas-turbine exhaust gas can be improved, thereby improving the plant efficiency.

In recent years, along with the increase in efficiency and capacity, owing to the enhancement of combustion temperature of the gas turbine, the steam system has come to use higher temperature / pressure and a reheating system, resulting in wider use of the reheating / triple pressure type, which can increase the plant efficiency more.

4) Conclusion

As described above, HRSG of both natural and forced circulation types are acceptable for this Project. However, the natural circulation type HRSG is preferred. With regard to the gas flow direction, horizontal or vertical gas flow types are both acceptable for this Project. There are also various types of reheating system and pressure type. These will be decided based on the manufacturer’s recommendation, and the layout will be proposed during the tender period.

5) Others (Duct Burner)

As a result of confirmation with TANESCO, there is no need to consider the duct burners. Therefore, the HRSG will not be furnished with duct burners.

(6) Steam Turbine

The steam turbine shall be of condensing type, directly connected to the generator.

The steam shall be downward or axially exhausted to the condenser, which is cooled by the fresh circulating water or seawater.

The steam turbine shall be of the manufacturer's standard with proven design and construction experience, to ensure economical and reliable service with minimum maintenance work. The steam turbine and auxiliary systems shall be designed to run continuously under all specified operating conditions for the specified lifetime of the plant.

The steam turbine’s maximum capacity shall be determined by the conditions of steam pressure, temperature, and flow as developed by the HRSG when the GT is operated on maximum capability ambient conditions.

The steam turbine shall be provided with the necessary number of scope ports for easy inspection of the operating conditions of the blades and rotor, at periodical intervals, if applicable.

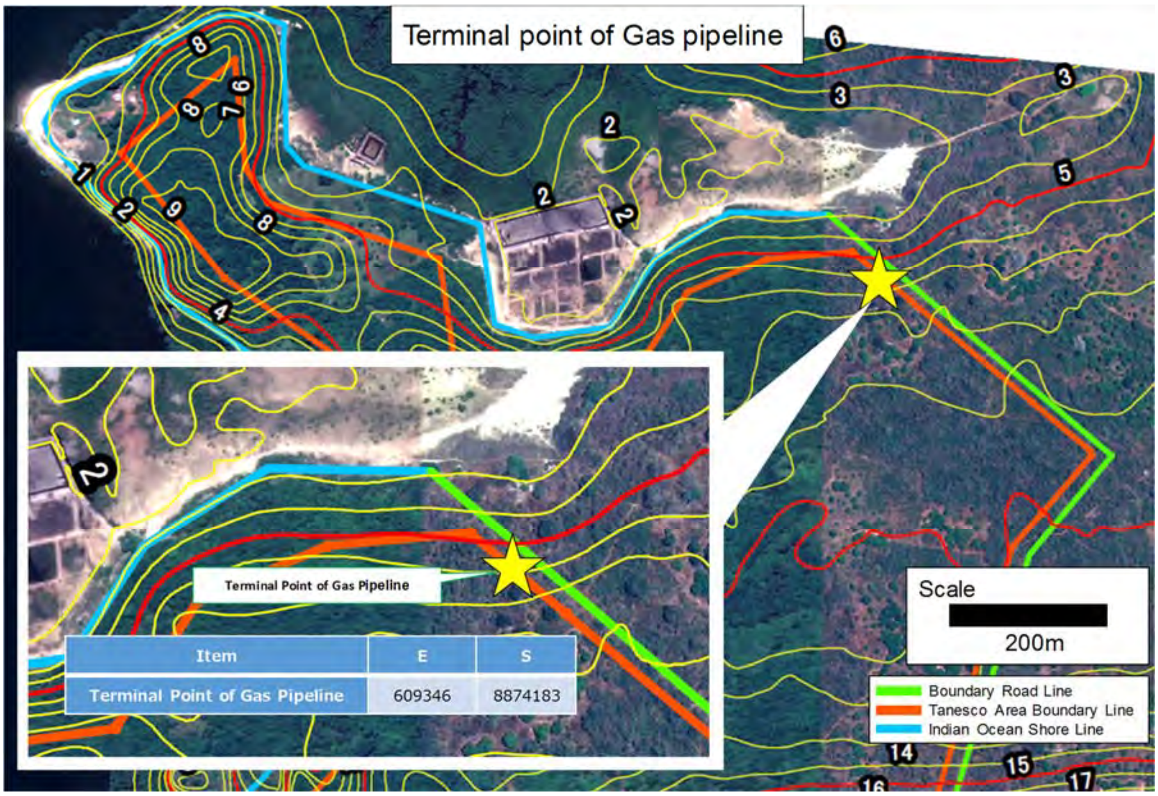
(7) Fuel Supply System

As mentioned in Section 4.2, fuel supply system should be installed at the site to operate gas turbine. Fuel gas supply system will have the following equipment to adjust the gas condition for firing in gas turbine.

- Shut-off valves
- Flow meter
- Separators for removing foreign substance
- Gas compressor or gas pressure reducing facility (If necessary)
- Gas heaters (If necessary)
- Gas flow and pressure regulating systems
- Gas detectors

- Fire extinguish system
- Gas sampling systems (if required)

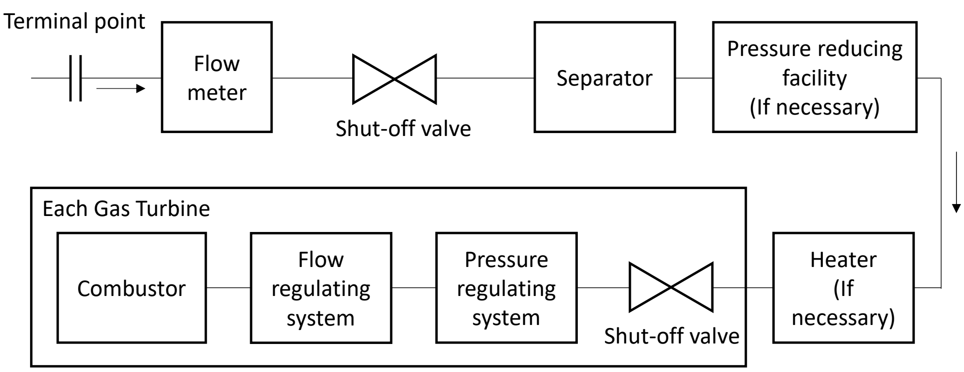
These equipment should be installed in the northeast of Kisiwa site. The figure shown below indicates the terminal points of gas supply.



Source: JICA Study Team

Figure 8-3 Terminal Point of Gas Supply Point

Specifications of these equipment are determined for the selected gas turbine requirements and gas specification. Terminal specification of the gas treated in fuel gas supply system should be confirmed by GT supplier during the tendering period.



Source: JICA Study Team

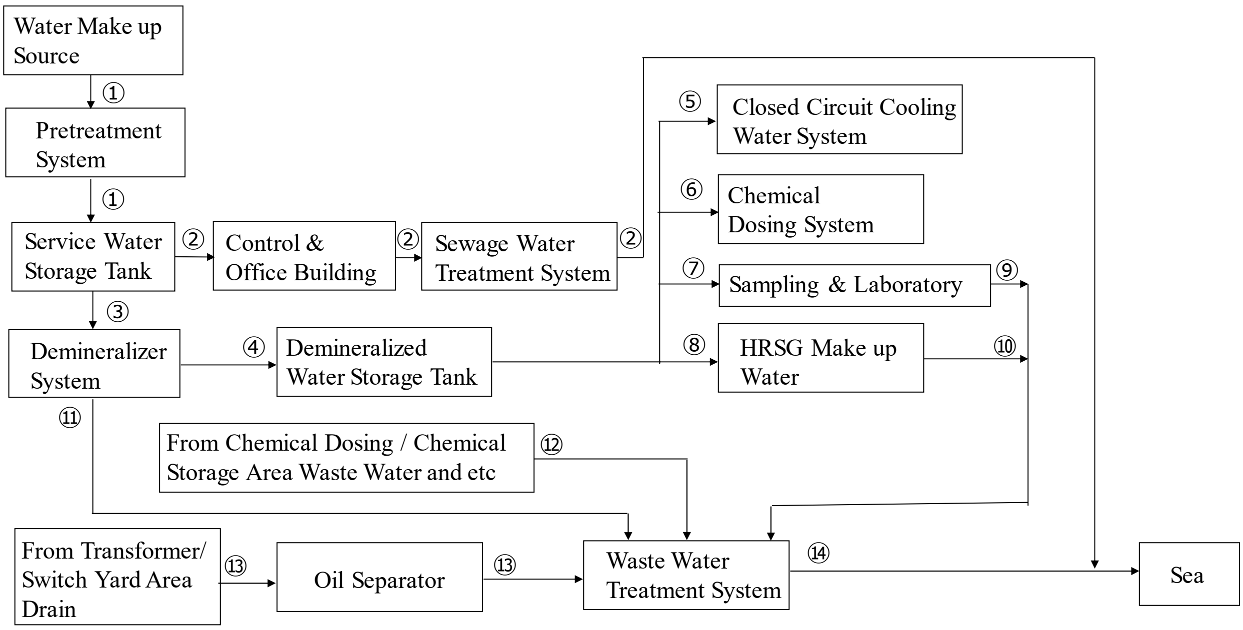
Figure 8-4 Preliminary Flow Diagram of Gas Supply System

(8) Water Supply and Treatment Systems

The water supplied to Kisiwa site will be the water used as demineralized water, drinking water, service water, water for fire-fighting, and water for miscellaneous use. And the water shall be sent back to the retreatment system, if necessary.

The demineralized water will be used as make-up water for the HRSGs, make-up water to the closed circuit cooling water system and water supply to chemical dosing system to keep the water quality. The EPC contractor shall confirm the quality of the produced demineralized water and check whether it is acceptable for the HRSG.

The demineralizer system will consist of chemical storage and regeneration equipment, etc. The necessity and specification of the pre-treatment system will be determined based on the quality of the supply water. The EPC contractor shall take appropriate countermeasures if required. The water treatment flow diagram is shown below.



Stream No.	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭
Flow (m^3/day)	300	80	220	160	45	5	30	80	30	80	60	15	45	230

Source: JICA Study Team

Figure 8-5 Water Treatment Flow (Water Balance)

(9) Wastewater System

Wastewater includes chemical drain from a demineralized water treatment facility, HRSG blow down water, floor drains from the GT and steam turbine buildings, and surface drainage of transformer area. Sewage and toilet drainage are treated by septic tanks. Chemical drains such as demineralized water treatment facility and HRSG blow down water are treated in a wastewater treatment system after the neutralization treatment. Floor drains from the GT and steam turbine buildings, and surface drainage of transformer area with some oil, are treated in a wastewater treatment system after being treated with an oil separation system. After wastewater treatment, the clean drainage is discharged to the sea.

(10) Fire Fighting System

In order to protect employees and facilities in the plant from fire, appropriate fire protection method shall be considered, such as securing separation distance between facilities, adopting fire-retardant or fireproof facilities, selecting appropriate firefighting system. Unless otherwise specified in Tanzania laws, NFPA 850 of National Fire Protection Association shall be applied as a standard for fire protection of the plant.

Fire area boundaries should be specified in consideration of the following.

- Types, quantity, density, and locations of combustible material
- Location and configuration of plant equipment
- Influences of the lost equipment by fire
- Location of fire detection and suppression system

Fire barriers for separating fire areas should be of a minimum 2 hour resistance rating.

Water supply for the permanent fire protection should provide water for 2 hours, and the hose stream should not be less than 1890 L/min. In case multiple fire pumps are required, the pumps should not be subject to common failure, and should be of sufficient capacity excluding the capacity of the largest pump. Based on the capacity of fire water tank from similar plant, approximately 1 × 700m^3 fire water storage tank will be considered in this GTCC plant. At the detail design phase, the accurate capacity of fire water storage tank will be decided according to Tanzania laws, NFPA and etc. According to TANESCO's requirement, a fire station with fire engines is basically necessary because this project is the first plant of the power complex.

The general combination of facility and firefighting system are shown in Table 8-11.

Table 8-11 General Combination of Facility and Fire Fighting System

Item	Facility	Firefighting System
1	Bearing for GT, ST and Generator	Carbon Dioxide Extinguisher
2	GT and ST Oil Tank	Carbon Dioxide Extinguisher
3	Generator Exciter room	Carbon Dioxide Extinguisher
4	Step up Transformer	Water Spray System
5	Office Building	Hydrant and Portable Extinguisher
6	Workshop and Storage	Hydrant and Portable Extinguisher
7	Cable Room	Carbon Dioxide Extinguisher or Water Splay System
8	Yard Area	Hydrant

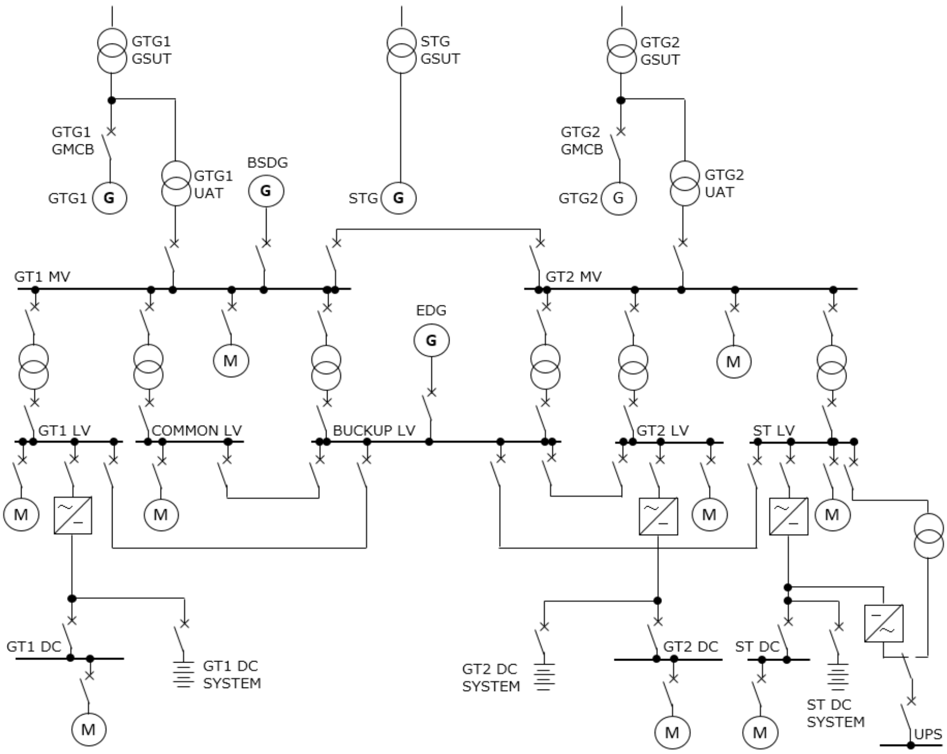
Source: JICA Study Team

8.1.4 General Specification of Electrical and Control System

(1) Electrical Facility

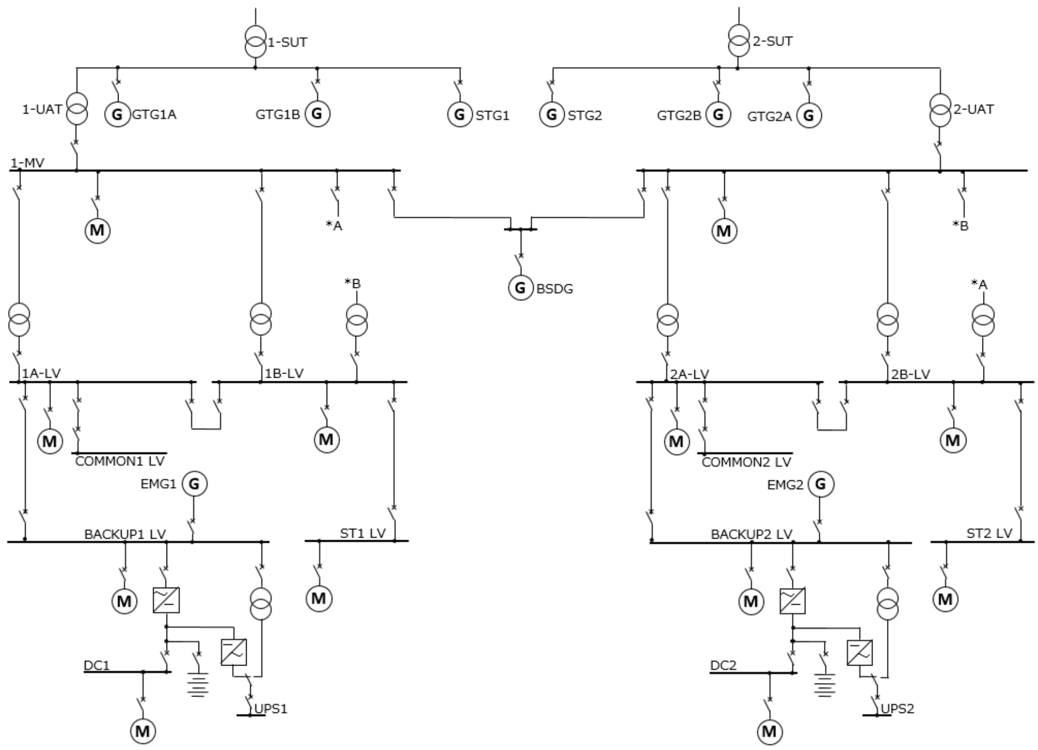
1) Outline of Electrical System

In order to supply power, step-up transformer circuit breaker will be used to connect a generator feeder to the grid system. On the other hand, in order to receive power to start up the power plant, Generator Main Circuit Breakers (GMCBs) will be disconnected and generator auxiliary transformers will be connected to the grid system via step-up transformers. Conceptual key single line diagrams are shown below.



Source: JICA Study Team

Figure 8-6 Conceptual Key Single Line Diagram of 1 Block



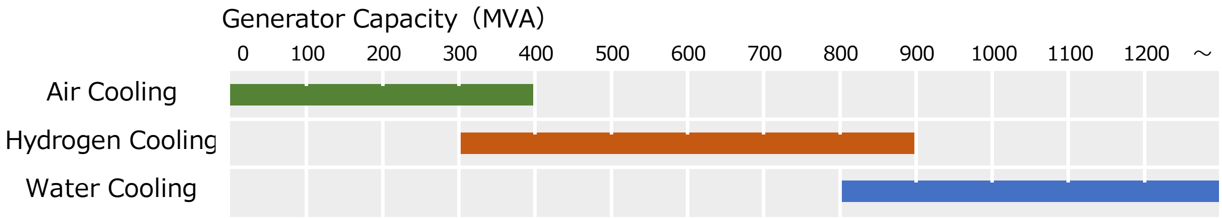
Source: JICA Study Team

Figure 8-7 Conceptual Key Single Line Diagram of 2 Blocks

2) GT and ST Generators

a) Generator Cooling System

A cooling system for generators is selected depending on manufacturer's conditions, etc. There are three types of cooling systems for generators as shown in Figure 8-13.



Source : Mitsubishi Electric Corporation, Turbine Generators General Catalog (January 2016) version

Figure 8-8 Generator Cooling System by Generator Capacity

For small to medium capacity generators, an air cooling system is generally adopted because of its simple structure and good maintainability. For medium to large capacity generators, a hydrogen cooling system is adopted because those generators require higher cooling performance than the air cooling system.

Hydrogen gas used for the hydrogen cooling system has the following characteristics.

(i) Since the density is low, windage and friction loss are small and the efficiency of the generator can be improved.

(ii) Since the thermal conductivity is high, the cooling effect is high and the generator can be miniaturized.

(iii) Since it is inactive, its impact on the deterioration of the insulator is small and the lifetime of the insulator can be long.

On the other hand, hydrogen gas may explode in the range of 7 to 76 (vol%) when mixed with air, so the generator frame should be kept in a sealed structure to avoid the make-up of explosive gas mixture. For this reason, accessories such as sealing oil devices and gas concentration control system are required, and the maintenance becomes complicated. The features of these cooling systems are compared in Table 8-12.

In the 300 MW class GTCC which will be studied, it is preferable to adopt the air cooling system from the viewpoint of capacity etc. It will be selected in accordance with the GT model.

Table 8-12 Feature Comparison of Cooling Systems

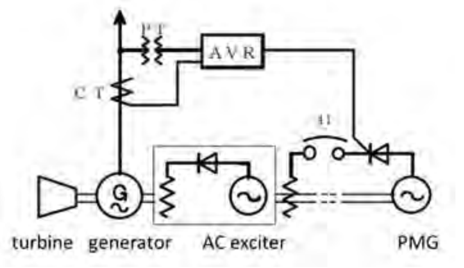
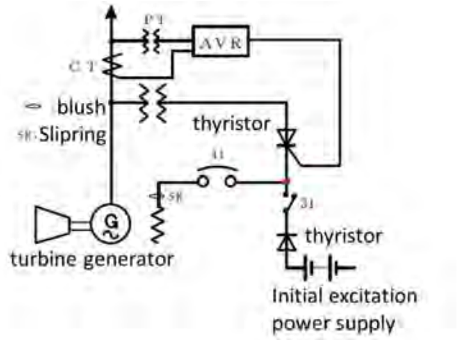
Item	Air Cooling	Hydrogen Cooling	Water Cooling
Cooling Performance	Low	Medium	High
Number of Accessories	small	large	large
Efficiency	～98.8%	～99.0%	～99.0%
Maintenance Work	Easy	Complicated	Complicated

Source : Mitsubishi Electric Corporation Turbine General Catalog (January 2016) version

b) Excitation System

Typical generator excitation systems adopted in thermal power plants are the AC excitation system (brushless excitation system) and the static excitation system (thyristor excitation system), which are classified according to the difference in the power supply devices. The configuration and features of these excitation systems are shown in Table 8-13. Although excitation system is usually selected by the manufacturer in accordance with the GT model, AC excitation system with less maintenance during operation is preferable because base load operation is assumed in this project.

Table 8-13 Comparison of Generator Excitation Systems

Item	AC Excitation System (Blushless Excitation System)	Static Excitation System (Thyristor Excitation System)
Configuration		
Accessories	(1) AC Exciter(Including Rotary Rectifier) (2) Permanent magnet generator	(1) Excitation Transformer (2) Rectifier Board (3) Slip Ring
Feature	- The output of the AC exciter is converted to DC by a semiconductor rectifier on the same rotation axis to supply the field current. - The field current is controlled by changing the voltage of the AC exciter. - Since the rectifier and the AC exciter are rotated together, a slip ring is unnecessary.	- The thyristor excitation system is composed of stationary devices and directly supplies field current to the generator using the thyristor. - The field voltage is adjusted by controlling the firing angle of the thyristor. Since there is no time delay due to the field winding of the exciter, the response speed of the excitation system is extremely fast. Therefore, it is suitable for peak loading. - Although the excitation power is supplied via the excitation transformer, a power source for initial excitation is required.
Maintenance Work	- Since there is no slip ring, care for the slip ring surface, inspection of the brush folder, the replacement of the brush are unnecessary. - Diodes and fuses of rotating rectifiers need to be replaced according to operation time.	- Care for the slip ring surface, inspection of the brush folder, the replacement of the brush are necessary. - The excitation transformer and the thyristor need to be inspected.

Source: JICA Study Team

c) AVR

AVR (Automatic Voltage Regulator) system shall include:

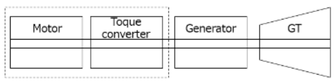
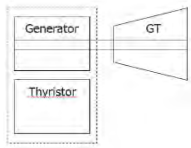
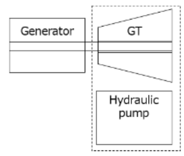
- Voltage regulator (90R)
- Field current regulator (70E)
- Under Excitation Limiter (UEL)
- Over Excitation Limiter (OEL)
- Power System Stabilizer (PSS)
- Load angle limiter

- Flux limiter
- Other necessary functions

d) GT Start up Method

It is necessary to have a starter device for speeding up the GT to the number of rotations. In general, GT start up method is determined by the manufacturer's standard. The configuration, features and the manufacturer of these GT start up methods are shown in Table 8-14.

Table 8-14 Comparison of GT Start up Methods

Item	Motor Drive Method	Thyristor Drive Method	Hydraulic Pump Drive Method
Configuration			
Outline	GT is accelerated by appropriate rotational torque made by the which motor and torque converter.	GT is accelerated by thyristor controlled generator which is used as a motor here.	GT is accelerated by the hydraulic motor whose oil is supplied by the hydraulic pump.
Feature	- The shaft is longer due to the starter system. - The starter system needs to be moved when generator rotor is withdrawn. - Additional lubricating oil system is required for the starter system. - Series start up is possible because the starter system is installed for each shaft.	- The shaft is shorter than the one used in motor drive method. - The starter system is shared by some of the GT shafts. In this case, series start up is not possible. - Starting current is larger. - Special generator is necessary to use the starter system.	- Series start up is possible because the starter system is installed for each shaft.
Manufacturer	- H-100 - SGT-800		- LM6000 PF+

Source: JICA Study Team

3) Generator Main Circuit

a) Generator Main Circuit Breaker

In order to supply power from the grid to the auxiliary transformer, a GMCB shall be installed between the generator and the generator step-up transformer. For the feeder which does not have the circuit to supply power to the auxiliary transformer, the GMCB can be omitted. The rated normal current of the GMCB shall be selected according to the capacity of the generator. The rated short-circuit breaking current shall be selected in consideration of the short-circuit current from the grid.

Specifications of the GMCB shall be:

- Type : SF6 insulation or vacuum insulation
- Continuous rated current : according to the manufacturer standard
- Rated voltage : approx. 11kV (according to the manufacturer standard)

b) Main Circuit Connection

Cross-linked polyethylene cable (XLPE) or Isolated Phase Bus (IPB) shall be installed between the generator and the GMCB, and between the GMCB and the generator step up transformer. Specifications of these circuits are determined according to specifications of the generator. XLPE shall be installed between the generator step up transformer and the main circuit breaker.

4) Transformers

a) Generator Step up Transformer

The generator step up transformer boosts the generator voltage to the transmission line voltage.

Specifications of the generator step up transformer shall be:

- Type	:	outdoor, oiled, one or three phase, 50Hz, load tap changer
- Rated capacity	:	approx. 70~450MVA (according to generator output and bus configuration)
- Rated voltage	:	Primary side; Switchyard bus voltage (approx. 400kV)
	:	Secondary side; Generator rated voltage (approx. 11kV)

b) Unit Auxiliary Transformer

The Unit Auxiliary Transformer (UAT) reduces the generator voltage to the auxiliary power voltage. The high voltage side of UAT shall be connected to the generator terminal. The voltage class of the low voltage side of UAT can be 6.6kV but shall be determined according to contractor's standard.

Specifications of the UAT shall be:

- Type	:	outdoor, oiled, three phase, 50Hz, load tap changer
- Rated capacity	:	approx. 5~9MVA (according to the design capacity of auxiliary power)
- Rated voltage	:	Primary side; Generator rated voltage (approx. 11kV)
	:	Secondary side; Auxiliary machines terminal voltage (approx. 6.6kV)

5) Emergency Power Supply System

a) Emergency Generator

For emergency generator, one diesel generator shall be installed for each unit. The Emergency Diesel Generator (EDG) is installed for the following purposes.

- To shut down unit safely in case of system blackout
- To prepare for immediate restart when power to start is received
- To secure disaster prevention security power

Considering the above purposes, the capacity of EDG shall be determined. In addition, the capacity for black start shall not be considered in EDG.

b) Black Start Generator

The black start generator is installed in order to start the power plant or the unit without receiving power supply from the grid, when a blackout occurs. For black start generator, one diesel generator shall be installed for the power plant. The capacity of Black Start Diesel Generator (BSDG) shall ensure that the unit can be restarted without receiving power from the grid. As described in Section 8.1.1(3) 5), the black start generator shall be installed in this Project.

c) Uninterruptible Power System (UPS)

UPS shall be installed in order to supply AC power continuously to important facilities, for which it is vital to avoid voltage fluctuation or loss of power supply. The UPS shall be composed of converter (AC to DC), inverter (DC to AC) and static switch to switch between UPS output and AC bypass.

Specifications of UPS shall be:

- AC input : 400V, 3 phase, 50Hz
- DC input : same as the DC battery voltage
- AC output : 230V, single phase, 50Hz

d) DC Battery

DC battery is installed for the following purposes.

- To supply power to facilities driven by DC voltage
- To shut down unit safely in case of system blackout until power from EDG is supplied
- To supply backup power when other emergency power supply fails

Considering the above purposes, the capacity of DC battery shall be determined. TANESCO has no standard for the voltage of DC battery, therefore the voltage depends on the manufacturer standard. According to the hearings with TANESCO, most of the power plants have 110V and some of the plants have 125V in Tanzania.

e) Protection of Main Electrical Facilities

Duplicated digital protection devices shall be installed for the protection of generators and transformers. AC and DC power input to these protection devices also shall be duplicated. The input to the lockout relay shall be determined based on the “AND” condition of outputs from each duplicated protection devices. The tables below show the basic configuration of protection relays.

Table 8-15 Generator Protection Relay

Item	Element
Generator step up transformer and generator differential protection	MG87
Generator differential protection	G87
Generator ground fault protection	G64
Generator negative sequence over current protection	G46
Generator excitation fault protection (loss of field)	G40
Generator over voltage protection	G59
Generator field over excitation protection	G53
Generator over current protection	G51
Exciter ground fault protection	E64
Generator voltage balance relay	G60
Generator directional over current relay	G67

Source: JICA Study Team

Table 8-16 Generator Step up Transformer Protection Relay

Item	Element
Generator step up transformer and generator differential protection	MG87
Generator step up transformer over current protection against ground fault	M51N

Source: JICA Study Team

Table 8-17 Unit Auxiliary Transformer Protection Relay

Item	Element
Unit auxiliary transformer differential protection	H87
Unit auxiliary transformer over current protection	H51
Unit auxiliary transformer over current protection against ground fault	H51N

Source: JICA Study Team

6) Methods to Conduct Pre-commissioning and Commissioning

a) Pre-commissioning

Pre-commissioning means test run of facilities excluding gas and steam turbines, generators and HRSGs. In the pre-commissioning phase, it is not possible to supply electrical power from the power grid. This is because, this project is in a green field, and there are no transmission lines to receive power. Therefore, electrical power will be supplied from temporary power supply facilities for the construction works or EDG / BSDG.

b) Commissioning

Commissioning means test run of gas and steam turbines, generators and HRSGs. Since the 400kV new transmission lines and 400kV new substations will be constructed by the time of commissioning, electrical power for commissioning will be supplied from the power grid. Specifically, power will be supplied from the 400kV bus of 400kV New Mtwara substation to each facility via generator step up transformer and unit auxiliary transformer.

(2) Control and Monitor System

1) Basic Design of the System

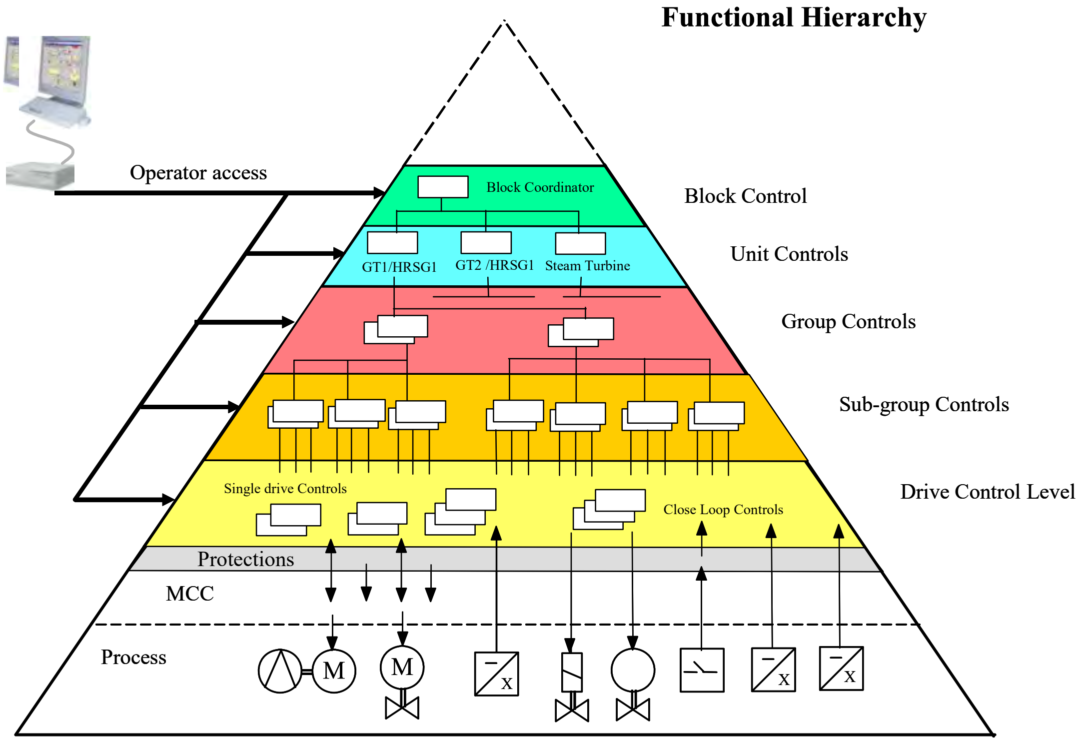
DCS (Distributed Control System) is used as the control system of Mtwara GTCC power plant. The DCS is a system that realizes control of the entire plant by distributing the controllers and integrating them, and is composed of man-machine interface units, control units, input /output units, network units, power supply units, detection units, driving units, etc. For maintenance work by operators, maintenance tools shall be installed. The maintenance tools shall have the functions to change control circuits settings and system diagrams settings.

2) Automation of the Power Plant

The purpose of plant automation is: 1) to rationalize the normal operation, and start up / shut down operation, 2) to ensure safety, reliability and flexibility of operation, 3) to operate with high efficiency. In order to realize these goals, the automation system is designed so that operators can conduct the start up and shut down operation, normal operation and special operation in the central control room.

In order to prevent a failure that will affect the entire plant, the automation system is hierarchized and decentralized. Specifically, the system is hierarchized into the several control levels that control and monitor the entire plant, the unit control, and the drive control. For reference, a functional hierarchy of the automation system is shown in Figure 8-16.

At the unit control and drive control level, in order to prevent some faults from the entire unit, the control devices are distributed and kept independent. Each control function is distributed to gas turbine control, heat recovery steam generator control, steam turbine control, etc. Moreover, owing to the distribution of the control device, the maintenance of the device can be performed without affecting the operation of the generation unit, as much as possible.



Source: JICA Study Team

Figure 8-9 Example of the Functional Hierarchy of the Automation System

- Block Control
  This hierarchy level is the highest in the functional hierarchy, and it is possible to start up and shut down the plant automatically, maintain the cooperative operations of the gas turbine, heat recovery steam generator and steam turbine during normal operation, and control the load.

- Unit Controls
  In this hierarchy, it is possible to control the main unit of the block (such as gas turbine, heat recovery steam generator, steam turbine) at the preset state.

- Group Controls
  In this hierarchy, the related sub-group controls and drive control levels are integrated and controlled by specific processing, such as, supplying water to the boiler by driving the feed water pump.

- Sub-group Controls
  In this hierarchy, single drive controls can be combined with blocks of controls by automatic sequence execution or specific processing. The operator can start and stop all devices associated with the sub-group controls through sub-group controls or group controls.

- Drive Control Level
  In this hierarchy, control of individual devices is possible. Individual devices can be controlled either by a higher level sub-group control or by manual operation. In consideration of safety, manual operation at the drive control level is prioritized and control by other automation hierarchies is restricted.

3) Communication System

a) Telephone System

In order to communicate with workers in the power plant, cordless extension telephones shall be installed. Extension calls and connections to the public telephone network shall be made via a private branch exchange. According to the hearings from TANESCO, the above described system using wire telephone network are installed in many power plants. But in some power plants, cell phones using wireless telephone network are adopted, because of the small number of operators and engineers in these plants. In this project, the former system is suitable because many operators and engineers will work in the Mtwara GTCC power plant.

b) Local Area Network System

In order to connect to the internet and intranet, the Local Area Network (LAN) system shall be built in the central control room, office room, etc.

c) Clock System

Clock system shall be synchronized with the DCS, the main control devices and SCADA system.

d) Closed Circuit Television System

Closed Circuit Television (CCTV) system shall have the functions of automatic patrol, manual operation, zooming, record. CCTV system shall be installed to monitor the following facilities.

- Important facilities for disaster prevention such as gas turbine, gas station, auxiliary boiler, etc.
- Facilities to be monitored for emission or discharge in accordance with environmental restrictions are stack, water intake facility, water discharge facility, etc.
- Other necessary facilities, where it is difficult to inspect by patrol inspection or those which can be intruded by any person without permission.

4) Physical Security System

Based on the hearings from TANESCO, there is a plan to construct two types of security control center. One is integrated center which will be constructed at the new TANESCO head office. Other is the local center which will be constructed at each power plant. Each security control center will be constructed within one or two year. The information sent to the security control center is the surveillance camera and intrusion alarm. Based on the intrusion alarm, surveillance camera will focus on the intrusion point and an operator at the integrated center will instruct action to an operator at the local center. In this project, the above described security information shall be sent to the guard room, so that the guard room can play the role of a local center. In addition, this security system shall be designed and modified in order to send such information to integrated center via Optical Ground Wire (OPGW) when the integrated center will be constructed in the future.

a) Guard Room

In order to prevent un-authorized entry into the Kisiwa site, the boundary of the site shall be surrounded by a fence. In addition, a guardhouse shall be constructed near the gate so that guard keepers can manage the people entering the site.

b) Intrusion Alarm System

In order to monitor the entry in Kisiwa site, the intrusion alarm system such as touch detection wire shall be installed on the fence, near important facilities. Intrusion alarm shall be sent to the guard room.

c) Surveillance Camera

As mentioned in Section 8.1.4(2) 3) d), surveillance cameras shall be installed around the Mtwara GTCC power plant for security.

8.1.5 Scope of Work

(1) Procurement and/or Manufacture

The contractor shall procure and manufacture the following facilities including all the equipment and materials related to operation, etc. However, the facilities to be procured and manufactured may not be limited to the following facilities.

1) GT, power generators and related facilities
2) Steam turbines, power generators and related facilities
3) Once through type seawater cooled condenser and related facilities
4) HRSGs and related facilities
5) Stacks
6) Fuel gas accepting facility
7) Fuel gas pipe line (from terminal point at site boundary to each facility)
8) Fuel gas compressor or gas pressure reducing facility (if necessary)
9) Gas treatment facility
10) Indirect gas warmer (if necessary)
11) Service and instrument air supply facilities
12) Generator step-up transformer
13) Auxiliary transformers
14) Switch gear for generator
15) Middle and low voltage power supply devices
16) Emergency generators
17) UPS and DC power supply devices
18) Cables (electric power, Instrumentation and Control (I&C))
19) Cable trays and duct facilities
20) Control and instrumentation facilities
21) Facility information system
22) Continuous environmental monitoring facility

23) Simple simulator facility
24) Drain recovery facility
25) Bearing coolant facility
26) Water supply and treatment facility and wastewater treatment equipment
27) Outdoor piping, trenching and covering
28) Fire protection facility
29) Ventilation and air conditioning facilities
30) Outdoor and indoor lighting
31) Outdoor drainage and clarification facility
32) Piping and facility foundation
33) Construction materials
34) Steam turbine building (steel frame, exterior, roof, windows, louvers, etc.)
35) Buildings for other facilities
36) Office building (including central control room and electricity room)
37) Workers' living quarters
38) Restrooms and shower rooms
39) Roads
40) All civil works including foundations for supplied equipment, buildings and houses
41) Temporary structure construction and facilities related to construction
42) Preparation, excavation and leveling work of site area including temporary storage area during construction and preparation of access road for transporting-in heavy components
43) Fencing around the new plant site, access road to stored equipment, and drainage inside the new plant site
44) Necessary temporary facilities on the downstream side from the connection points of utilities such as electric power and water, etc., necessary for construction
45) Paint/coating materials for equipment and materials
46) Spare parts for periodical repair
47) Standard and special tools
48) RMS (Remote Monitoring System)

(2) Works and Services to be provided by Contractor

The scope of work of the Contractor shall include the design of the new GTCC including design and manufacture of equipment, tests, transportation, installation, construction, trial operation and performance tests thereof.

The construction scope of the contractor shall include the preparatory construction in the early phase including the power supply for construction, the construction of temporary facilities for trial operation and tests that are necessary for the pre-commissioning of the power generation facility, and the construction of the permanent facilities.

The work scope of the contractor shall include technical instructions to the sub-contractors and the equipment suppliers, so that the operation of the power generation facility can be commenced along with the training of operation and maintenance personnel for the newly-installed power generation facility.

In cooperation with the TANESCO GTCC operation personnel, the contractor shall start and continue instructing the operation personnel for the smooth start-up of the entire plant Note that any additional construction and work items shall comply with the agreements of the contract.

1) Engineering Services

1) Engineering and structural facilities
2) Architectural facilities
3) Mechanical facilities
4) Chemical facilities
5) Electrical facilities
6) Control and instrumentation
7) Switching station facilities
8) Power flow calculation for electrical facilities

2) Documents and Drawings

The newly-installed power generation facility shall be equipped with all equipment mentioned in this Section. The required documents in the purchase specifications may not be limited to the below-listed design documents. The asterisked documents are those that shall be submitted at a minimum for the approval of TANESCO. Within thirty days from the contract, the contractor shall submit a list of drawings and documents.

*1) Facility design criteria

*2) Premises layout

*3) Floor-by-floor equipment layout

*4) Heat balance diagrams

*5) Skeleton diagrams

*6) Facility piping and measurement drawing

*7) Building front view and elevation

*8) Entire plant control block diagram

*9) Purchase specifications:
- GT
- Steam turbine
- HRSG
- Once through type seawater cooled condenser
- Feed and condensate pumps
- Power generator and exciting arrangements
- Transformers (generator step-up, and auxiliary transformers)
- Middle-pressure metal clad switchgear
- Distributed Control System (DCS) and data storage unit

*10) Performance test procedure

11) Concrete foundation and structure drawings
12) Purchase specifications of major equipment
13) Design study and evaluation
14) Detailed designs
15) Logic diagrams
16) System diagrams
17) Wiring diagrams
18) Facility instruction manuals
19) Test and inspection schedule
20) Trial operation instructions
21) Test and inspection report
22) Performance test report
23) Operation manual
24) Maintenance manual
25) Equipment manuals (including catalogs)
26) Installation instructions
27) Complete documentation

3) Construction and Trial Operation

The contractor shall execute the following work with regard to construction and trial operation of the newly-installed power generation facility. However, note that the work items may not be limited to the followings.

1) Supervision of construction
2) Management of construction schedule
3) Preparation and control of construction workers and preparation of tools to be used by them
4) Preparation of construction machines
5) Safety and loss control program
6) Quality assurance program
7) Procurement promotion assurance
8) Receiving, handling and storing devices and materials
9) Preparation condition check, tests, start-up and trial operation
10) Supplying lubricants necessary for start-up, tests and operation in the early phase and chemicals necessary for water treatment and chemical analyses
11) Supplying lubrication devices and lubricants for flushing and filling in the early phase
12) Performance and reliability tests
13) In-factory and on-site training of operation/maintenance personnel from TANESCO

14) Support supervision of operation and maintenance for six months after the acceptance test by three engineers resident on site (i.e., mechanical, electrical and control)
15) Completion of construction
16) Construction of warehouse
17) Safety and medical aid during construction
18) Participating in arrangement meetings required by TANESCO and other meetings
19) Payment of lodging expenses, wages and traveling expenses with regard to factory tests and inspections
20) Obtaining local, provincial and national approvals and authorizations necessary for construction of the newly-installed power generation facility

4) Participating in Design Meetings

In order to appropriately execute the design works of the power plant, it is recommended that periodical meetings be held with TANESCO, the contractor and the consultant.

The design meeting shall be held every month at least. The meeting shall be separated into four or more working groups including engineering, mechanical, electrical and instrumentation/ control working groups.

All the documents and drawings to be discussed at each design meeting shall be submitted to TANESCO at least one month prior to the meeting. To obtain the approval of TANESCO and the consultant, the contractor shall, within one month after commencement of work, submit a list of participants, a list of discussion items, detailed schedule documents and a list of drawings, as well as a design meeting schedule with regard to the requirements from TANESCO. To complete the project as scheduled, TANESCO will review and supervise the contractor's designs and construction with the assistance of project implementation consultant (PIC or the Consultant, hereinafter)

(3) TANESCO's Construction Work and Work Items

TANESCO will execute the following construction work and items with regard to the newly-installed power generation facility:

1) Supplying water, natural gas and electric power from the pre-commissioning stage

2) Supplying power for start-up

3) Preparing an environmental assessment

4) Supporting the obtainment of all approvals and authorizations necessary for the construction and operation from related authorities

5) Offering information on natural gas and electric power loads for trial operation and assurance and reliability tests

6) Evaluation of the periodical data and information with regard to the operation and maintenance during the two-year guarantee period

7) Preparation of on-site staffs, facilities and tools with regard to inspection to be executed after the expiration of the guarantee period

(4) Terminal Points

The terminal points of fuel gas and water are shown in Section 4.2. (Figures 4-18 and 4-23)

8.1.6 Civil and Architectural Works

(1) Major Components of Civil and Architectural Works

The major architectural and civil facilities for the Mtwara GTCC power plant at Kisiwa site are described below.

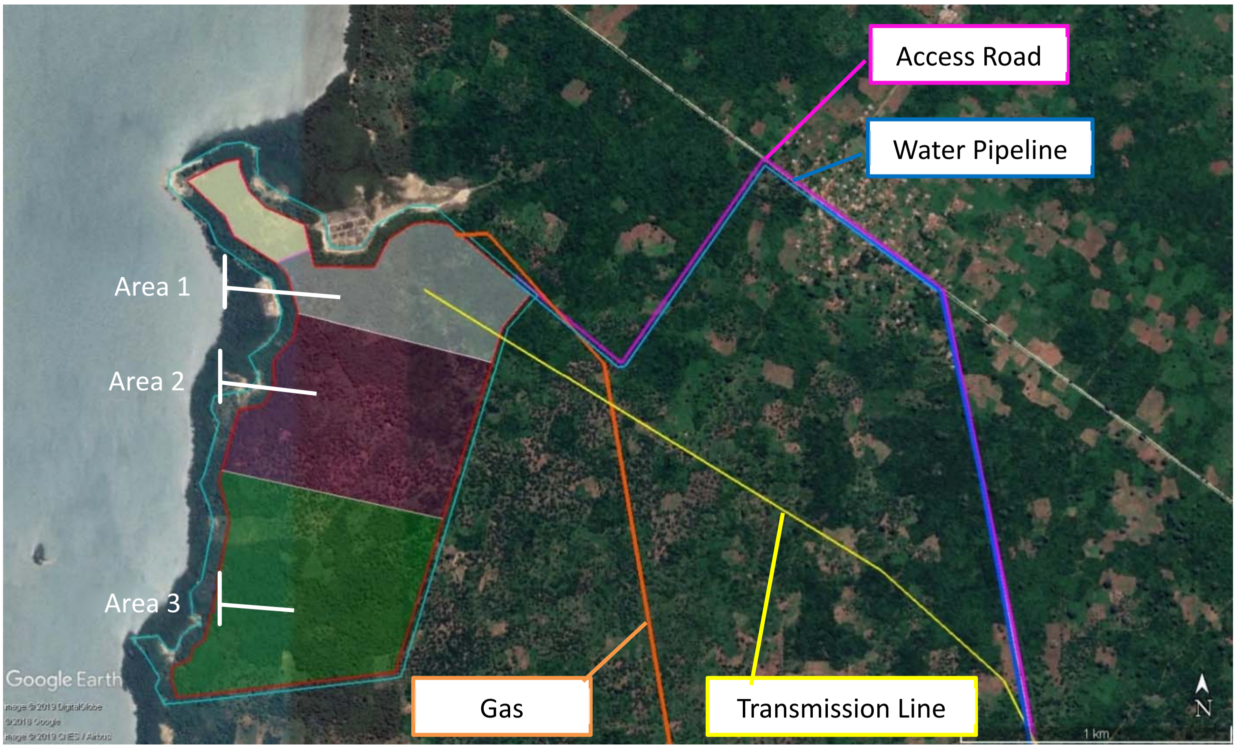
1) Plant site development (including site preparation, disposal of waste soil, material and equipment yard, unloading area, cut/fill work)
2) Turbine and generator buildings
3) Administration and control building
4) Warehouse and other buildings
5) Sea water intake and discharge channel
6) Foundation works
7) Road works (access road and administrative road)

Since the existing civil and architectural facilities will be used for the 400kV New Lindi substation, the necessary civil and architectural works for facilities shall be carried out at Kisiwa site.

(2) Plant Site Development

1) Draft Master Plan of Kisiwa site Land Utilization

As described in Chapter 4, JICA Study Team recommends to divide Kisiwa site into three (3) areas as shown in Figure 8-10 to efficiently utilize the site area.



Source: JICA Study Team

Figure 8-10 Development Plan at Kisiwa Site

Draft land-use plan of Kisiwa site is as follows in the light of topographic condition;

Area 1, which has an area of 34 ha and colored in gray and yellow in Figure 8-10, is leveled at altitudes between 5 to 8 m above sea level, and power plant facilities consisting of 300 MW × 2 GTCC (Phase-I and II) and 400kV substation will be constructed.

Area 2, which has an area of 47 ha and colored in red, is planned to be leveled at altitudes between 12 to 17 m, and future power plant facilities of 300 MW × 6 GTCC (air cooled type) are planned to be constructed here.

Area 3, which has an area of 50 ha and colored in green, is planned to be leveled at altitudes between 20 to 25 m and to be used as residential area for the personnel in charge of operation and maintenance of the power complex.

All related facilities of the Project, which are targeted in this preparatory survey will be settled within Area 1.

Since the current terrain of the site is gradually sloping upward from Area 1 to Area 3 with many uphills and downhills, it is hardly possible to use each area without land leveling work. Therefore, draft land leveling plan of Kisiwa site is proposed in consideration of the balancing cut and fill soil volume and land-use plan of the power complex.

2) Ground Elevation of the Area 1

In order to determine the ground level for thermal power generation plants located near the coastal sea area, the following aspects should be considered. Generally, ground level (GL) is configured at the highest high tide plus allowance height (1- 2 m) according to the Design

Guideline of Thermal and Nuclear Power Plant Civil Engineering Structures (Japan Electric Power Civil Engineering Association, 1996).

a) Highest high tide (Safety from natural disasters)

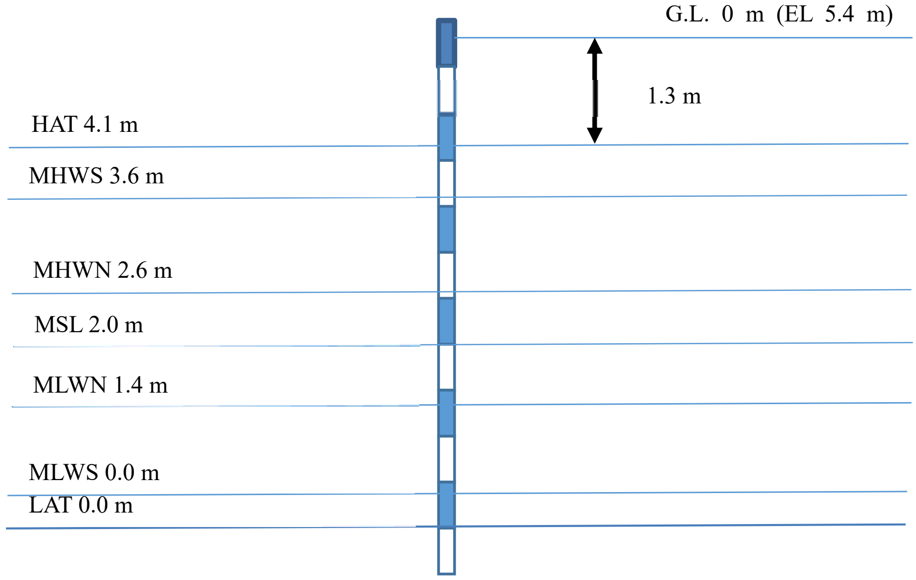
According to the result of the site condition study described in the Chapter 7, the highest tide in Mtwara port is 4.1 m, and high tide due to cyclones and tsunamis has never been recorded.

b) Efficiency of operation (economic performance)

As per the requirement mandated by GTCC power generation, the ground level for the GTCC should be set at a low altitude, as much as possible.

c) Rainwater drainage

To drain rainwater in the site safely, allowance height is set as 1.3 m based on the experience of JICA Study Team.



Source: JICA Study Team

Figure 8-11 Relationship between Tidal Levels and Ground Level of the Site

In consideration of the above aspects, JICA Study Team set the design ground elevation level of Area-1 at 5.4 m (HAT 4.1 m + 1.3 m).

Highest Astronomical Tide (HAT)	4.1 m
Mean High Water Springs (MHWS)	3.6 m
Mean High Water Neaps (MHWN)	2.6 m
Mean Sea Level (MSL)	2.0 m
Mean Low Water Neaps (MLWN)	1.4 m
Mean Low Water Springs (MLWS)	0.4 m
Lowest Astronomical Tide (LAT)	0.0 m

Source: TPA (Mtwara Port Office)

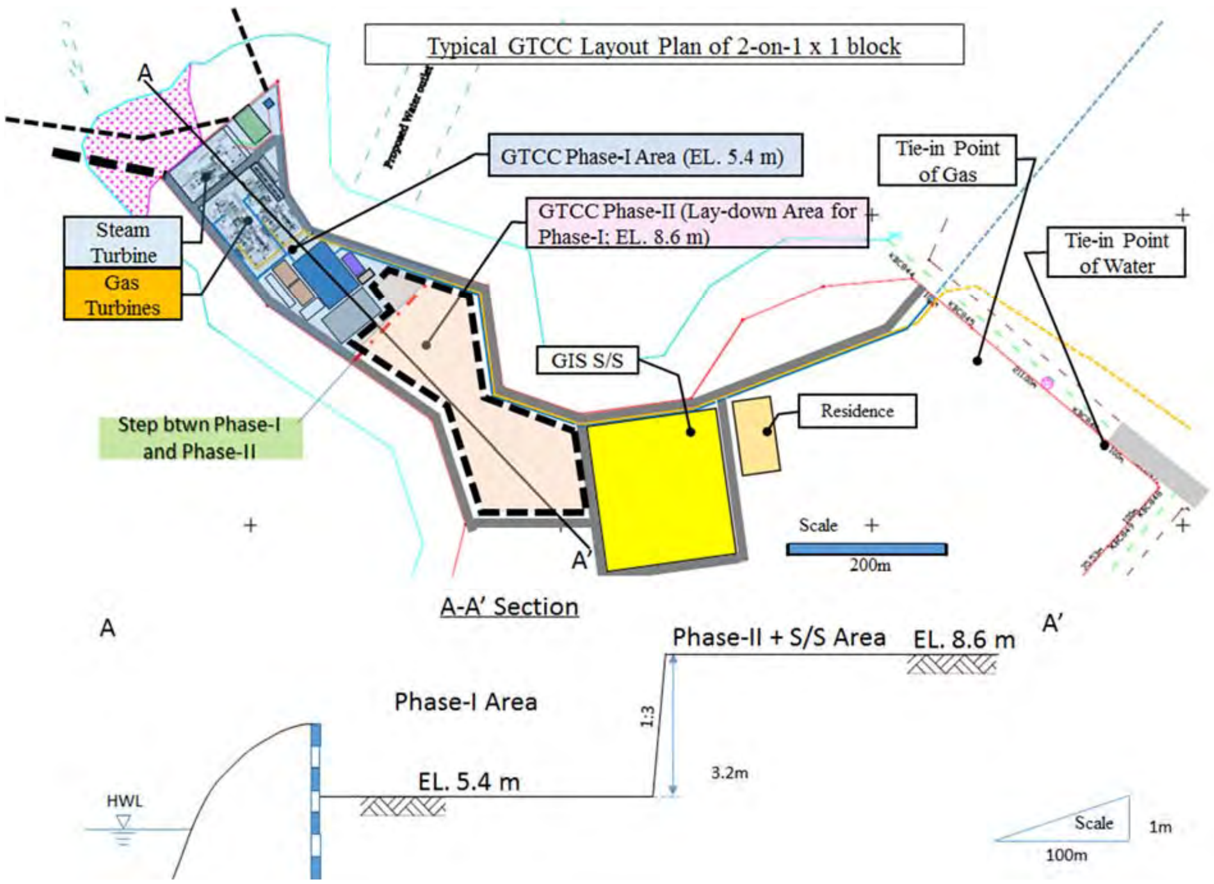
3) Plan of the Area 1

In case the ground level of Area-1 is leveled to the height of 5.4 m, huge quantities of surplus soil (over 1,000,000 m^3) will be excavated and it will be relatively time-consuming and costly.

In order to reduce volume of earth works, a slope is formed between Phase-I and Phase-II area in consideration of the following conditions;
Since Phase-II area may be used to lay down GT/ST equipment of Phase-I, road gradient should be below 3 percent (3/100) to allow passage of long trailer trucks.

Length of the slope is approximately 110m, thus the height difference between Phase-I and Phase-II is 3.2 m. An image of the Phase-I and Phase-II area is shown in Figure 8-12. Accordingly the height of Phase-II area will be at 8.6m.

As a result of the above consideration, volume of earth works can be reduced from 1,000,000 m^3 to 340,000 m^3 approximately.



Source: JICA Study Team

Figure 8-12 Ground and Sectional Plan of Phase-I and Phase-II Area

4) Proposed Elevation of Area 2 &3

Surplus soil from Area 1 excavation is filled in Area 2 and Area 3, in order to utilize such surplus soil for future development. In consideration of the balancing cut and fill volume, ground elevation of Area 2 is set between 15 - 16 m and the ground elevation of Area 3 is set between 20 - 21 m above sea level as shown in Figure 8-13.

Therefore, in the draft site development plan, the proposed ground elevation of the Area 1 is EL 5.4 m and EL. 8.6 m, and for Area 2: it is EL 15 m, and for Area 3: it is EL 20 m for the related consideration of this Study.

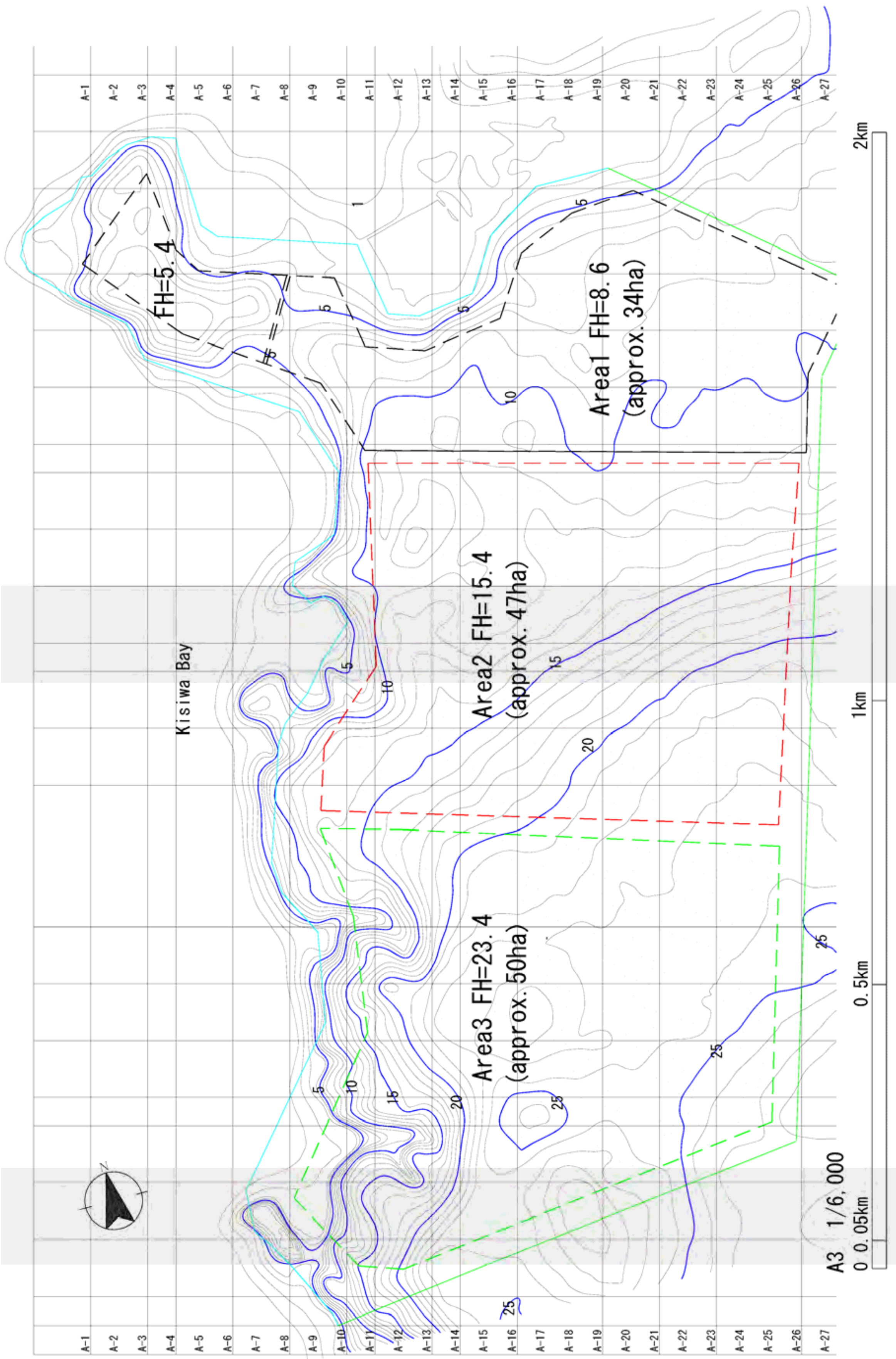
Boundaries between Area 1 and Area 2, and Area 2 and Area 3 are formed by slopes with a height difference of 6.4 m and 5 m.

5) Plan of Retaining Wall in the Area 1

The power plant and its facilities (Phase-I) need to be installed in the limited and narrow area of Area-1 along the coastal line. Referring to Figure 8-1 and Figure 8-2, JICA Study Team determined that there is no space to form slopes by land reclamation. Therefore, GTCC Phase-I area should be enlarged as much as possible.

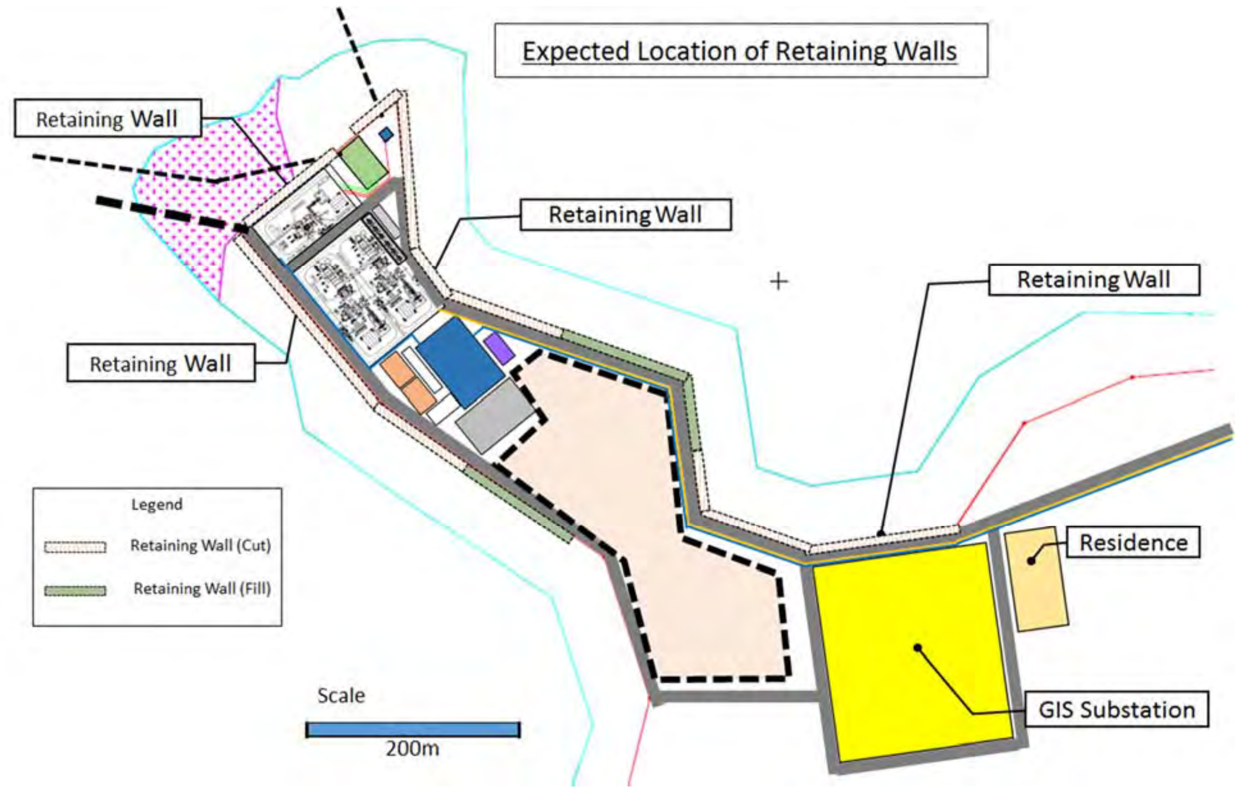
Due to the above condition, retaining walls have to be installed on the site boundary lines in order to use this narrow land effectively.

Places where retaining walls are installed, are indicated in Figure 8-14 and the conceptual design of the retaining wall which will be of height ranging from 2 – 4.5 m along the site boundary is shown in Figure 8-15. Length of the retaining wall for cutting soils is approximately 1,150 m, and wall for filling soils is 330 m approximately.



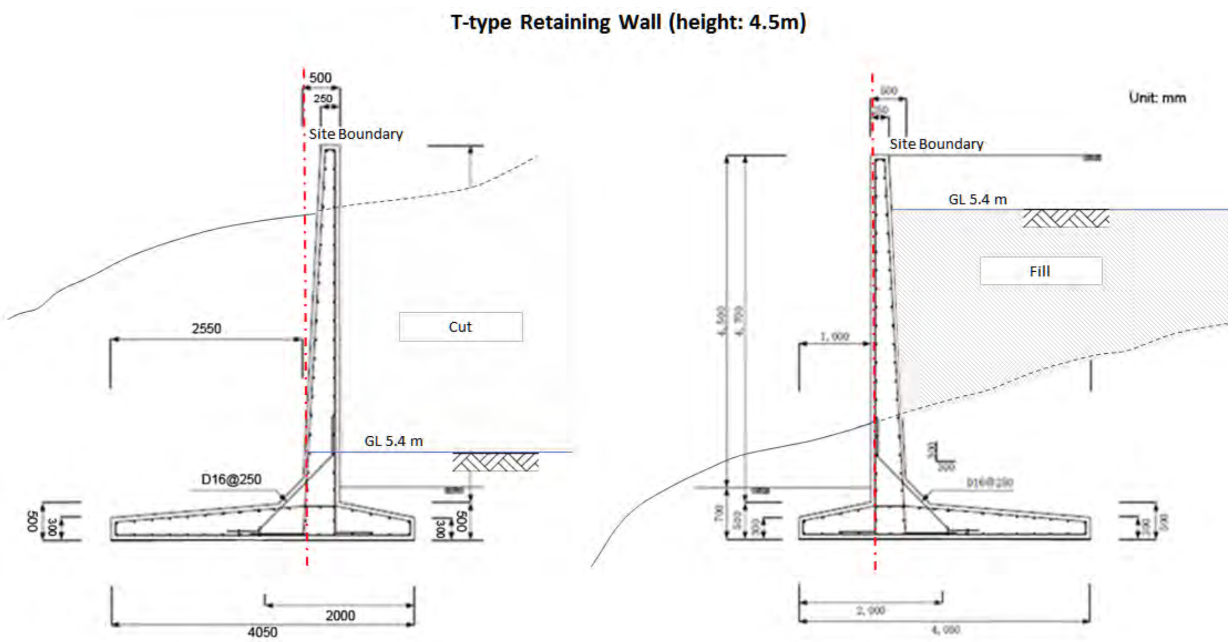
Source: JICA Study Team

Figure 8-13 Proposed Land Reclamation Plan of Kisiwa Site



Source: JICA Study Team

Figure 8-14 Location of Retaining Walls



Source: JICA Study Team

Figure 8-15 Draft Design of a Retaining Wall

(3) Foundation Work

Deferential settlement of foundation ground should be avoided at places where major equipment and structures of the thermal power project and pile foundation works are planned, basically, the area of ST and GT turbines.

According to the result of geological survey of Kisiwa site, the place where power plant and other heavy equipment will be installed, has a relatively favorable geological condition as shown in Table 8-18.

In general, a foundation, with N-value more than 30 for sand or N-value more than 20 for clay, is defined to have enough strength. Although Layer-3 (Cl2) does not meet the above condition, JICA Study Team recommends adopting the Layer-4 (Lm) as supporting layer.

Table 8-18 Summary of Geology at Kisiwa Site

No.		D-4	D-5	D-6	Soil Classification	N-Value
Location		Turbine	S/S	Area-3		
Length (m)		40.8	39	42.3		
Ground Level		6.0	7.0	15.0		
Elevation (El. m)	Layer-1 (S1)	6.0 ~ -0.5	7.0 ~ 2.0	15.0 ~ 9.0	Silty Sand	N < 10
	Layer-2 (SG)	-0.5 ~ -8.0	2.0 ~ -8.0	-	Sand mixed with clay	N = 20-30
	Layer-3 (Cl1/Cl2)	-8.0 ~ -15.0	-8.0 ~ -17.0	-	Sand mixed with gravel	N < 10
	Layer-4 (Lm)	-15.0 ~	-17.0 ~	9.0 ~	Coral Limestone	N > 50

Source: JICA Study Team

There are roughly two kinds of structure foundation, namely, the mat foundation and the pile foundation. The pile foundation is usually several meters to several tens of meters deep from the ground surface. Therefore, when an earthquake occurs, the ground sways and the pile is shaken by the force which acts on the pile, the deformation and stress of the pile affect the strength of the foundation.

In case where a pile is driven into a ground with a relatively high strength, when the earthquake occurs, the ground will act as a cushion and the pile will not shake easily.

In order to design an economical foundations with the necessary bearing capacity of the ground, the design of the pile is carried out by the following procedures.

1) The pile length, pile diameter and type of pile are selected based on data such as the result of ground survey, loading tests, design examples of similar structures, investigation of construction examples, etc.

2) The allowable vertical bearing capacity is obtained considering the safety factor, and the allowable horizontal bearing capacity is obtained based on the horizontal displacement data.

3) Assume the number and arrangement of piles based on the planned size of footing, and then calculate the design external force on the pile foundation.

4) From the calculation result of the pile head reaction force, estimate the displacement magnitude of the footing.

5) Based on the permissible stress level peculiar to the pile, check the cross sectional stress of the pile and design the joint part of the pile and the footing.

(4) Rainwater Drainage System

According to the site condition described in the Chapter 7, flood is one of the risks that needs to be paid special attention. It is expected that rainfall erosion rarely occurs in Kisiwa site, because a gradual slope, which is covered with vegetation, is developed and most of the rainwater percolates into the sandy soil.

Two (2) kinds of rainwater need to be managed in this project. One is rainwater flowing from out of the plant area and the other is rainwater inside the plant area. The former should be controlled outside the plant by facilities such as ditches around the boundary and land slopes. The latter should be controlled by the plant, and the drainage system in the plant should have the capacity to manage rainwater.

Table 8-19 Probable Daily Maximum Rainfall at Mtwara

Period (Year)	Daily Rainfall (mm)
200	599.33
100	512.25
50	429.65
30	371.11
20	325.89
10	251.13

Source: JICA Study Team

1) Design Rainfall Intensity

The daily rainfall of 10 years period, 252mm, is adopted for the design as shown in Table 8-23. When considering the climate characteristics of this region, it can be noticed that the period of rainfall is not long and heavy rainfall tends to stop within 1.5 hour from the start of rain. Therefore, the hourly rainfall of 10 years period is estimated as 168 mm from the following calculation.

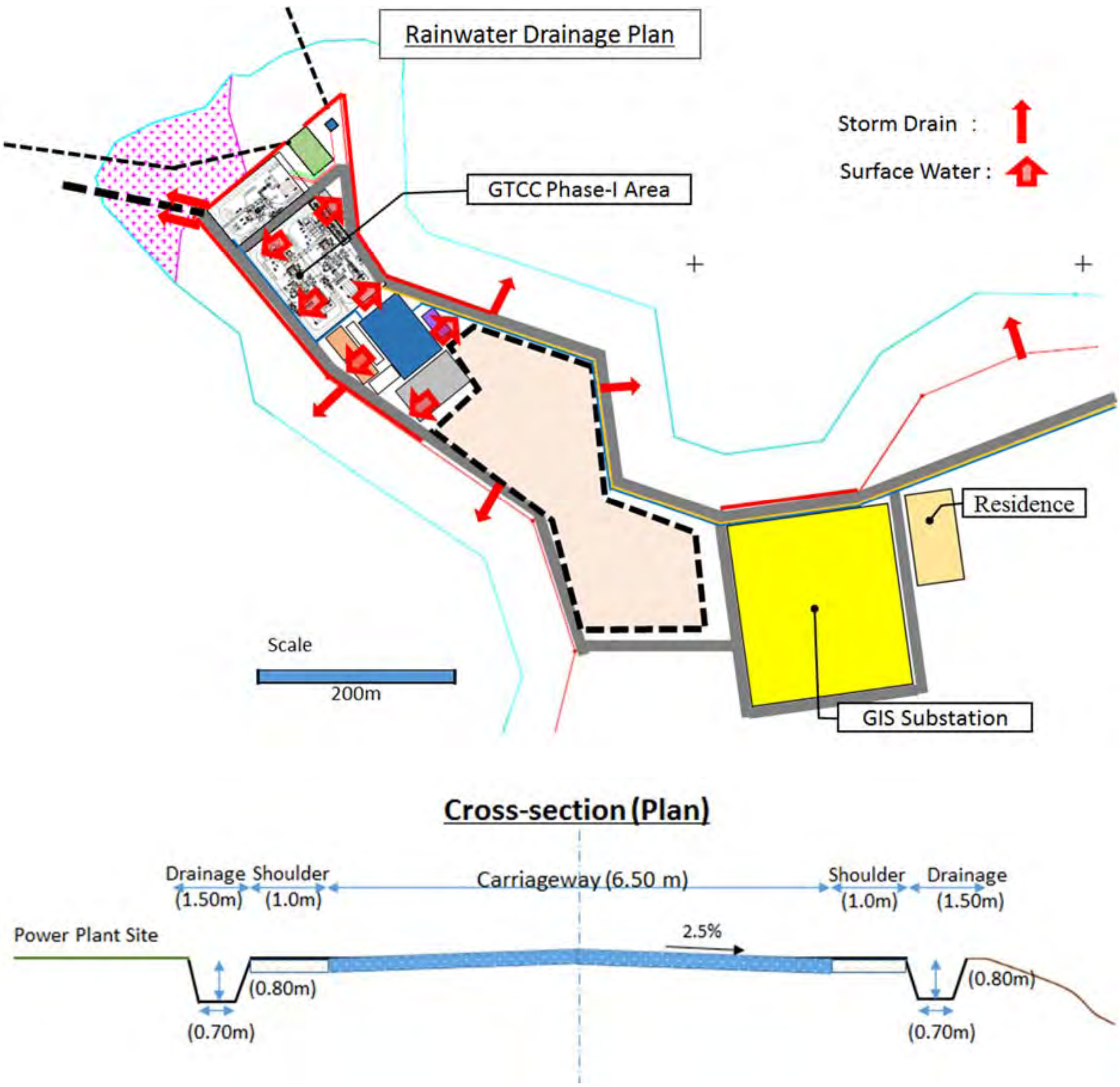
According to the Chapter 7, maximum daily rainfall in Mtwara is 232.7 mm/24hrs (1 day) and the maximum hourly rainfall is 155 mm. The above-mentioned, estimated 10-year rainfall probability (daily/ hourly) is considered as reasonable and proper for basic design of drainage system at Kisiwa site.

2) Plan of Rainwater Drainage System

Based on the following conditions, the total runoff volume from the plant site is 3.5 m^3/s, therefore, seven (7) drainage outlets are needed, in order to drain out rainwater safely.

Design rainfall intensity:	168 mm
Plant area (Phase-I):	7.5 ha
Volume of runoff:	3.5 m^3/s
Drainage channel bed slope:	1%
Capacity of channel:	0.89m^3/s (W: 70 cm, H: 80 cm)

The draft plan of the rainwater drainage system and its cross-section is shown in Figure 8-16, and the draft design of roadside ditches is shown in Figure 8-20 as the design of road cross-section.



Source: JICA Study Team

Figure 8-16 Draft Plan of Rainwater Drainage System and Cross-section

(5) Road Plan

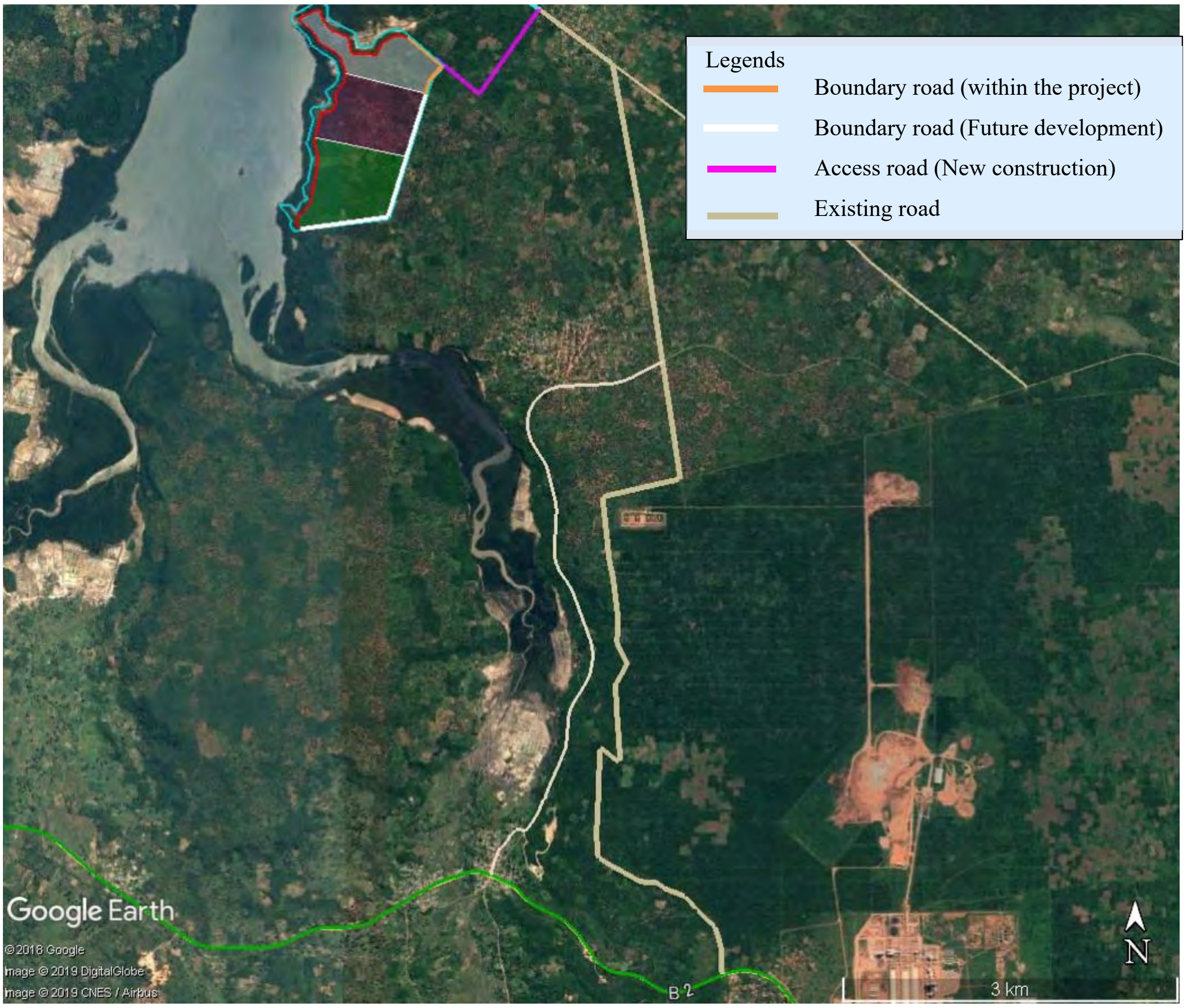
Administration structure of roads development and management in Tanzania is as follows;

The Tanzania National Road Agency (TANROADS) is responsible for national roads, and Tanzania Rural and Urban Road Agency (TARURA) is responsible for lower classed local roads, and they are in charge of planning, design, construction, maintenance and management in collaboration with regional council (RAS) and district council.

1) Access Road

The road from the intersection of the national road (B-2) near Dangote Cement Factory to the area near Kisiwa site, shown in Figure 8-17 is administrated by TARURA and it is an unpaved single-lane road. There are also tight curves and culvert structures along the route. For the passage of construction vehicles such as large and long trucks, the road needs to be improved and widened in accordance with the standards for the national road.

The route from Kisiwa Village to Kisiwa site, does not have suitable access roads for large-size vehicles. Therefore, a new access road shall be planned and constructed. The result of detailed study is described in Chapter 13.

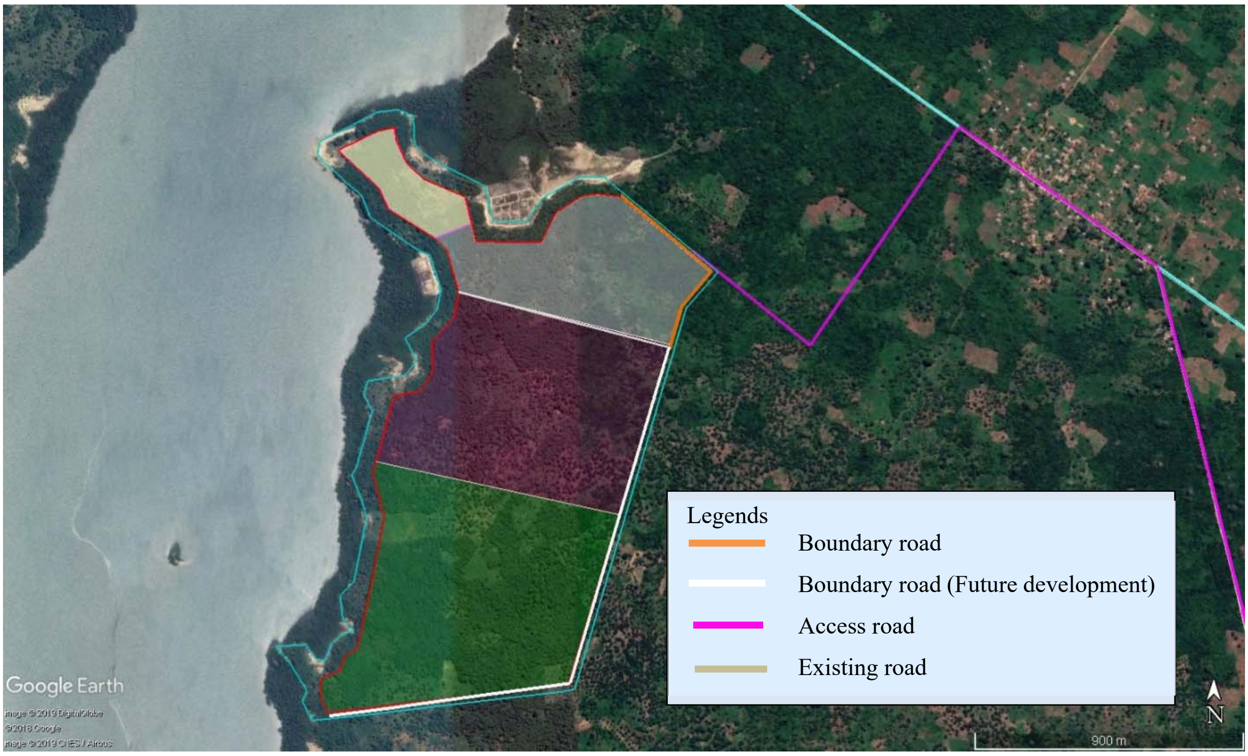


Source: JICA Study Team

Figure 8-17 Draft Plan of Access Road

2) Road of the Site Boundary

According to the RAS, TANESCO is responsible for the road development of 15 m width from the center line of the road and the adjacent developer is responsible for the other half. As shown in Figure 8-18, the site boundary road (750 m approximately) needs to be developed and is to be constructed during the Area 1 development of the Project. Standard road cross-section is shown in Figure 8-20.



Source: JICA Study Team

Figure 8-18 Site Boundary Road

3) Administrative Road inside Kisiwa site

Administrative road inside Kisiwa site is designed based on the criteria mentioned below.

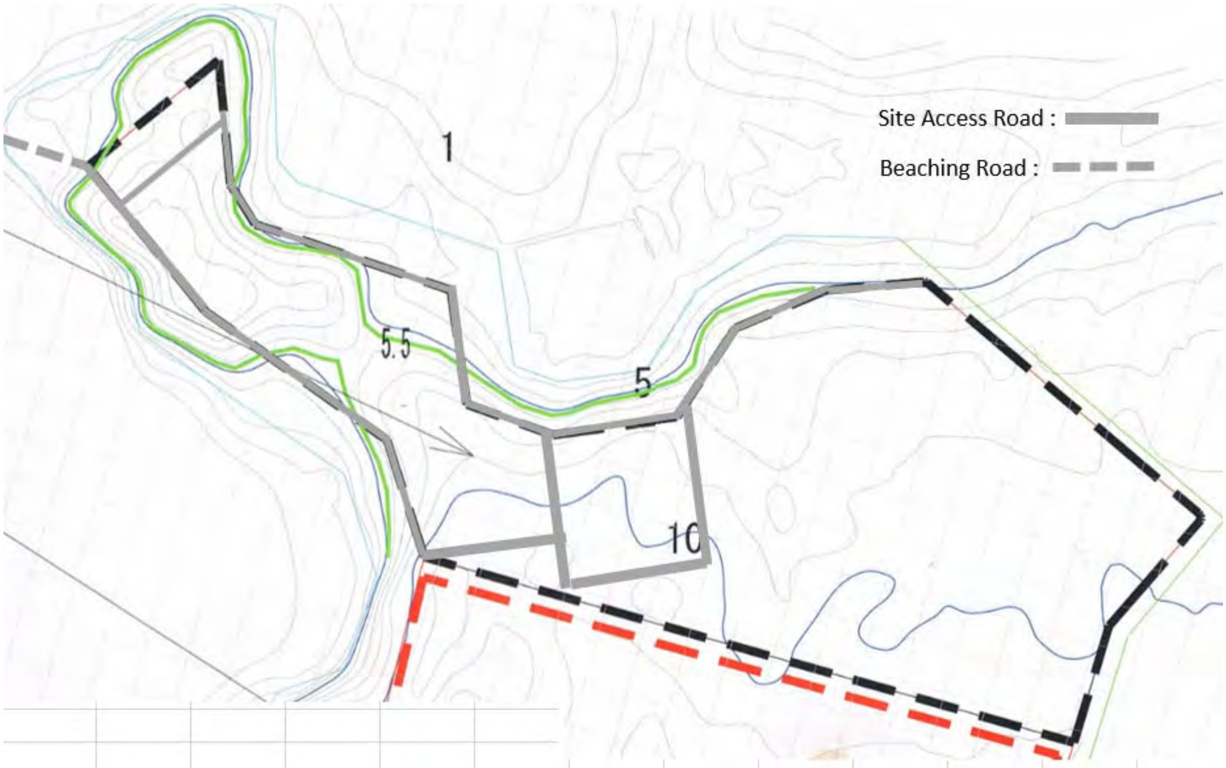
(a) A road with a standard width of 10 m that does not interfere the general traffic even if a large vehicle stops on the roadside.

(b) A road with a standard width of 8 m without much traffic volume, where one way of the road can be used for transportation even if maintenance personnel work on the other side of the road.

(c) A road with a standard width of 4 to 6 m with no traffic stop throughout the entire route even if traffic is restricted by construction etc.

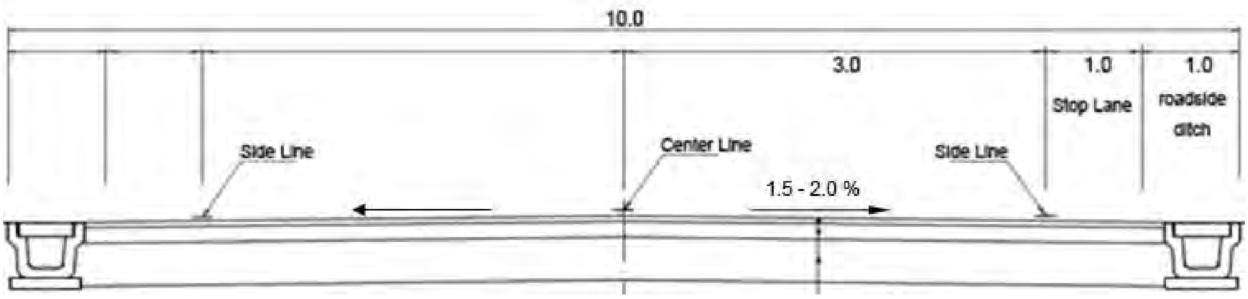
For this project, administration roads with a standard width of 10 m is applied, considering construction works, transportation and maintenance works.

Following the Design Guideline of Thermal and Nuclear Power Plant Civil Engineering Structures (Japan Electric Power Civil Engineering Association, 1996), roads can have a transverse slope to discharge road surface water, and a longitudinal slope can be provided in accordance with the change of ground height. It is desirable that the transverse slope of the on-site road be 1.5 to 2% and the longitudinal slope be 5% or less. Draft plan of administrative road is shown in Figure 8-19 and the standard design of administrative road is shown in Figure 8-20.



Source: JICA Study Team

Figure 8-19 Draft Plan of Administrative Road



Source: JICA Study Team

Figure 8-20 Draft Design of Roads with Roadside Ditch

(6) Architectural Structures

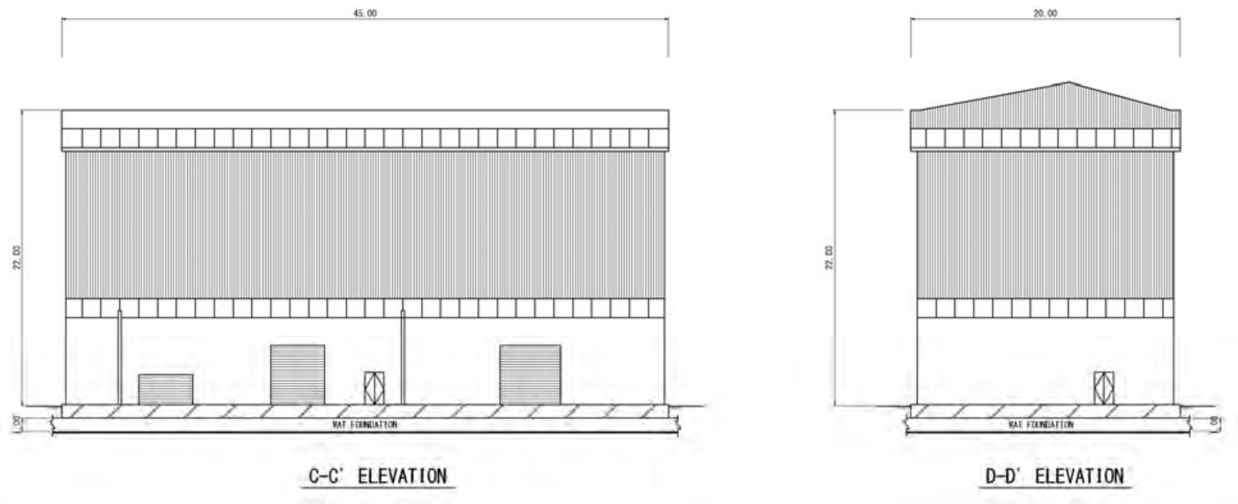
The specifications required for the major building in this Project are summarized in Table 8-20.

Outline drawing for the steam turbine building and administration building are shown in Figure 8-21 and Figure 8-22. This basic drawing is designed based on the assumption that the building for ST is required.

Table 8-20 Specifications of Major Buildings of the Project (draft)

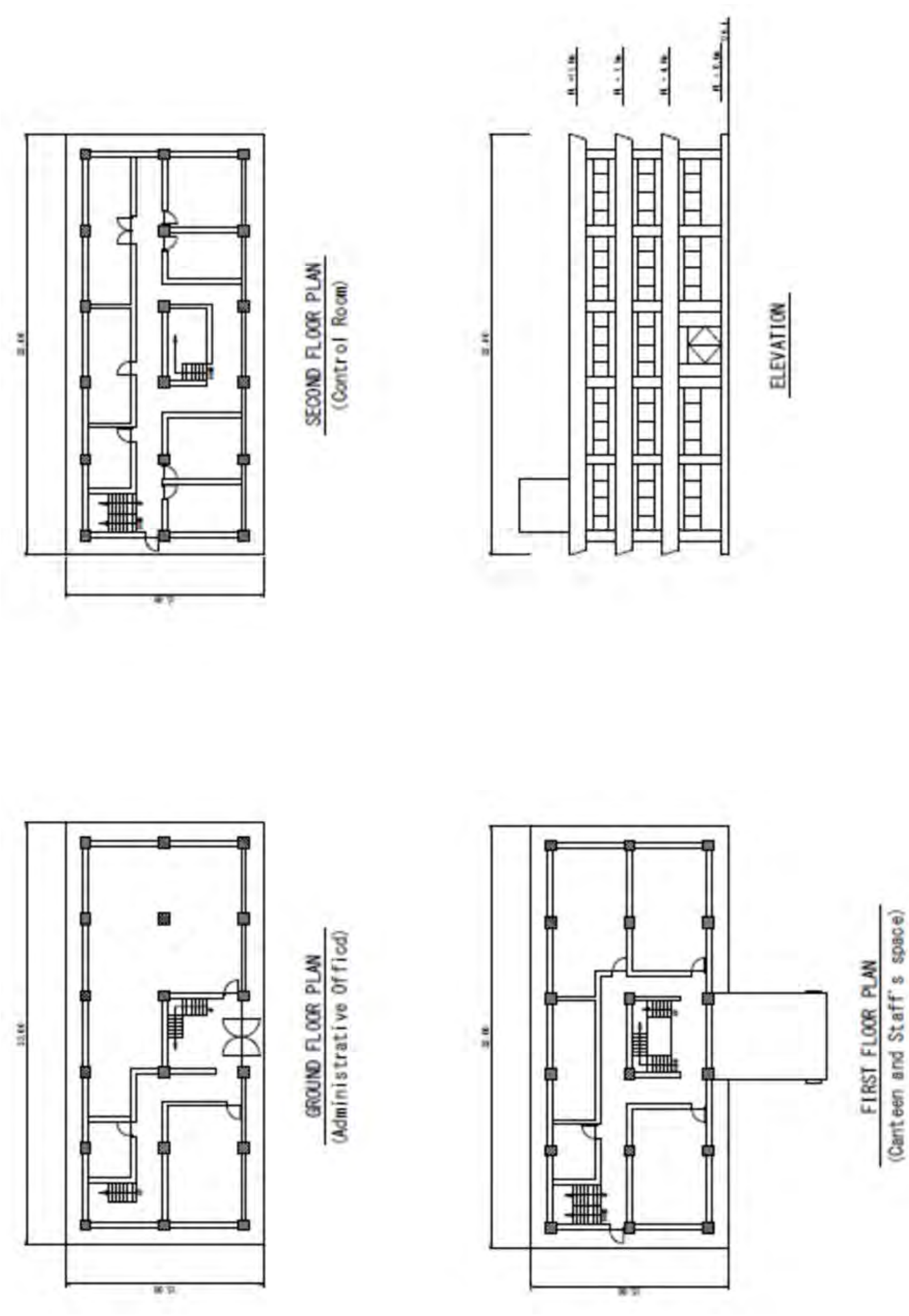
	Name of building	Specification
Kisiwa Site	Steam Turbine Building	- Steel frame structure equipped with overhead cranes - Side walls: corrugated plates and steel plates - Roof structure: steel truss - Windows: purpose of ventilation - Lifetime: 20 – 30 years
	Administration Building	- Frame structure: reinforced concreate and three (3) floors - Side walls: bricks and mortar with appropriate number of windows - Facilities: Air Conditioning (A/C) system, internet, gas, electricity, portable water
	Substation Control Building	- Frame structure: reinforced concreate and two (2) floors - Side walls: bricks and mortar with appropriate number of windows - Facilities: A/C system, internet, gas, electricity, portable water
	Warehouse	- Steel frame structure with overhead cranes and one (1) floor
Lindi Site	Substation Control Building	- Frame structure: reinforced concreate and two (2) floors - Side walls: bricks and mortar with appropriate number of windows - Facilities: A/C system, internet, gas, electricity, portable water

Source: JICA Study Team



Source: JICA Study Team

Figure 8-21 Draft Design of Steam Turbine Building



Source: JICA Study Team

Figure 8-22 Draft Design of Administrative Building

(7) Construction Works for Intake and Discharge Structures

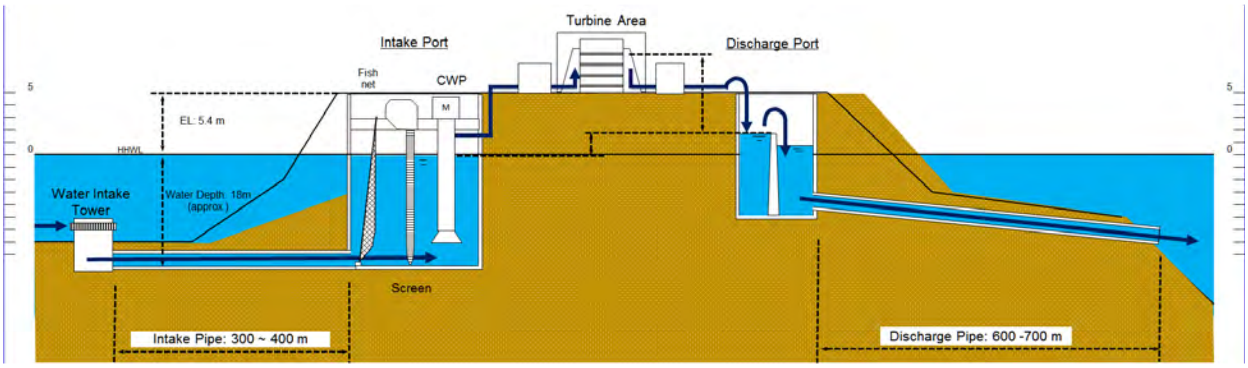
Types of seawater intake and discharge facilities are considered in Chapter 4, and their construction plans are studied in this Section, since the civil engineering work has much impact on the feasibility of project implementation as well as the project cost.

1) Structure Layout

Based on the study of the Chapter 4, tower type seawater intake and offshore discharge is adopted in the Project. The planned intake and discharge structures consist of water intake tower, intake pipe, intake port, circulating water pipe, discharge port, discharge pipe and so on. Basic layout of the intake and discharge structures are shown in Figure 8-23 and Figure 8-24.

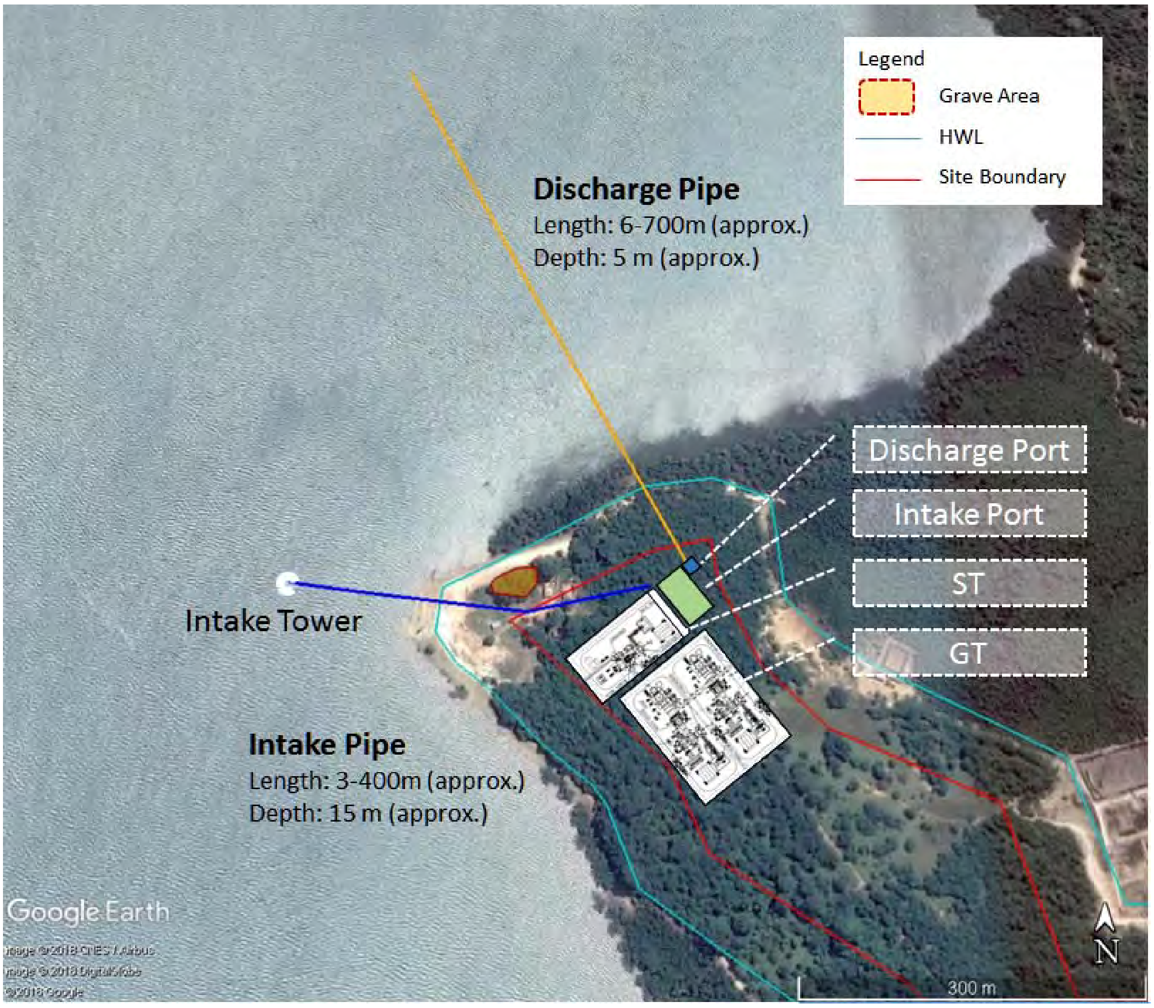
Water intake tower is located at a distance of 150 m away from the coastline and the point of water discharge is located approximately 600 m away from the coastline. Water intake port, which consists of fish prevention screen, bar screen and sea water intake pump, is installed at the depth of 15 - 20 m, with a width of 10 m, and a length of 20 m approximately.

The discharge port is 10 m deep and the discharge pipe extends for about 600 -700 m.



Source: JICA Study Team

Figure 8-23 Cross-section of Intake and Discharge Structures



Source: JICA Study Team

Figure 8-24 Conceptual Layout of Intake and Discharge Structure

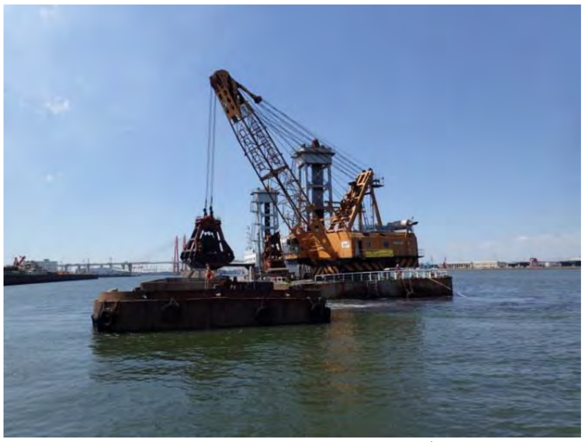
2) Construction Method

Construction of the intake pipe is divided into two sections; 220 m in the onshore section and 150 m in the offshore section.

In order to install intake pipe in the offshore section and intake tower, temporary cofferdam construction method needs to be applied to build a foundation in the sea. Cofferdam is constructed in order to keep water out of the excavation area, and it consist of manufactured steel corrugated plates welded to each other. The bottom part of the cofferdam is embedded, for up to one meter depth, into the foundation rock layer. The overall height of the structure will be almost 20 m.

Excavation inside the steel sheet piles is carried out using heavy equipment such as pile drivers, cranes with clamshell buckets and so on. Excavated soil from sea bed is placed in the vicinity temporarily and used as backfill soil. When crushed stone is necessary for installing the intake pipe, it has to be transferred from the dump truck to the barge ship using the beaching road. An image of construction method is shown in Figure 8-25.

Source: Japan Press-in Association
URL: http://www.atsunyu.gr.jp/

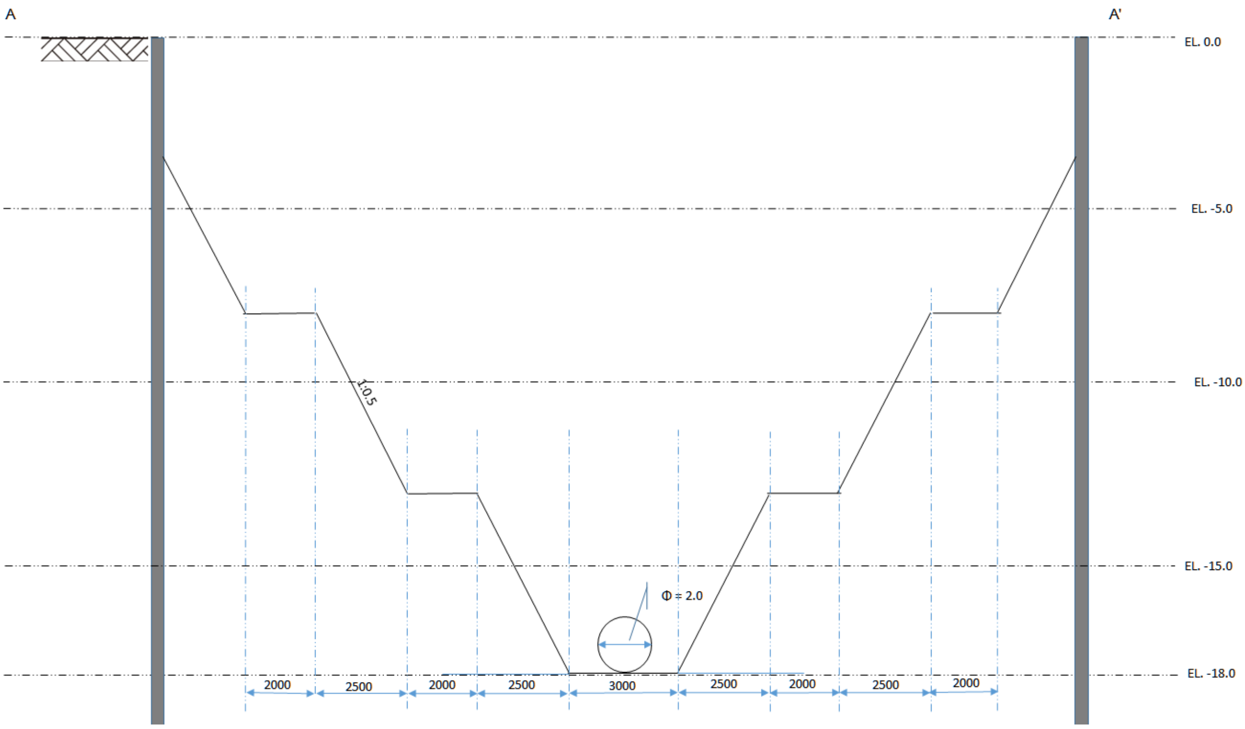


Source: Okamura Co., LTD

Figure 8-25 Sheet Pilling and Crane with Clamshell Bucket (Image)

The discharge structures to be constructed are the water discharge port and the water discharge pipe. Excavation / flattening of offshore section is carried out using clamshell buckets, and the excavated soil is temporarily placed in the vicinity and used as backfill. However, JICA Study Team presumes that temporary cofferdam construction method is unnecessary for the discharge pipe, and the method should be applied based on the condition of sea floor geology.

Draft drawing of excavation on the onshore section including a part of intake and discharge port is shown in Figure 8-26, and it is excavated with a slope of 1: 0.5 and a small step (2 m) is made at every 5 m depth.



Source: JICA Study Team

Figure 8-26 Working Drawing of Water Intake / Discharge Port (Draft)

JICA Study Team recognizes that the construction work for intake and discharge structures will be an important and critical work to implement the construction of the plant with seawater cooling type. Therefore, a contractor having enough experience on this type of marine construction works should be selected.

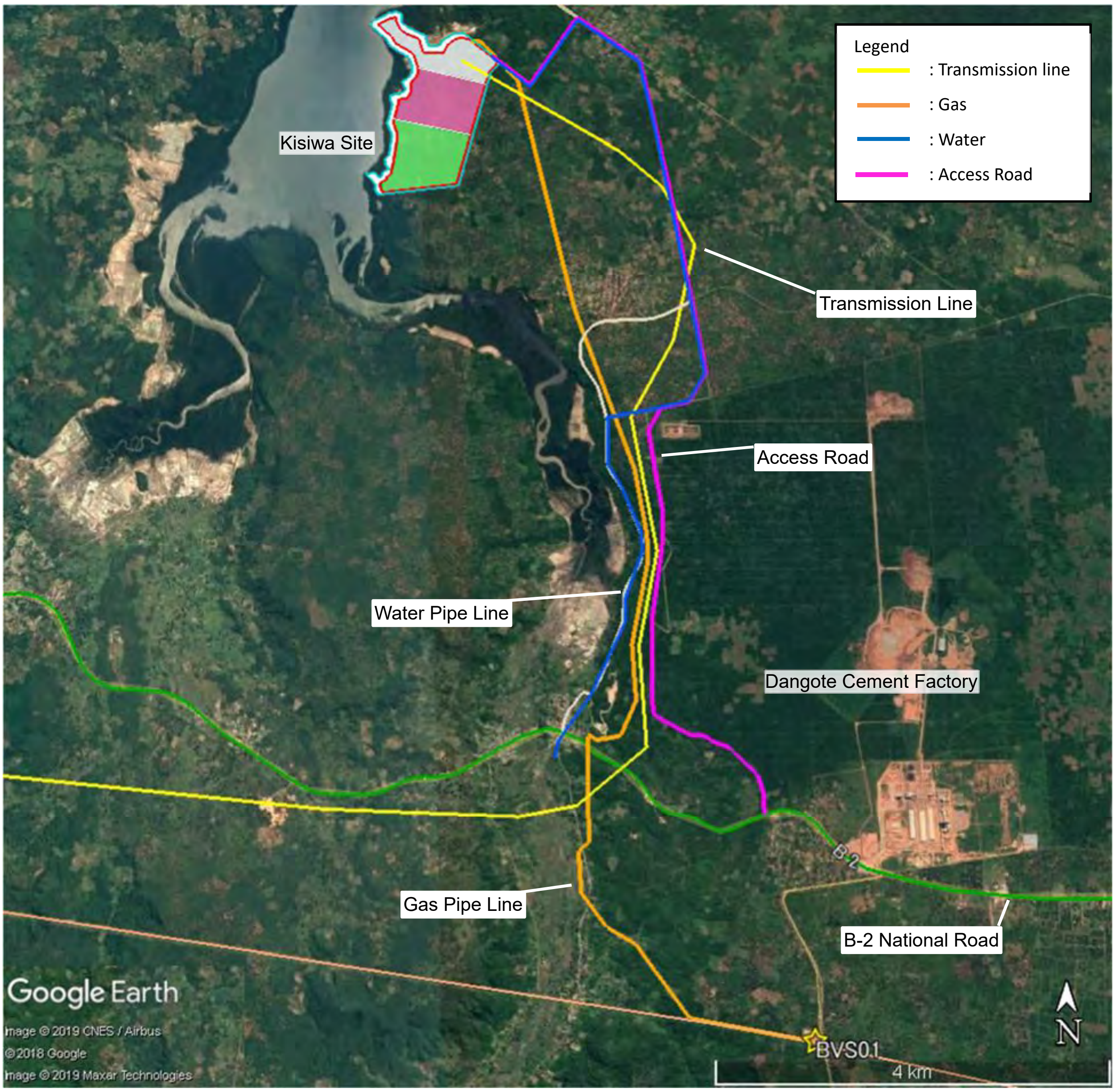
(8) Utilities and Road Route around Kisiwa site

As previously mentioned in the Chapter 4, gas pipe line to Kisiwa site will be planned and installed by the Tanzania Petroleum Development Corporation (TPDC). The current gas pipe line plan including the alternate route has been provided by TPDC.

Water supply will be planned and installed by the Mtwara Urban Water Supply and Sanitation Authority (MTUWASA). The current water pipe line plan has been provided by MTUWASA.

Transmission line route and road plan are studied and described in previous sections.

All plans, including the alternatives for these facilities, which are related to development of the Project, are integrated in Figure 8-27.



Source: JICA Study Team

Figure 8-27 Draft Plan of Utilities, Transmission Line and Road

8.2 BASIC DESIGN OF 400 KV TRANSMISSION LINE FACILITY

8.2.1 Transmission Line Outline

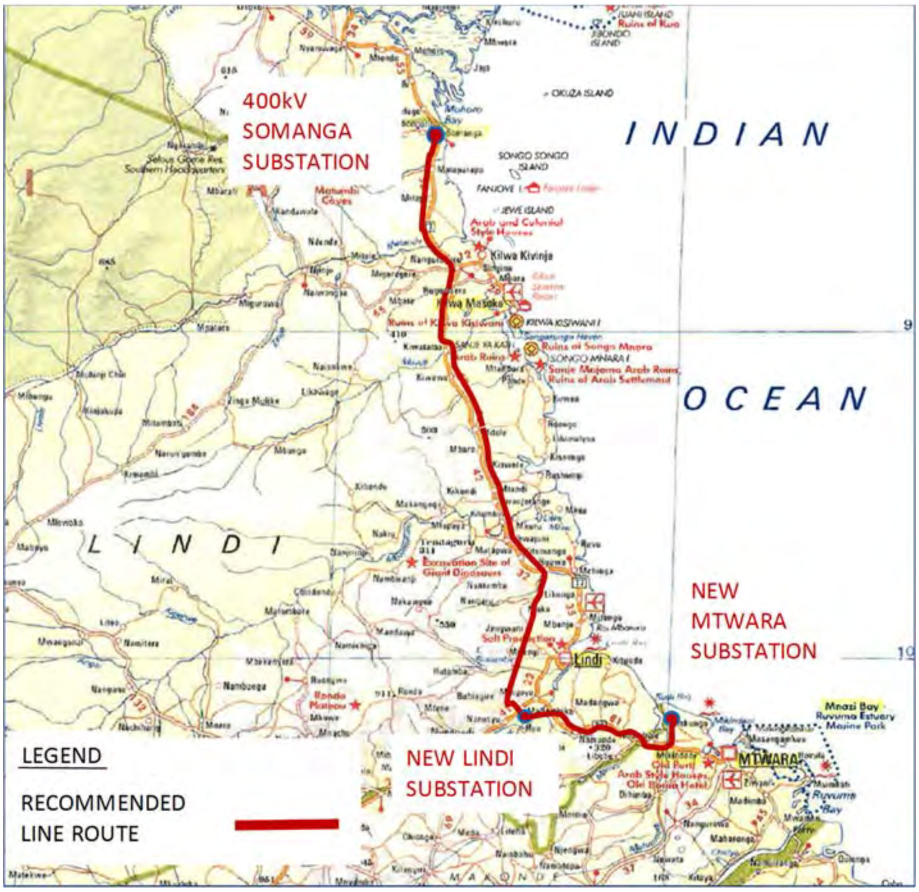
(1) Outline of 400 kV transmission line feature

Outline of 400 kV transmission line between the New Mtwara Substation and the 400kV Somanga Substation via the New Lindi substation is shown below.

Table 8-21 Outline of Transmission Line Equipment

Description		Line Data
Number of 400kV circuit		2
Number of conductors per phase		4
Route Length	New Mtwara Substation ~ New Lindi Substation	59 km
	New Lindi Substation ~ 400kV Somanga Substation	209 km
	Total	268 km
Conductor type		ACSR Bluejay (Low loss conductor)
Earthwire		GSW 110 mm^2 or AS 110 mm^2
OPGW		OPGW 110 mm^2
Type of towers		Self-supporting steel lattice structures
Type of foundations		In-situ reinforced concrete

Source: JICA Study Team



Source: JICA Study Team

Figure 8-28 Transmission Line Route

(2) Basic Design Data

Table 8-22 shows the minimum design requirements from the view point of electrical system and other general data.

Table 8-22 Basic Design Data

Description	Unit	Data
Nominal voltage	kV	400
Maximum operating voltage	kV	420
Power frequency	Hz	50
Basic Insulation Level Design BIL (lightning impulse)	kV_{peak}	1,425
Switching impulse withstand voltage phase - earth	kV_{peak}	1,050
Ratio of switching overvoltage phase-to-phase and phase to ground		1.5
System highest 3-phase short-circuit current level (1s)	kA	40
Short circuit current (1s) for thermal stability check of the earthwires	kA	10
Design creepage distance for medium pollution as per IEC 60815	mm/kV	31

Source: JICA Study Team

(3) Transition from octuple conductor to quad conductor

1) Transition from octuple conductor to quad conductor

Background for changing basic design of 8-bundled (octuple) conductors per phase to 4-bundled (quad) conductors per phase are explained as follows.

1) Two years construction period would limit the application of the design with 8-bundled (octuple) conductors per phase, due to its complex design and construction.

2) The construction period for 8-bundled (octuple) conductors per phase may require over three (3) years.
(New development and design for tower, conductor fittings such as spacer and insulators with fitting will be required.)

3) Only the design for 4-bundled (quad) conductors per phase, having the designed transmission line capacity can be constructed within two (2) years.

4) Based on the power flow analysis by PSSE, the design for 4-bundled (quad) conductors per phase will satisfy the necessary transmission capacity.

2) Comparison between multiple Quad (4) and Octuple (8) conductors

The technical feature of multiple quad (4) conductors and octuple (8) conductors are compared in following table.

Table 8-23 Comparison of Conductors Quad (4) and Octuple (8) Conductors

Description		Unit	Quad bundle Conductors	Octuple bundle Conductors
Nominal voltage		kV	400	400
Number of conductors per phase			4	8
Conductor type			Bluejay	Bluejay
Foundation Reactions	Compression	ton	330	532
	Uplift	ton	290	454
Tower type Line Angle 15° Tension tower	Tower height	m	70	80
	Tower weight	ton	60	88
	Leg member size		HL 200 × 200	HL 250 × 250
Insulator assembly			Existing	New development
Spacer			Existing	New development

Source: JICA Study Team

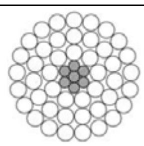
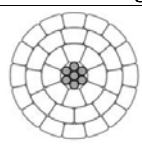
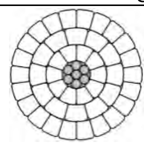
8.2.2 Conductors and Earth Wires

(1) Conductor type

Table 8-24 shows the specifications of candidate conductors. One is a popular conductor in Tanzania named as Bluejay. The others are two kinds of Low Loss conductors (hereinafter called as "Low Loss") with the same outside diameter as Bluejay.

Construction and features of typical Conductors including Low Loss is shown in Table 8-24.

Table 8-24 Conductor Type

Description		Unit	Bluejay	Low loss A	Low loss B
Nominal Diameter		mm	32.0	32.0	32.0
Cross sectional area	Al	mm^2	564.0	719.2	697.5
	Core		39.3	22.0	29.1
	Total		603.3	741.2	726.6
Nominal weight	Total		1,868	2,154	2,165
DC Resistance at 20 deg. C		Ohm/km	0.051	0.040	0.0416
Sag of 350 m span*1		m	13.96 m at 90 deg. C	13.96 m at 81.4 deg. C 14.25 m at 90 deg.C	12.53 m at 82.3 deg. C 12.82 m at 90 deg.C
Current capacity at 90 deg. C*2		A	964 A at 90 deg. C	964 A at 81.4 deg.C 1082 A at 90 deg.C	967 A at 82.3 deg.C 1069 A at 90 deg.C
Cross sectional view					

Note
*1Conditions
Every tension: Not exceeding 20% RTS
Every temperature: 25 degree C

*2Conditions
Ambient temperature: 40 deg. C
Wind velocity: 0.5 m/s
Wind direction: 45 degrees
Solar radiation: 0.1 W/cm^2
Emissivity of conductor surface: 0.5
Absorptivity of conductor surface: 0.5
Calculation method: In accordance with JCS 0374

Source: JICA Study Team

Low Loss has various specifications, but this time the ones which have the same outside diameter as Bluejay were chosen. As a result, the wind pressure loads applied to conductors are equal for all cases, and therefore, the tower design conditions for both are almost same.

(2) Life cycle cost of Conductor

AC resistance is one of the important characteristic for a conductor because high resistance causes large transmission loss. Low Loss has a low AC resistance of 80% compared to Bluejay, therefore, the conductor can reduce the transmission loss under the same condition. As a result, this advantage leads to less loss of electricity, produced by a power plant. That is, Low Loss can contribute to the reduction of fuel cost and environmental impacts too. A fuel cost or generation cost spent for the transmission loss is estimated as below.

$$\mathrm{I} = \frac{\mathrm{P}}{\sqrt{3} \times \mathrm{V} \times \mathrm{P}_f} \times 10^3 \qquad [\mathrm{A}]$$

$$\mathrm{i} = \frac{\mathrm{I}}{\mathrm{N}_{con} \times \mathrm{N}_{cir}} \qquad [\mathrm{A}/conductor]$$

$$\mathrm{W}_{loss/con} = \mathrm{r} \times (\mathrm{i})^2 \times \mathrm{L} \times 10^{-6} \qquad [\mathrm{MW}/conductor]$$

$$\mathrm{W}_{loss} = \mathrm{W}_{loss/con} \times 3 \times N_{con} \times N_{cir} \qquad [\mathrm{MW}]$$

$$\mathrm{P}_{loss/y} = \mathrm{W}_{loss} \times \left(0.3 \times \mathrm{L}_f + 0.7 \times \mathrm{L}_f{}^2\right) \times 365 \times 24 \qquad [\mathrm{MWh}/year]$$

L	:	Route length [km]
P	:	Transmission capacity [MW]
V	:	Voltage [kV]
P_f	:	Power factor
I	:	Current [A]
N_{cir}	:	Number of circuit
N_{con}	:	Number of conductors
i	:	Current on a conductor [A/*conductor*]
r	:	AC resistance [Ohm/*km*]
$W_{loss/con}$	:	Transmission loss per conductor [MW/*conductor*]
W_{loss}	:	Transmission loss [MW]
L_f	:	Load factor
$P_{loss/y}$	:	Power loss per year [MWh/*year*]

$$\mathrm{C}_{loss/y} = \mathrm{P}_{loss/y} \times 10^3 \times \mathrm{C}_{gen} \times 10^{-6}$$

C_{gen}	:	Generation cost [$/*kWh*]
$C_{loss/y}$	:	Generation cost spent for the transmission loss [milli.$/*year*]

Low Loss is expensive compared to Bluejay, therefore the initial cost for conductor will become almost double. Considering the total cost, it can be calculated as below.

$$\mathrm{C}_{int} = \mathrm{C}_p \times \mathrm{L} \times 3 \times \mathrm{N}_{cir} \times \mathrm{N}_{con} \times 10^{-6} \qquad [\mathrm{milli.}\ \$]$$

$$\mathrm{C}_{total} = \mathrm{C}_{int} + \Sigma_{\mathrm{Y}}^{\mathrm{n}} \left[\mathrm{C}_{loss/y} \times \left(1 \div (1 + \mathrm{int})^{\mathrm{Y}}\right)\right] \qquad [\mathrm{milli.}\ \$]$$

C_{total}	:	Total cost [milli. $]
C_{int}	:	Initial cost [milli. $]

C_p : Unit price cost of a conductor [\$/*km*]
int : Rate of increase in interest rate [%]
Y : Year of operation [year]

Figure 8-39 compares the life cycle cost or C_{total} of Bluejay and Low Loss under several conditions.

The 400kV system makes it possible to connect additional power plants to the system in the future, because it has a sufficient power transmission capacity.

Suppose power development is as follows:

Case (I) GTCC output 300MW + 330MW (2030)
Case (II) GTCC output 300MW + 330MW (2030) + 330MW (2035)
Case (III) GTCC output 300MW + 330MW (2030) + 330MW (2035) + 330MW (2040)

(New Lindi S/S ~ 400kV Somanga S/S)

The result of total cost evaluation indicates that Low Loss cannot exhibit its cost advantage within 40 years after the Commercial Operation Date (COD) in case (I).

If the development of additional generators in Mtwara area is accelerated like in case (II) or case (III), Low Loss may show its cost advantage within 30 years.

In case (II), the total initial investment, operational and power loss cost for the Low Loss is larger than the that of Bluejay until 30 year of operation, but after 30 years it will be reversed and the cost for Low Loss will be lower by about 1.4 million US dollar per year. As a result, after 30 years of operation, the transmission line with Low Loss will have economic advantages.

In case (III), the total of initial investment, operational and power loss cost for the Low Loss is larger than the that of Bluejay until 23 year of operation, but after 23 years it will be reversed and the cost for Low Loss will be lower by about 2.6 million US dollar per year. As a result, after 23 years of operation, the transmission line with Low Loss will have economic advantages.

(New Mtwara S/S ~ New Lindi S/S)

The result of evaluation indicates that Low Loss cannot exhibit its cost advantage within 40 years after COD in case of (I) and (II).

If the further development of generators is accelerated in Mtwara area in the future like in case (III), Low Loss may have advantages over Bluejay within 40 years.

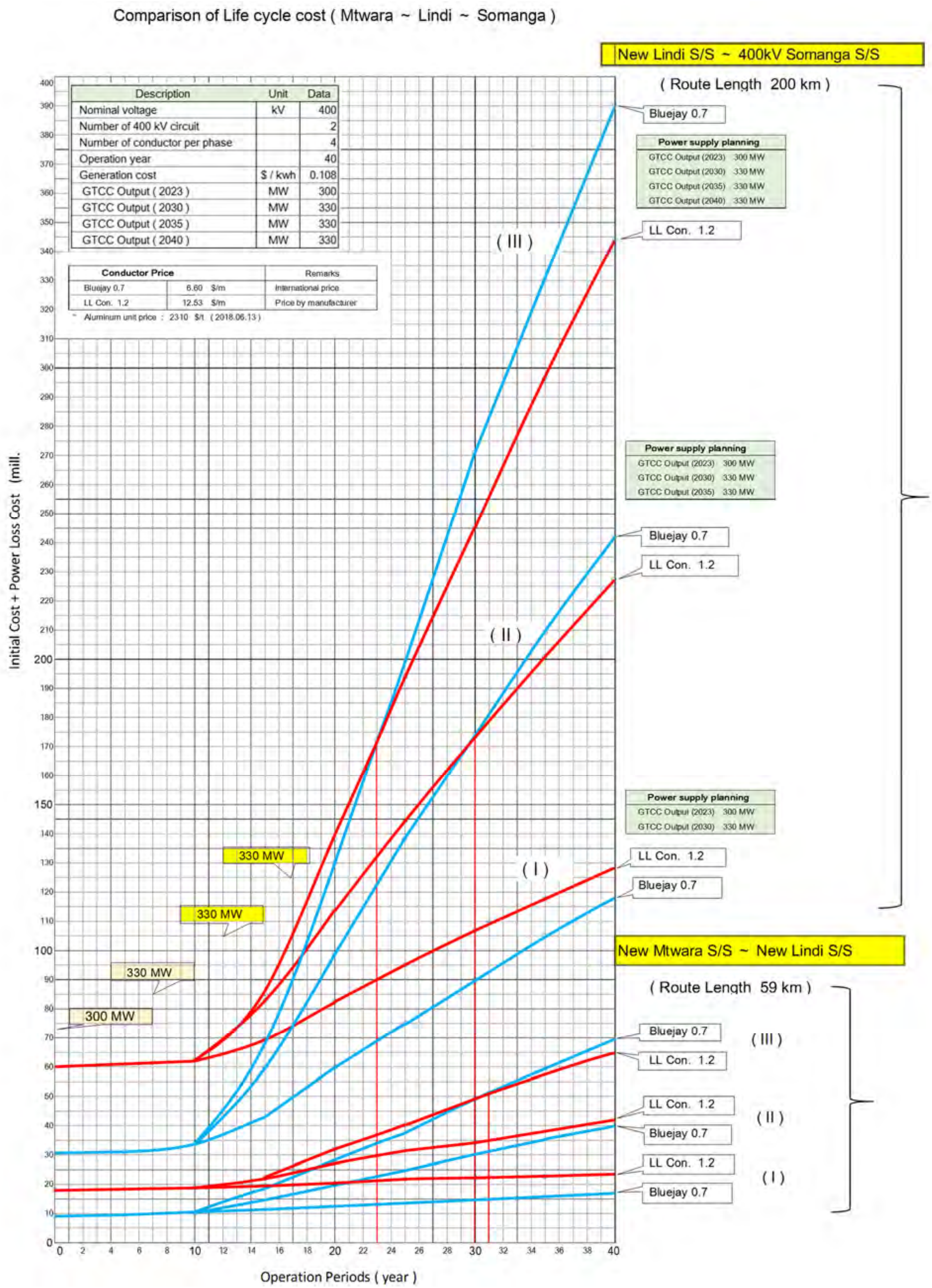
In case (III), the total initial investment, operational and power loss cost for the Low Loss is larger than the total of Bluejay until 31 year of operation, but after 31 years it will be reversed and the cost for Low Loss will be lower by about 0.4 million US dollar per year. As a result, after 31 years of operation, the transmission line with Low Loss will have economic advantages.

As shown in Figure 8-29, the conductor type to be applied for the 400kV Transmission Lines in this project has been studied by comparing the life cycle cost of each conductor. Under the condition of power flow in “Case (I)” which is based on the official power load plan of TANESCO, the “ACSR Bluejay” conductor will have more advantages and it can be recommended as a conductor for this 400kV transmission line.

On the other hand, the application of Low Loss will be one of the most effective countermeasures to reduce the Greenhouse-Gas (GHG) emissions of GTCCs. TANESCO's reports and documents also state that there will be future power expansions in the southern region of Tanzania.

Considering such factors and the new condition, the power flow of Case (II) or Case (III) in the figure will be applicable, in case the capacity factor = 85.9%.

So in the case the growth rate of power demand is greater in the future power development plan than the current plan, due to the progress of power development in the southern region of Tanzania, the Low Loss will be a candidate conductor of this 400kV transmission line.



Source: JICA Study Team

Figure 8-29 Current for the Breakeven Point

(3) Properties of applied Earth wires

An earth wire shall be selected in consideration of the following conditions.

a) The sag of earth wire must be the same as that of the conductor or slightly less.

b) To increase the shield effects of the phase conductors against lightning, earth wire sags will be approximately 20 ~ 25% less than conductor sags at everyday temperatures.

c) Earth wire should withstand the expected faults and lightning currents.

d) To avoid troubles caused by pollution and corrosion, a proper material should be chosen for a ground wire.

1) Earth wire GSW 110 mm^2

Taking the above into account, an earth wire of Galvanized Steel Wire (GSW) 110 mmP^{2}P (GSW 110 mm^2) with a stranding of 7/4.5mm will be applied in TANESCO's transmission system.

The properties of earth wire are shown as follows.

Table 8-25 Properties of Earth Wire GSW 110 mm^2

Earth wire		GSW 110 mm^2
Stranding and Wire diameter	Galvanized Steel Wire	7/4.5 mm
Calculated Area of GSW		111.30 mm^2
Approximate Overall Diameter		13.50 mm
Calculated DC Resistance at 20°C per km		2.4423 ohm/km
Total weight per km		882 kg
Ultimate Breaking Strength		more than 126.0 kN

Source: JICA Study Team

2) Earth wire AS 110 mm^2

Aluminum clad steel wire of 110 mm^2 shall be applied as the alternative ground wire. All requirements and test methods shall be mainly in accordance with the relevant standards of IEC 1232, ASTM B415, ASTM B832, or equivalent standard. The design of an Aluminum-clad Steel wire (AS) with a specified conductivity is based on 61% IACS of aluminum and 9% IACS of steel. (International Annealed Copper Standard, percentage of material conductivity)

The properties of the alternative ground wire AS 110 mm^2 are shown as follows:

Table 8-26 Properties of Earth Wire AS 110 mm²

Earth wire		AS 110mm²
Stranding and Wire diameter	Aluminum-Clad Steel Wire	7/4.5 mm
Calculated Area of AS		111.3 mm²
Approximate Overall Diameter		13.5 mm
Calculated DC Resistance at 20°C per km		less than 0.8603 ohm/km
Approximate mass per km		704.8 kg
Ultimate Breaking Strength		more than 123.2 kN

Source: JICA Study Team

Except for the properties shown in Table 8-26, the conductors shall comply with ASTM B-415 and B-416 or equivalent standard.

Due to the lower value of impedance compared to the GSW 110 mm², AS 110 mm² is recommended for the earth wire. This means that AS 110 mm² can protect the OPGW against a big short circuit current running on the earth wire.

3) OPGW 110 mm²

The properties of the OPGW 110 mm² are as follows:

Optical Ground Wire or OPGW shall be made of AS and stainless steel loose tube containing optical fiber cable with slotted aluminum spacer for usage as overhead ground wire and telecommunication line. All requirement for individual wires and completed conductor shall be mainly in accordance with JCS 389A 97 (Japanese Cable makers' association Standard) or relevant standards of IEC.

Table 8-27 Properties of OPGW 110 mm²

Earth wire		OPGW 110mm²
Stranding and Wire diameter	Aluminum-Clad Steel Wire	9/3.6 mm
Calculated Area of AS		121.0 mm²
Approximate Overall Diameter		14.4 mm
Calculated DC Resistance at 20°C per km		less than 0.8603 ohm/km
Approximate mass per km		658.0 kg
Ultimate Breaking Strength		more than 99.7 kN
Maximum working tension of OPGW		21.6 kN
Quantity of Optical Fibers		48 cores
Diameter of AI. core		1/7.2 mm²

Source: JICA Study Team

Optical fiber shall be of single mode or dispersion shifted single mode type in conformance with the ITU-T G652 (International Telecommunication Union-Telecommunication sector). Characteristics of optical fibers shall be equal or superior to those given in the table below. Maximum allowable temperature shall be 80°C for continuous condition and 200°C for 1.0 sec.

Mode field diameter at 1,310 nm	Range of nominal values	9.2 μm
	Tolerance	± 1.0 μm
Cladding Diameter	Nominal	125 μm
	Tolerance	± 2 μm
Core concentricity error	Maximum	1.0 μm
Cladding no circularity	Maximum	2.0%
Cable cut-off wavelength	Maximum	1,100 nm-1,330 nm
Proof stress	Minimum	1.0%
Attenuation coefficient	Maximum at 1,310 nm	0.40 dB/km
Attenuation coefficient	Maximum at 1,550 nm	0.25 dB/km

4) Earthing

(1) Two overhead ground wires make the shielding effect to about 100% to protect the conductors from direct lightning strikes. But there is possibility of back flashover from earth wire or from the top of the tower as a result of a lightning strike. Therefore, it is necessary to install special grounding in order to minimize the occurrence of such an event.

(2) Tower-footing resistance can be reduced by the installing the grounding steel angle at the tower leg of the foundation. Furthermore, for the towers, which still have high footing resistance, counterpoise shall be provided to prevent the line fault due to a back flashover. It is desired that the tower footing be less than 10Ω. Galvanized iron wire of 38 mm^2 (7/2.6) shall be used for counterpoise. This wire shall be buried in the ground for a length of 30 m length and each piece shall be radially extended from the tower footings at the depth of about 0.5 m from the ground surface.

(3) It seems that there are some sites with very high footing resistance, where the counterpoise is not enough to reduce the footing resistance.
In such cases, the countermeasure to be carried out first is the application of grounding sheets that are fixed on the counterpoise wires. Furthermore, in case the first countermeasure is not effective, grounding by boring to a deep layer will be necessary.

8.2.3 Insulation

(1) Insulator Type

Table 8-28 shows the characteristics of insulator. The porcelain type insulator is suitable for the trunk power system because of its reliability.

Table10-3 in Chapter 10 shows the possible impact on cost due to insulator failures. This table shows below.

It is said that the failure rate of the insulator disc caused by the manufacture process is one (1) per one ten thousand (10,000) per year for the glass type. On the other hand, the porcelain type can achieve very low failure rate not exceeding one (1) per one hundred thousand (100,000) per year. Considering that a total of two hundred thousand (200,000) pieces of insulator discs are estimated to be used in this Project, if the glass type is selected, eight hundred (800) pieces will be requested for replacement during the operation period of 40 years. On the other hand, the failure rate of the porcelain type is one tenth compared to the glass type. Therefore as “Total life cost in Table 10 3 (i)” shows, the porcelain type can minimize the cost and the frequency of power failure for the replacement work.

Table 8-28 Insulator Type

Insulator	Advantage	Disadvantage
Porcelain 	- Standardized units - Electrically and chemically stable - Long term reliability	- Weight during handling - Close range inspection
Glass 	- Standardized units - Electrically stable - Easy detection of defective units	- Weight during handling - Shell shattering from Inclusions, Erosions, Vandalism
Polymer 	- Light weight for handling - Contamination performance - Initial cost of string	- Aging and Brittle fracture - Live line work - Handling damage - Bird and rodent damage - Close range inspection - Difference of string design

Source: JICA Study Team

(2) Number of Insulator Units in Polluted Region

The following Table 8-29 shows the number of insulator units necessary in the polluted region.

Table 8-29 Insulator Units in Contamination Area

Pollution level	Mi. nominal specific creepage distance	distance from the coastline	Tension	Suspension	
			300kN Normal	Span 300 m	Span 400 m or more
				160kN Fog	210kN Fog
			Number of insulators	Number of insulators	Number of insulators
Light	16 mm/kV	20 km over	16 × 2	19 × 1	19 × 2
Medium	20 mm/kV	10-20 km	18 × 2	19 × 1	19 × 2
Heavy	25 mm/kV	3-10 km	22 × 2	20 × 1	20 × 2
Very Heavy	31 mm/kV	0-3 km	27 × 2	24 × 1	24 × 2

Note: IEC60815-2-2008 compliant

Source: JICA Study Team

(3) Contamination (salt)

The Contamination (salt) distribution map is shown below.

Source: JICA Study Team

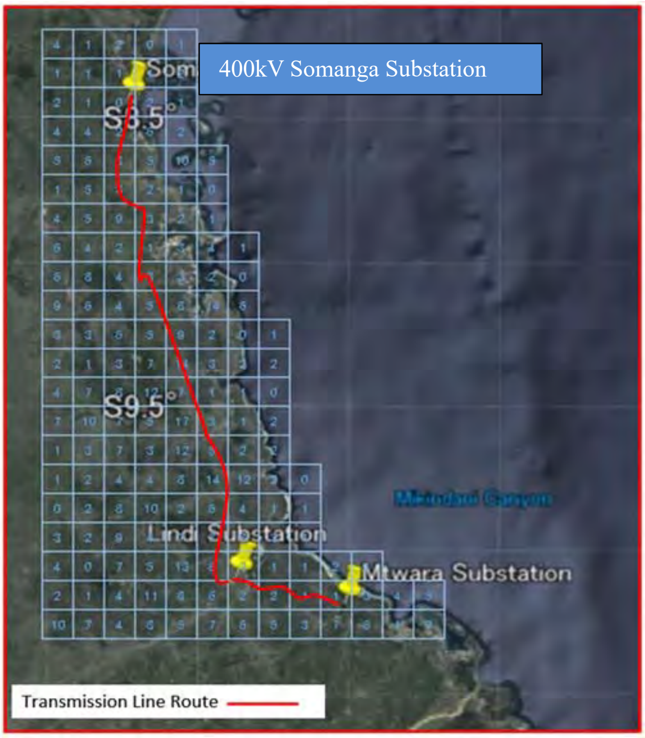
Figure 8-30 Contamination (Salt) Distribution Map

(4) IKL

The IKL map for 400kV New Mtwara Substation and 400kV Somanga Substation via 400kV New Lindi Substation is shown below.

Iso Keraunic Level (IKL) in the transmission line route has a value in the range of 22-36.

If IKL level is assumed as "100" in Africa, the probability of a lightning strike to actually reach the ground is estimated to be small, and the failure rate of the equipment without lightning protection is expected to be very low, therefore normal design for lightning protection will be sufficient for substations and transmission lines between Mtwara and Somanga.



Source: JICA Study Team

Figure 8-31 IKL Map

(5) Insulator Set and Fittings

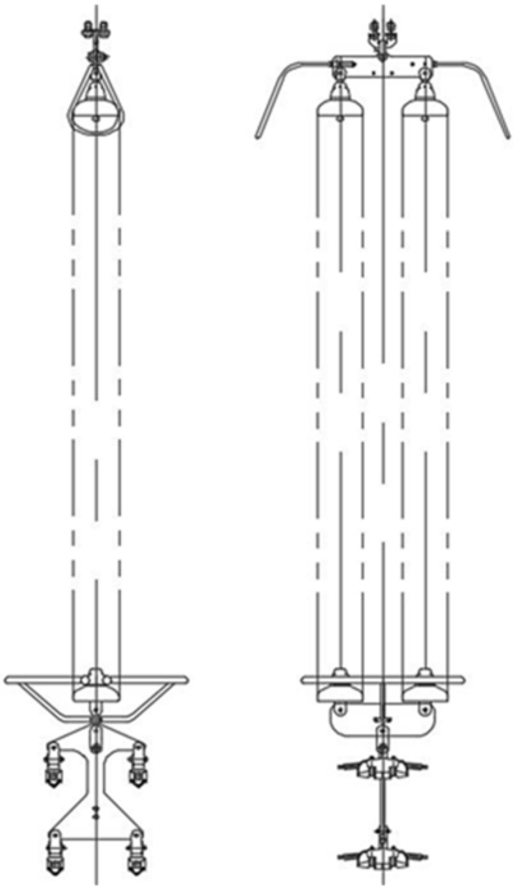


Figure 8-32 Insulator Set and Fittings (Suspension)

Source: JICA Study Team

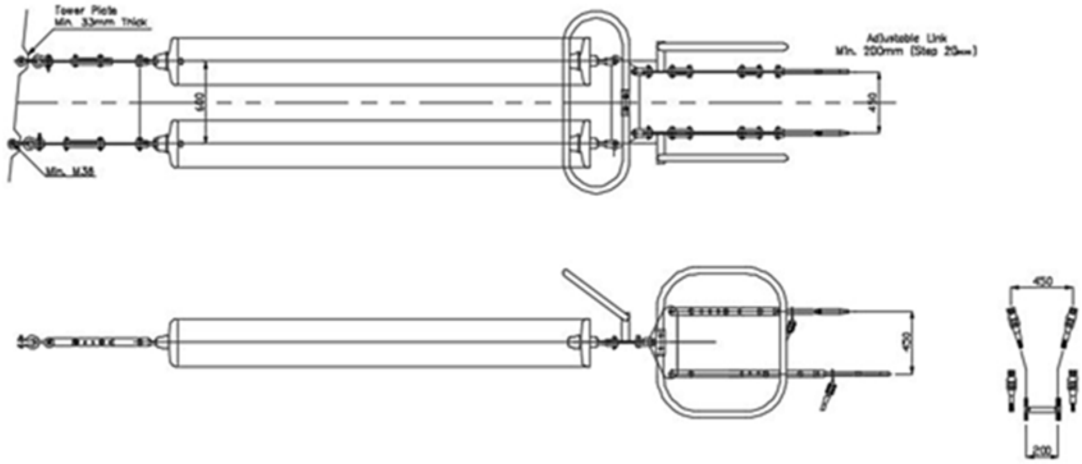


Figure 8-33 Insulator Set and Fittings (Tension)

Source: JICA Study Team

8.2.4 Towers

(1) Tower types

The supporting structures will be two-circuit steel angle towers with concrete foundations. These towers should withstand the severest condition including the breakage of two wires, that is, either 1 ground wire + 1 line conductor or 2 line conductors.

Considering the topography of line routes in this Project, it will be most economical to design tower of the basic types as shown in Table 8-30.

Table 8-30 Tower Type

Tower Type	Insulator String	Horizontal Angle of Line	Nominal span	Wind Span	Weight Span	Phase Span
NS Tower Normal Suspension	Suspension I-string	0° – 2°	400 m	440 m reduced i)	max 700 m min 200 m	650 m ii)
HS Tower Heavy Suspension	Suspension I-string	0° – 2° long span	400 m	800 m reduced i)	max 1100 m min 300 m	950 m ii)
LA Tower Light Angle	Tension string	0° – 15°	400 m	440 m	max 700 m min -350 m	650 m ii)
MA Tower Medium Angle	Tension string	0° – 30°	400 m	440 m	max 700 m min -350 m	650 m ii)
HA/DE Tower Heavy Angle/ Terminal	Tension string	30° – 70° 0° – 90° iii)	400 m	440 m	max 700 m min -350 m	650 m ii)
TP Tower Transposition	Tension string	2°	400 m	440 m	max 700 m min -350 m	650 m

Source: TANESCO data (New Iringa-Shinyanga Report July 2010)

i) Wind span values for the line angle of 0°; for line angles >0°
The wind span has to be decreased accordingly.

ii) These are minimum values for the mid-span criterion; actual maximum spans may be higher in case mid-span phase-to-phase spacing is determined by phase-to-tower steelwork clearances.

iii) Considering the slack span between terminal tower and S/S gantry.

Beside the basic type (±0), the towers shall have body extension of 4 m, 8 m, and 12 m with interchangeable leg extensions from -3 m to +3 m.

The height of the basic type suspension tower can be determined as follows:

Maximum sag for a 400 m span and 85 ºC	17.50 m
Length of insulator string I-type	4.70 m
Minimum clearance to ground	8.60 m
Height of crossarm	30.80 m **say 31.00 m**

(2) Clearance

The minimum clearance between line conductors and ground or other objects shall be specified in the following table.

Table 8-31 Clearance

Situation	Minimum clearance (m)
	400 kV
Normal ground	10.00
*Roads - road level	8.60
Power transmission & Telecommunications lines:	
- Lowest line conductor of upper line to highest conductor or earthwire of lower line	4.40
- Lowest line conductor of upper line to support the lower line on which a person may stand	5.30
Railway crossing	11.00
- Rail level	
- Electrified Railway crossing, building, gantries, or other structures on which a man can stay	7.20
Ground level at animal corridors crossing Transmission line route	11.00
Ground level at roads or yards where road mobile cranes are likely to be employed	12.20
Any wall, building or other structure on which a man stand, or on which a ladder may be placed	5.30
Street lighting / Grown trees	4.70

*Any road that is normally maintained by Government and / or other recognized public authority.

Source: TANESCO data (New Iringa-Shinyanga Report July 2010)

(3) Working Loads and their Combinations

The following normal and abnormal loads are assumed to be simultaneously applied to suspension, angle, and dead-end towers in the combinations shown in Table 8-32.

1) Assumed Loads

a) Vertical loads:

- Steel tower weight (Wt)
- Weights of conductors, insulator strings, ground wires and hard ware (Wc)
- Vertical component due to the differences between supporting levels of conductor/ ground wire (Wc')

b) Horizontal transverse loads:

- Wind pressure on tower (Ht)
  In determining Ht for the transverse face, the following formula shall be applied:

$$\left(\begin{array}{c}\text{The sum of the projected areas of}\\ \text{all members of the transverse faces}\end{array}\right) \times \left(\begin{array}{c}\text{The unit wind pressure for}\\ \text{transverse faces (kg/cm}^2\text{) indicated}\\ \text{in loading trees}\end{array}\right)$$

- Wind pressure on conductors/ground wires insulator strings etc. (Hc)

- Horizontal transverse component of assumed tension of conductor/ ground wires in case a line has a horizontal angle (Ha)
- Torsional force resulting from conductor/ground wire breakage (q)

c) Horizontal longitudinal load:

- Wind pressure on tower (Ht')
- Horizontal longitudinal component of the unbalance tension of conductors ground wires on suspension, angle tower and dead - end tower (P_1)
- Horizontal longitudinal component of the unbalance tension which develops as a result of conductors/ground wires breakage (P_2)
- Torsional force which develops due to conductors/ground wire breakage (q_1')

2) Load combination

a) Normal Working Loads

The following loads shall be deemed to work simultaneously. The wind direction shall be classified as either perpendicular to the line or parallel to the line, and a larger portion of the load acting on the line shall be taken as the design stress of the component material.

Vertical Load	:	Wt, Wc
Horizontal Transverse Load	:	Ht, Hc, Ha.
Horizontal Longitudinal Load	:	Ht', P_1

b) Broken Wire Condition (Abnormal Working Loads)

In case any two conductors or one ground wire plus any one conductor at one side are assumed to be broken, the unbalance tension and torsional force shall be added to the loads specified in the above mentioned "Normal Working Loads".

In case of power conductor breakage, the tension on the suspension type tower shall be reduced to 60% of the specified maximum working tension. This reduction shall not be assumed for the tension type towers.

Vertical Load	:	Wt, Wc
Horizontal Transverse Load	:	Ht, Hc, Ha, q
Horizontal Longitudinal Load	:	Ht', P_1, P_2, q

Table 8-32 Assumed Load Combination

Kind of steel tower	Condition	Wind direction	Assumed load combination									
			Vertical load		Horizontal transverse load				Horizontal longitudinal load			
			Wt	Wc	Ht	Hc	Ha	q	Ht’	P1	P2	q_1’
Suspension and Tension Tower	Normal	Right angle	✔	✔	✔	✔	✔			✔		
		Parallel	✔	✔			✔		✔	✔		
	Abnormal	Right angle	✔	✔	✔	✔	✔	✔			✔	✔
		Parallel	✔	✔			✔	✔	✔		✔	✔
Dead-end Tower	Normal	Right angle	✔	✔	✔	✔				✔		
		Parallel	✔	✔					✔	✔		
	Abnormal	Right angle	✔	✔	✔	✔		✔		✔		✔
		Parallel	✔	✔				✔	✔	✔		✔

Source: JICA Study Team

3) Wind load

(a) Wind pressure (P) on the unit projected area of steel tower, conductor and insulator is expressed generally by the following formula:

$$P = \frac{1}{2} \cdot \rho \cdot C \cdot V_0^2 \qquad (\text{kg/m}^2)$$

Where, Vo : Mean wind velocity (m/s)
ρ : Air density (kg sec^2/m^4) : 0.127

$$\rho = \frac{1.293 \times 273}{t + 273} \cdot \frac{H}{760} \cdot \frac{1}{9.8} \qquad (\text{kg sec}^2/\text{m}^4)$$

t : Temperature
H : Air pressure
C : Air resistance coefficient

(b) The values of mean wind velocity, air pressure and temperature at this velocity are required for the calculation of wind pressure (P) per unit sectional area.

(c) The data of 28 m/s 10.0°C and 760 mmHg at the height of 10 m are used for the calculation.

For the tower, each of the values are as follows;

Vo	28 m/sec (Intact)	10 m/sec (broken wire)
C	3.95	
p	200 kg/m^2	25 kg/m^2

Source: JICA Study Team

As for the conductor and the insulator, the air resistance coefficient (C) is variable according to Reynolds number, and the wind velocity usually increases according to the height of conductor.

(d) After study of wind pressure on each of them, the following values are obtained.

Conductor

	Intact (m/sec)	Broken wire (m/sec)
Vo	28	10
C	1	1
p	77	10

Insulator

	Intact (m/sec)	Broken wire (m/sec)
Vo	28	10
C	1.4	1.4
p	108	15

Source: JICA Study Team

(e) Using the above explanation, the ultimate loading in gust wind is obtained. This can be calculated by multiplying mean wind load by dynamic factor as expressed below:

$$\textit{Dynamic factor} = \alpha^2 \cdot \beta$$

Where, α : Gust factor
β : Scale reduction coefficient of facility

Gust factor is determined as 1.5 for intact condition, and 1.7 for broken wire condition, based on the data of Japan and European countries.

The coefficient β is not considered for relatively small scale facilities such as towers and insulators, namely $\beta = 1$ is used. However, as conductors are extending for over several hundred meters, β is considered.

Here, $\beta = 0.62$ is adopted.

Using the above figures, wind load at instantaneous max. Wind velocity is calculated. The values thus computed are shown as follows:

Wind Load at Instantaneous Max. Velocity

(kg/m^2)

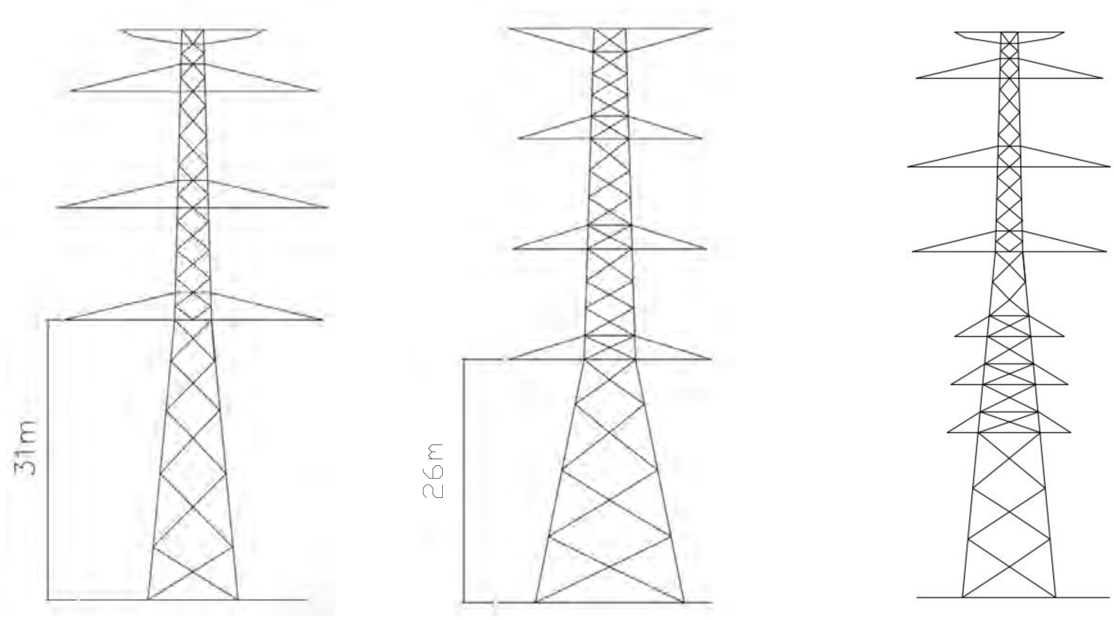
Normal condition			Abnormal condition		
Tower	Conductor	Insulator	Tower	Conductor	Insulator
380	90	206	75	20	45

Source: JICA Study Team

(4) Tower Design

Fundamental tower types design to be applied for this Project are shown in Figure 8-34. The suspension type is applied in the condition where the horizontal angle of line is below 2 degree.

Four (4) circuit tower is designed to combine two (2) additional circuits of 132kV transmission line below the two (2) circuits of 400kV transmission line on the same tower.



Suspension type Tension type 4CCT type

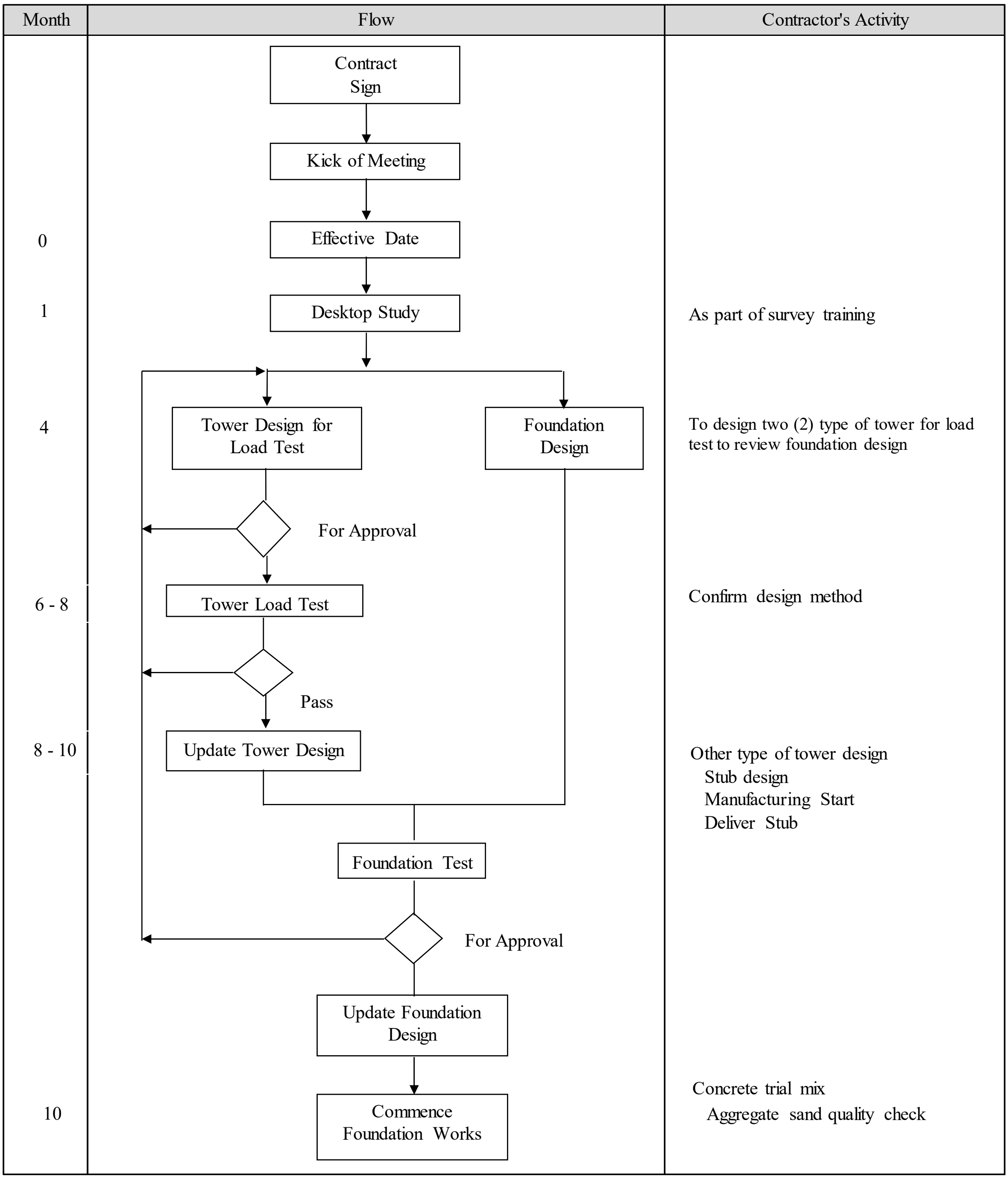
Source: JICA Study Team

Figure 8-34 Type of Tower

8.2.5 Foundation

(1) Design flow for the tower and foundation

Figure 8-35 shows the design flow for the tower and foundation.



Source: JICA Study Team

Figure 8-35 Design Flow for the Tower and Foundation

(2) Basic Parameters for foundation design

Foundation type should be designed according to soil condition, which is determined by soil type, the N-value corresponding to soil hardness measured by the standard penetration test and water level.

Fundamental foundation types are shown in Table 8-33 and Figure 8-36.

Table 8-33 Basic Parameters for Foundation Design

Foundation types		I	II	III	III-w	IV	V	V-w1	V-w2	VI
		Concrete Pad & chimney				Rock anchor	Raft enlarge	Raft enlarge (Swamp)	Raft enlarge (Swamp / High Water)	Pile
Approximate soil description		Stiff Clay / Dense Sand	Firm Clay / Medium Dense Sand	Soft Clay / Silt / Loose Sand	Soft Clay / Silt / Loose Sand with Water	Homogeneous Rock	Bad Soil condition with Water	Bad Soil condition with Water	Bad Soil condition with High Water	Very Bad Soil condition with High Water
N-value	Sandy soil	More than 30	30 - 10	10 - 4	10 - 4	More than 50	Less than 4	Less than 4	Less than 4	Less than 4
	Clayey soil	More than 8	8 - 4	4 - 2	4 - 2		Less than 2	Less than 2	Less than 2	Less than 2
Design uplift frustum angle		20 deg.	15 deg.	10 deg.	0 deg.	30 deg.	0 deg.	0 deg.	0 deg.	0 deg.
Concrete unit weight (kg/m^3)		2,400	2,400	2,400	1,400*	2,400	1,400*	1400*	1,400*	1,400*
Soil/Rock unit weight (kg/m^3)		1,600	1,500	1,400	950*	1,950	950*	950*	950*	950*

*Submerged unit weight

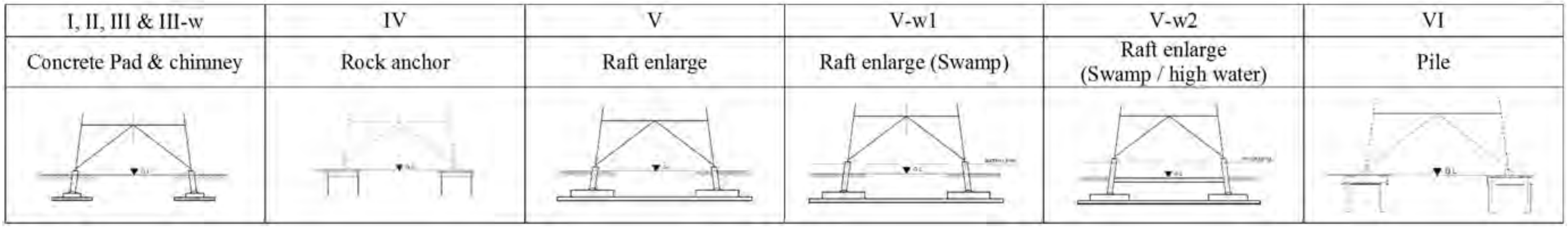


Figure 8-36 Type of Foundation

(3) Soil investigation and Foundation type

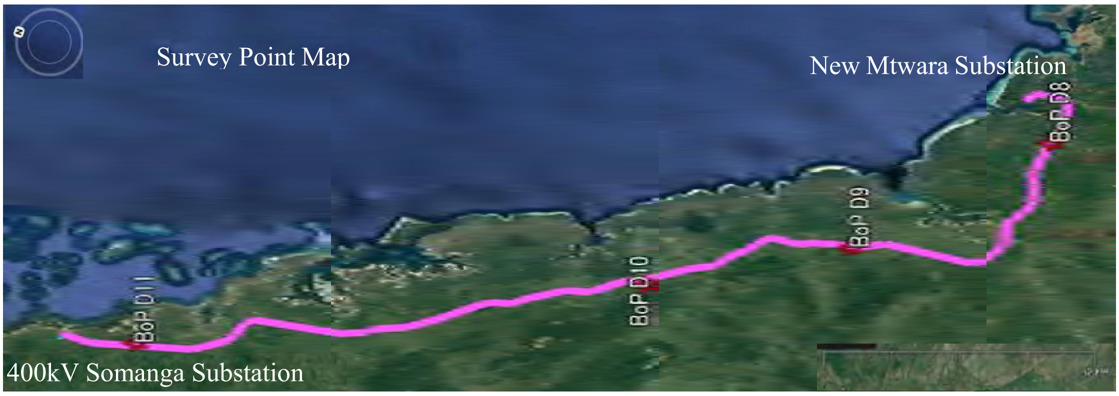
Based on the geological survey conducted during the Study, the foundation type for each tower was examined as shown in below.
(Including soft ground bearing capacity, N-value less than 10)

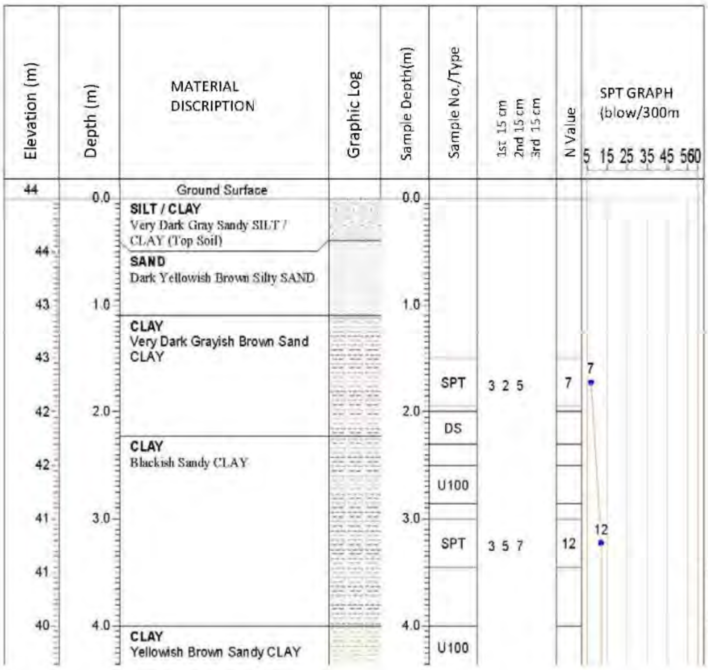
According to the result of geological investigation, it is not necessary to secure the borrow pit and the spoil bank for the following reasons.

a) Since the transmission line route is generally flat, a large amount of soil cutting and banking will not occur.

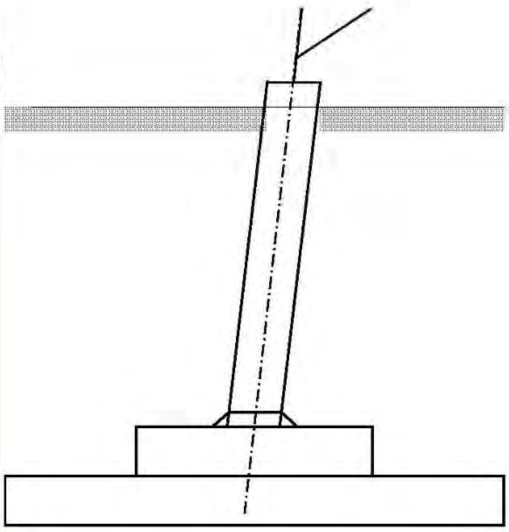
b) The soil after backfilling in the foundation works will be utilized for the leveling of tower site.

c) According to the result of geological investigation, it is known that no layer adversely affects backfilling and leveling of tower site.

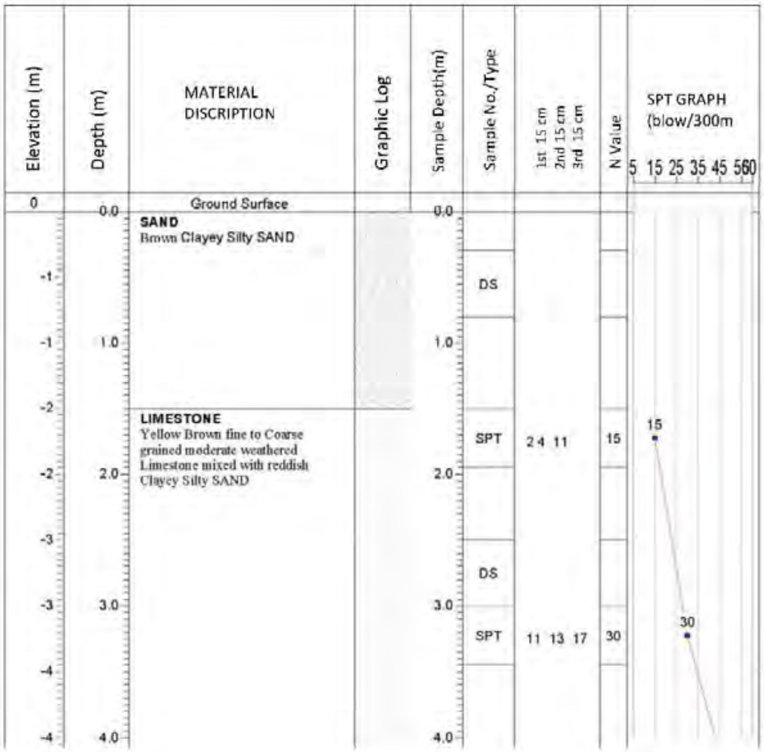


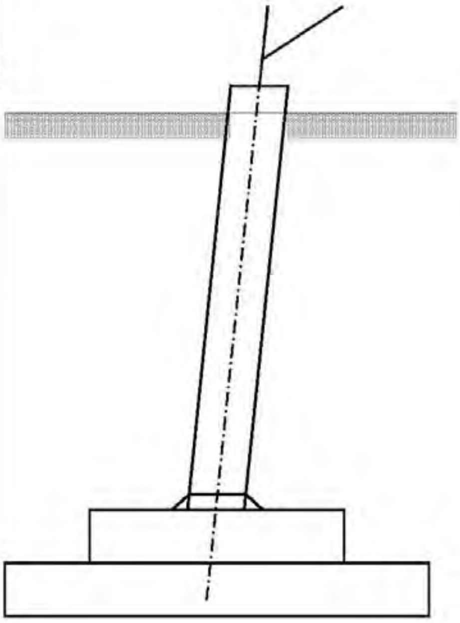


Survey points D 8

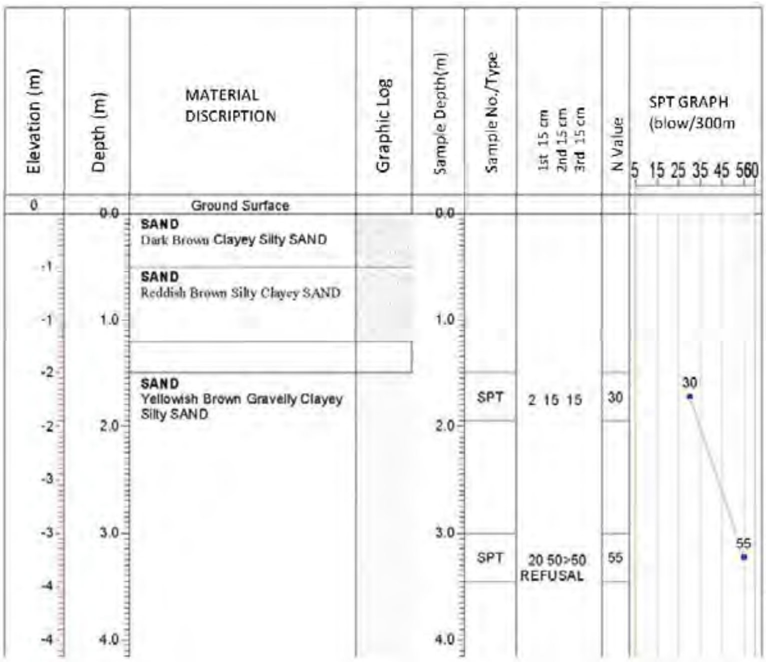


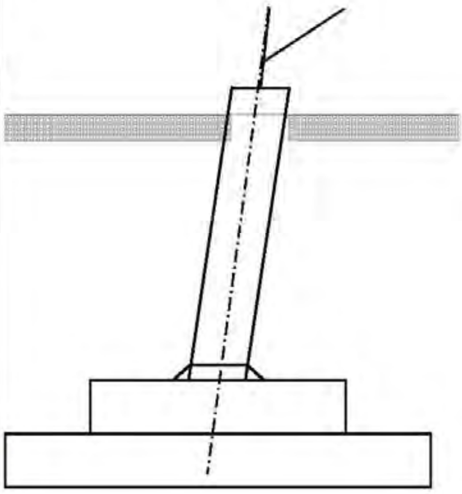
Concrete Pad &chimney II



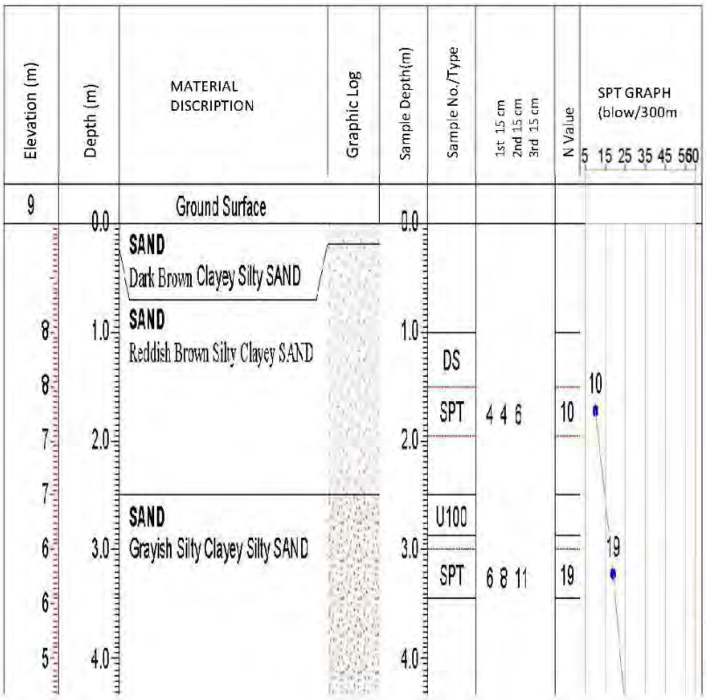


Survey points D 9 Concrete Pad &chimney I

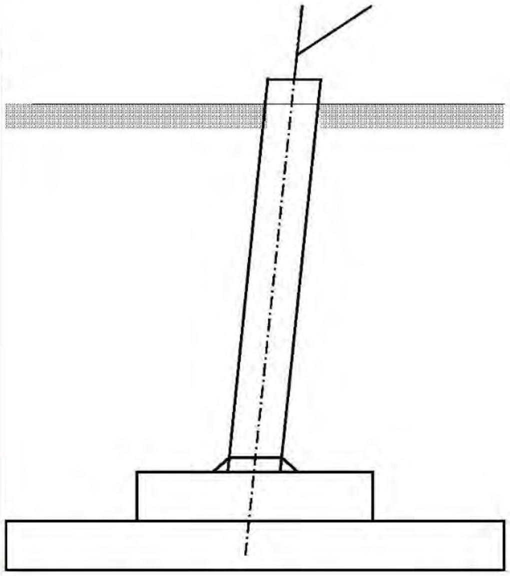




Survey points D 10 Concrete Pad &chimney I



Survey points D 11



Concrete Pad &chimney II

Source: JICA Study Team

Figure 8-37 Soil Investigation and Foundation Type

8.3 BASIC DESIGN OF 400KV SUBSTATIONS

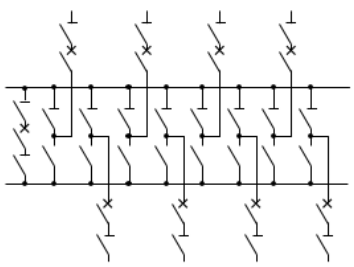
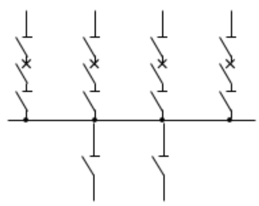
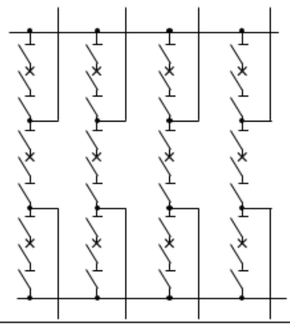
8.3.1 Bus Configuration

As for the operation of the substation, an optimal bus and breaker arrangement shall be selected taking the reliability, safety during accidents, expandability, and economic efficiency into consideration.

As shown in Table 8-34, there are three categories of bus and breaker arrangement, namely, a single bus system, a double bus single breaker system, and a double bus 1.5 (one and a half) breaker system. A single bus system is applied to a relatively small substation. The operation is simple, because the number of transmission lines connected to the bus is small and there is no bus switching operation. On the other hand, when a bus accident occurs, the entire substation suffers a blackout. Therefore, it is not selected for the 400kV substations.

Considering the double bus system, it is possible to separate the buses for normal and emergency operation. In addition, it has advantages in terms of high operability with regard to the maintenance of buses, and it can be expanded in the future. Even though the number of breakers increases, the 1.5 circuit breaker system is superior in terms of operability, because there is no need to cut off the line even when inspecting the circuit breaker.

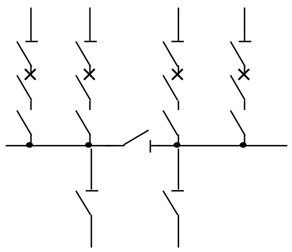
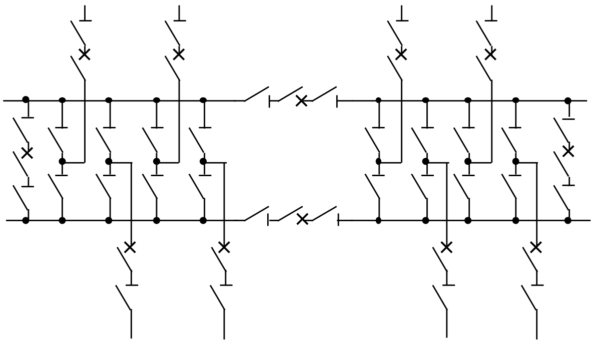
Table 8-34 Comparison of Substation Bus and Breaker Arrangement

type	Double bus single breaker (1CB) method	Single bus method	Double bus one and a half breaker (1.5CB) method
Composition			
1 Bus accident	blackout on accident bus side	blackout	no blackout
Maintenance constraint	base	many	few
Construction cost	base	low	high

Source: JICA Study Team

As for 132kV secondary bus system, double bus method are used to have power supply reliability with flexible operation. When number of feeders will increase, double bus single breaker with segment breakers as shown in Table 8-35, shall be suggested to contribute higher operability.

Table 8-35 Bus System (with Segment Breakers)

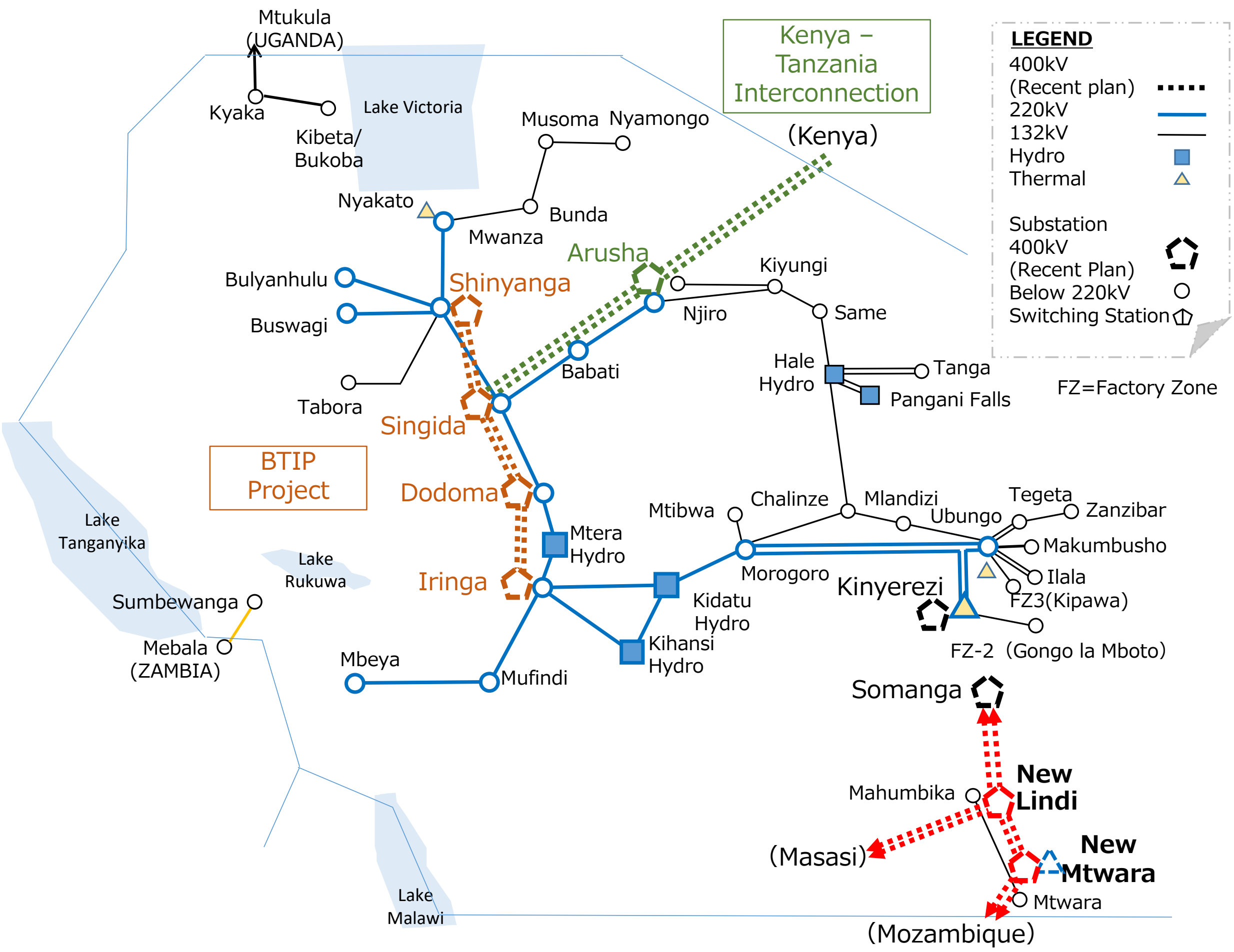
type	Single bus method (segment disconnector)	Double bus single breaker (1CB) method (4 segments)
Composition		
Construction cost	slightly higher than Single bus method	slightly higher than Double bus single breaker (1CB) method

Source: JICA Study Team

From the research on the existing/planned substations owned by TANESCO, the existing 220kV substation (Kinyerezi I) uses a double bus system, and it is confirmed that the double bus system will be applied to the new 400 kV substations (Iringa, Dodoma, Singida, Shinyanga). "The Tanzanian grid code - the network code" prescribes that the new transmission system of 220 kV and above must adopt a double bus system.

According to the "National power system master plan final report" issued in March 2017, the 220 kV and 400kV substations must use a double bus system. In addition, for 400kV substations, 1.5 circuit breaker system shall be generally considered.

JICA Study Team confirms that TANESCO prefers the 1.5 circuit breaker system for both 400kV New Mtwara Substation and 400kV New Lindi Substation. The 400kV Arusha Substation, which is the connection point in the Kenya – Tanzania Power Interconnection Project, is being planned to adopt the 1.5CB method, because the substation will act as an international interconnection. Considering its importance as an interconnection network with Mozambique, the New Mtwara Substation shall be constructed with 1.5 circuit breaker system.



Source: JICA Study Team

Figure 8-38 Recent 400kV Plan

8.3.2 Transformer

(1) Transformer Type and its transportation method

The comparison of transformer types is shown in Table 8-36, although it varies depending on the capacity or manufacturers.

A single-phase transformer is composed of coils, cores and insulators for one phase inside a tank. Three single-phase transformers are transported one by one and connected into a three phase use at the substation site.

In the case of special three-phase transformer, the coils and cores of one phase are stored in the tanks of each phase like a single-phase transformer, and each tank is sealed and transported to the substation site. Three tanks are connected at the site by a three-phase connection unit which is put over the tanks.

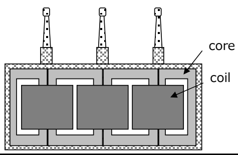
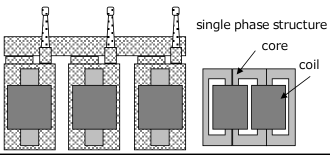
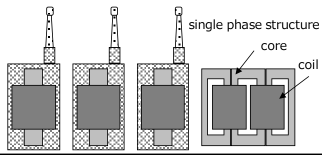
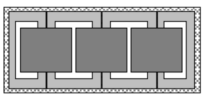
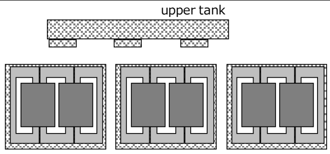
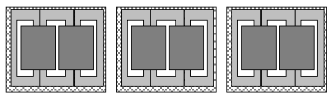
Since the single-phase transformers consist of three units, a larger installation area is required when compared with the ordinary three-phase transformer. The special three-phase transformer also needs a large space. On the other hand, the special three-phase transformer is integrated in three phases, the installation area can be reduced when compared with the single-phase transformer. In general, a three-phase transformer and a special three-phase transformer are lighter because the exterior parts, such as soundproof tanks, are shared by all the phases.

Regarding the total weight after assembly, the single-phase transformer is the heaviest. However regarding the weight for transportation process, the three-phase transformer is the heaviest. The weight of the single-phase transformer is 50% and the special three-phase transformer is 40% when compared with the three-phase transformer.

With regard to the installation period, the three-phase transformer has the shortest installation period. Assembling process of the single-phase transformers shall be sequential. That is, after installing the first single-phase transformer with a crane, the next single-phase transformer is installed with the same crane. In such a case, the installation period of the single-phase transformer takes the longest time, taking about twice as long as the ordinary three-phase transformer.

For the 400kV New Mtwara Substation, which is adjacent to the Mtwara port, ordinary three-phase transformer is the best because of its short installation period and reasonable cost. In case of the 400kV New Lindi Substation, JICA Study Team suggests special three-phase transformer as the optimum transformer type, considering transportation penalties, transportation route restrictions, duration of installation period and flexibility of expanding the substation etc.

Table 8-36 Comparison of Transformer Type

		Ordinary three-phase transformer	Special three-phase transformer	Single-phase transformer（3 units）
Structure (Installation form)				
Transportation form				
Outline	installation space	100%	120%	200%
	weight	100%	130%	140%
Transportation	max weight	100%	40%	50%
On-site installation	period	100%	110 ～ 130%	180 ～ 210%
	work space	100%	100 ～ 120%	150 ～ 180%

Source: Electric Cooperative Research Vol. 69, No. 2
(Disassembly transportation of transformer and quality management standard of local work)

As for transportation, there is no problem with regard to landing at the Mtwara port. A 100 ton crane was installed in 2015 and a 300 ton crane has been added in February 2019. In addition, JICA Study Team can use these two cranes for landing. On the other hand, for a load which weighs more than 56 tons, a surcharge of US$ 140,000 will be charged for road transportation. Although other than the weight is not actual restriction, the constraints on the length of vehicle according to TANROADS are indicated below for reference. :

Maximum Overall Length	:	Rigid Vehicle 12.5m, Articulated Vehicle 17m, Any Combination of Vehicles 22m
Maximum Overall Width	:	2.6m
Maximum Overall Height	:	4.6m

An application to the Ministry of Works will be required for road transportation of more than 56 tons as mentioned. The weight of the 100MW transformer including the trailer will be 110 tons for the three phase, 55 tons for the single phase and 48 tons for the special three phase. According to TANROADS, the application for over 100 tons load will be evaluated individually and it might take some time. In addition, we cannot neglect the risks involved in fixing of roads between Mtwara port and the 400kV New Lindi Substation, when we select a three-phase transformer.

As shown in Figure 8-39 and Table 8-37, it seems that the bridges do not need special reinforcement for the single phase and the special three phase. The transportation over 100 tons for the three phase shall be determined carefully. Even though it may not affect the total construction cost significantly, such reinforcement work will cause serious delay and it will become difficult to keep to the construction schedule.

In addition, JICA Study Team can use two cranes of the ship to land shipment more than 100 tons. On the other hand, for the load with weights of more than 56 tons, a surcharge of US$ 140,000 will be charged for road transport, according to TANROADS. There are also constraints on the length of vehicle as mentioned below:

Maximum Overall Length	:	Rigid Vehicle 12.5m, Articulated Vehicle 17m, Any Combination of Vehicles 22m
Maximum Overall Width	:	2.6m
Maximum Overall Height	:	4.6m

Source: JICA Study Team

Figure 8-39 Transport Route

Table 8-37 List of Bridges from the Mtwara Port

Mtwara

Name	Classification	Length (m)	Width (m)	Name	Classification	Length (m)	Width (m)
01 Magomeni1	Box Culvert	4.9	12	02 Magomeni2	Box Culvert	4.85	12
03 Magomeni3	Box Culvert	4.85	12	04 Magomeni4	Box Culvert	8	12
05 Magomeni5	Box Culvert	4.85	12	06 Mitengo1	Concrete Pipe	4	12
07 Mikindani1	Concrete Slab	11.85	7.1	08 Mikindani2	Concrete Slab	12	7.1
09 Mikindani3	Concrete Beam	30	8.7	10 Mbuo1	Concrete Beam	30	8.7
11 Mbuo2	Concrete Pipe	2.4	12	12 Changrawe	Box Culvert	4.85	12
13 Mpapura	Concrete Beam	28.9	8.7				

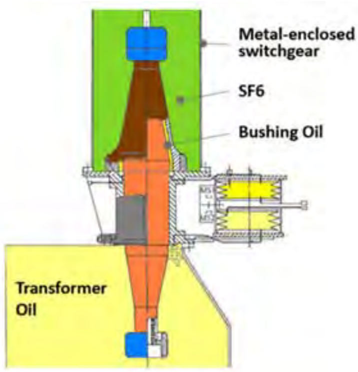
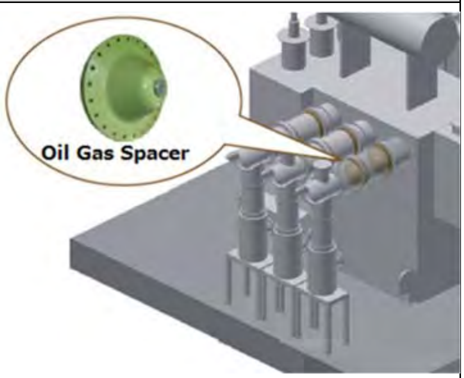
Lindi

Name	Classification	Length (m)	Width (m)	Name	Classification	Length (m)	Width (m)
01 Mkwaya1	Pipe Culvert	14.2	-	02 Mkwaya2	Box Culvert	14.2	-
03 Mkwaya3	Box Culvert	8	-	04 Mkwaya4	Box Culvert	8	-
05 Mkwaya5	Box Culvert	120	-	06 Mloweka	Concrete Pipe	15.2	-

Source: JICA Study Team

As a result, the special three phase transformer shall be selected for New Lindi Substation, considering the regulation of transport and risks of fixing the roads to transport heavy equipment over 100 tons.

In 400kV New Mtwara Substation, original three phase transformer shall be applied and the transformer will be directly connected to GIS to protect against salt. The oil gas spacer, which connects GIS and transformer, shall be applied to improve construction and maintenance. Since the long bushing is not required at the connecting point, construction and inspection become easy, and the cost and reliability are improved.

	Oil Gas Bushing	Oil Gas Spacer
Image		
Design, Constriction, and Maintenance	Difficult	Easy
Cost	Expensive for materials	Base

Source: JICA Study Team

Figure 8-40 Oil Gas Spacer

(2) Capacity of transformer

1) Normal Condition (100%)

As shown in Table 2-31, Chapter 2, demand forecast of two new substations is estimated as follows. For the reference, Masasi is a 400kV substation that will be expanded near Lindi after the project. The capacity of transformers will determined such that it will avoid the replacement of transformers, because transformers generally have a long life of more than 20 years. In addition, the power system in Tanzania does not have enough, therefore, the decrease of replacement works contributes to promote other power system projects. Secondly, each transformer should have the same capacity to simplify the management of power system.

In the case of Mtwara and Lindi, the demand in the year 2040 shall be considered to select the capacity of each unit.

<Written again > Table 2-31 Forecasted Demand for Each 400kV Substation (MW)

Area	400kV Substation	2022	2025	2030	2035	2040
Lindi	Lindi	125*	188*	163	199	214
Masasi	Masasi	-	-	76	93	111
Mtwara	Mtwara	43	89	107	124	142

*The demand of the New Lindi Substation in 2022 and 2025 includes Newala, Masasi, and Tandahimba.

a) New Mtwara

The estimated demand is 43 MW in 2022, however it is assumed to be 89 MW in a few years by 2025. If the power factor is set to 0.85, the required capacity until 2025 will be 105 MVA (89/0.85). After that, it will be 126 MVA (107/0.85) in 2030 and 167MVA (142/0.85) in 2040 due to the increase in demand. To supply 167MVA by two transformers, transformers with 83.5MVA and more are enough. Considering the popular size of 400kV transformer, 100MVA shall be selected.

b) New Lindi

The estimated demand is 125 MW in 2022, however it is assumed to be 188 MW in 2025. The required capacity in 2025 will be 221 MVA (188/0.85) if the power factor is set to 0.85. It will decrease one time to 192 MVA (163/0.85) in 2030 and increase to 252MVA (214/0.85) in 2040.The demand in 2030 will be decreased after the completion of 400kV New Masasi Substation. To supply 252MVA, the best option would be to use three 100MVA transformers. The following simulations evaluate that a group of transformers with the capacity of 100MVA can deal with one transformer fault.

Hence each capacity will be fixed to 100 MVA considering the unified capacity of each substation. If the unified capacity of transformers is not considered, then 130MVA*2 units of transformer can be selected for normal condition in New Lindi. But it cannot supply enough power in case of one transformer fault condition in 2040, as shown in Table 8-38, thus the alternative plan is rejected.

Table 8-38 Affordable Capacity of Transformers

Normal Condition	2040	At least 100MVA*2units is required in New Mtwara (167MVA in 2040)	OK
		At least 100MVA*3units or 130MVA*2units are required in New Lindi (252MVA in 2040)	OK
Fault Condition	2025	100*2 in New Mtwara and 100*3 in New Lindi can supply 273MVA sufficiently.	OK
		100*2 in New Mtwara and 130*2 in New Lindi is enough to supply 273MVA	OK
	2040	100*2 in New Mtwara and 100*3 in New Lindi is required to supply 357MVA	OK
		100*2 in New Mtwara and 130*2 in New Lindi is <u>not sufficient to supply</u> 357MVA.	NG
Conclusion		**100MVA*2 units for New Mtwara and 100MVA*3 units for New Lindi shall be planned**	

2) One transformer Fault (110% overload, Connection of 22 MW GT)

a) In 2025

The required capacity will be more than 273 MVA after one transformer fault.

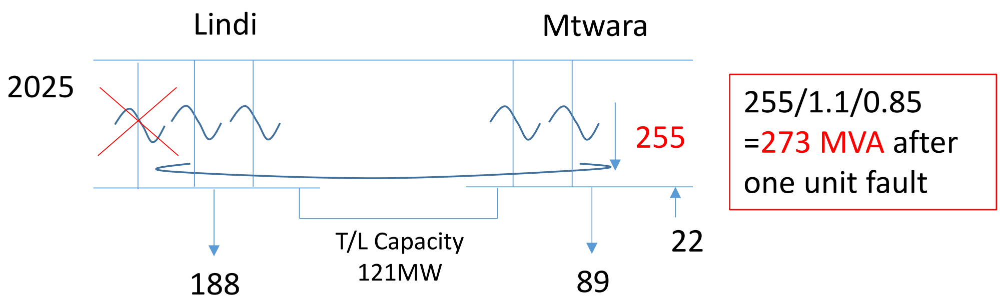


Figure 8-41 Power Flow in 2025

b) In 2040

The required capacity will be more than 357 MVA after one unit fault.

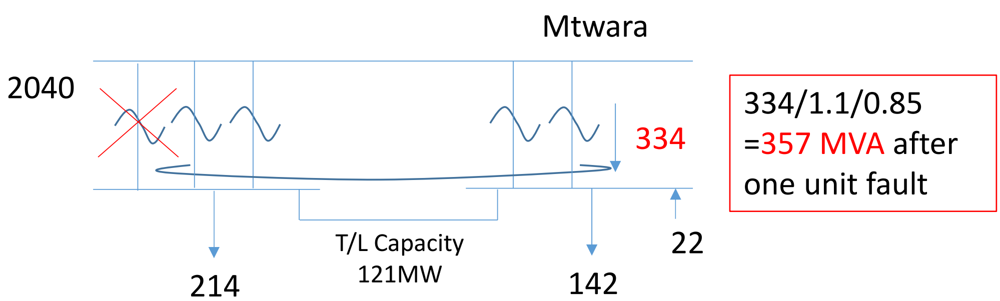


Figure 8-42 Power Flow in 2040

c) Capacity of transformer

If there is only one transformer at the substation, it is difficult to stop it for maintenance, and the power system reliability for these important substations cannot be satisfied. Hence, two or more transformers are planned for each substation.

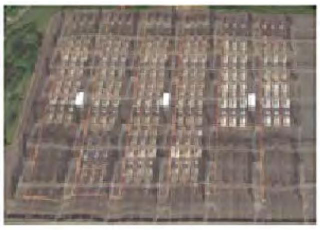
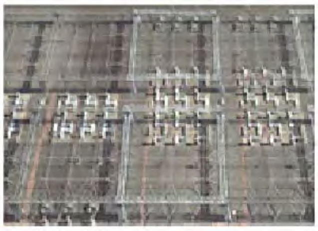
100MVA will be used as unit capacity by the following study until 2040. Capacity may be excessive at the initial stage, however sufficient capacity is needed for the 400kV bulk power system. In addition, frequent construction/expansion works can be avoided, thereby minimizing the total cost and the power outage for the works.

8.3.3 Switchgear

(1) Type of switchgears

As shown in Table 8-39, substations are classified into three types (AIS substation, Hybrid-GIS (H-GIS) substation, Full-GIS substation) according to the difference in the insulation method (air insulated or SF6 gas insulated) of each facility such as transformers, circuit breakers, disconnect switchgears, and other facilities.

Table 8-39 Comparison of Substations by Switchgears

	AIS Substation	Hybrid-GIS Substation	Full-GIS Substation
Type of Substation			
Specification	Busbar, GCB, DS,ES: Air Insulation	GCB, DS, ES: SF6 Gas Insulation Busbar: Air Insulation	GCB, DS, ES, Busbar: SF6 Gas Insulation
Reliability	Base	Higher	Highest
Construction Period	Base	Short	Short
Installation Space	Base	Smaller	Smallest
Maintenance Work	Base	Same	Less
Safety	Base	High	High
Tolerance to Pollution	Base	Higher	Highest
Construction Cost	Base	Higher	Highest

Source: JICA Study Team

AIS substations are composed of air insulated switchgears which secure insulation distance in air. H-GIS substations are composed of gas insulated facilities except for the bus bars. Full-GIS substations are composed of gas insulated facilities including the bus bars. Both substations contain gas insulated switchgears which use SF6 gas.

Substations are constructed in various places ranging from mountain area to city area. In general, Full-GIS substations are adopted in areas such as dusty area and city area, where the land acquisition is difficult, or in areas which are prone to salt damage due to the flow of sea breeze. Full-GIS substation and H-GIS substation need less land than AIS substations, owing to the high insulation performance of SF6 gas, and are resistant to salt damage because they are placed in sealed facilities.

(2) 400kV New Mtwara Substation

400kV New Mtwara Substation needs to adopt GIS to counter the salt pollution. Furthermore, the GIS has advantages, considering the uncertain power system configuration for the future expansion of power station and the importance of 400kV New Mtwara Substation as Mozambique interconnection point.

It is possible to install the GIS both outdoor and indoor. The indoor GIS is mainly applied for urban buildings and landscape requirements.

Salt damage countermeasures shall be especially considered in case of Mtwara. The candidate site #1 for 400kV New Mtwara Substation must need salt damage countermeasures because it is located at the coastline. Salt damage countermeasures such as adopting longer creepage distance for insulators, installing hot-line washing equipment for insulators, etc., should be implemented.

1) Creepage Distance

The pollution level of substations is classified as shown in Table 8-40. The pollution level at the 400kV New Mtwara Substation may exceed the highest category of very heavy.

The polluted level is selected based on dust and salt level. It is very severe in Tanzania. For example, “Very Heavy” has been applied for BTIP even in the inland areas around Dodoma. As a result, the Full-GIS shall be considered for the New Mtwara Substation next to the Sudi creek.

Table 8-40 Pollution Level (IEC60815)

Pollution Level	Minimum Nominal Specific Creepage Distance [mm/kV]
Very Light	12.7
Light	16
Medium	20
Heavy	25
Very Heavy	31

2) Countermeasure of reinforced insulation

Bus bar insulators have difficulty with regard to hot-line washing and maintenance. Therefore, reinforced insulations are commonly carried out as a countermeasure. Because, it is relatively easy to lengthen the creepage distance by adding insulators. Countermeasures can be taken by reinforced insulation not only in bus bar insulators but also in the other equipment. If it is difficult to deal with reinforced insulation alone due to production limit and economic efficiency, countermeasures by washing are also generally adopted.

3) Countermeasures of washing

If reinforced insulation is impossible due to production limit and economic efficiency, hot-line washing will be adopted as a countermeasure for the substation equipment. If hot-line washing is carried out, it is necessary to secure the washing withstanding voltage not less than the pollution withstanding voltage, and to wash in the contamination limit. As shown in Table 8-41, there are three washing methods, namely, a fixed spray type, a water type and a jet nozzle type. In this Project, 132kV AIS facilities need washing equipment. JICA Study Team considers that the jet nozzle type is preferable because the equipment cost is low.

Table 8-41 Washing Method and Overview

Washing method	Summary
Fixed spray type	The shape, number and arrangement of nozzles is determined according to its shape and size of the insulating tube as washing target. And the whole insulator is washed uniformly with water sprayed from the nozzle. In designing, the number of equipment facilities of the substation is so many that it is impossible to wash all the equipment at the same time. Therefore, it is necessary to design to be divided into several sections and to sequentially wash from low-level equipment to high-level equipment.
Curtain water type	If the fixed spray equipment is insufficient at typhoon in the coastal area etc., it creates a curtain of water on the windward side of the substation, shielding the equipment inside the substation from the salt wind and washing them.
Jet nozzle type	There are two methods such as fixing the position of the monitor nozzle and a method of cleaning while moving by human power. The jet washing method is washing by the operation of a worker towards washing target of insulator. Therefore, a nozzle mounting base is necessary in order to prevent reaction by the jet injection and to operate the nozzle freely. Firefighting monitor nozzles or similar structures are used for jet nozzles. In general, the diameter is 6 to 18 mm, the water pressure used is 4 to 15 kg / cm^2, and the water amount is about 100 to 400 l / min. On the other hand, the application point of this method is commonly used for hot-line washing of 20 to 140 kV class bus insulator or support insulator. And the advantage of this method is low equipment cost. The disadvantage of this method is that it takes time to wash insulator one by one, requires a lot of water, and requires manual labor for washing. Therefore, it is inappropriate to apply to a place with a short cleaning cycle. The mobile jet washing method is used for substations with a relatively low contamination level of 70 kV or less.

Sources: Electric Cooperative Research Vol. 63, No. 4 (Internationalization of substation specifications)

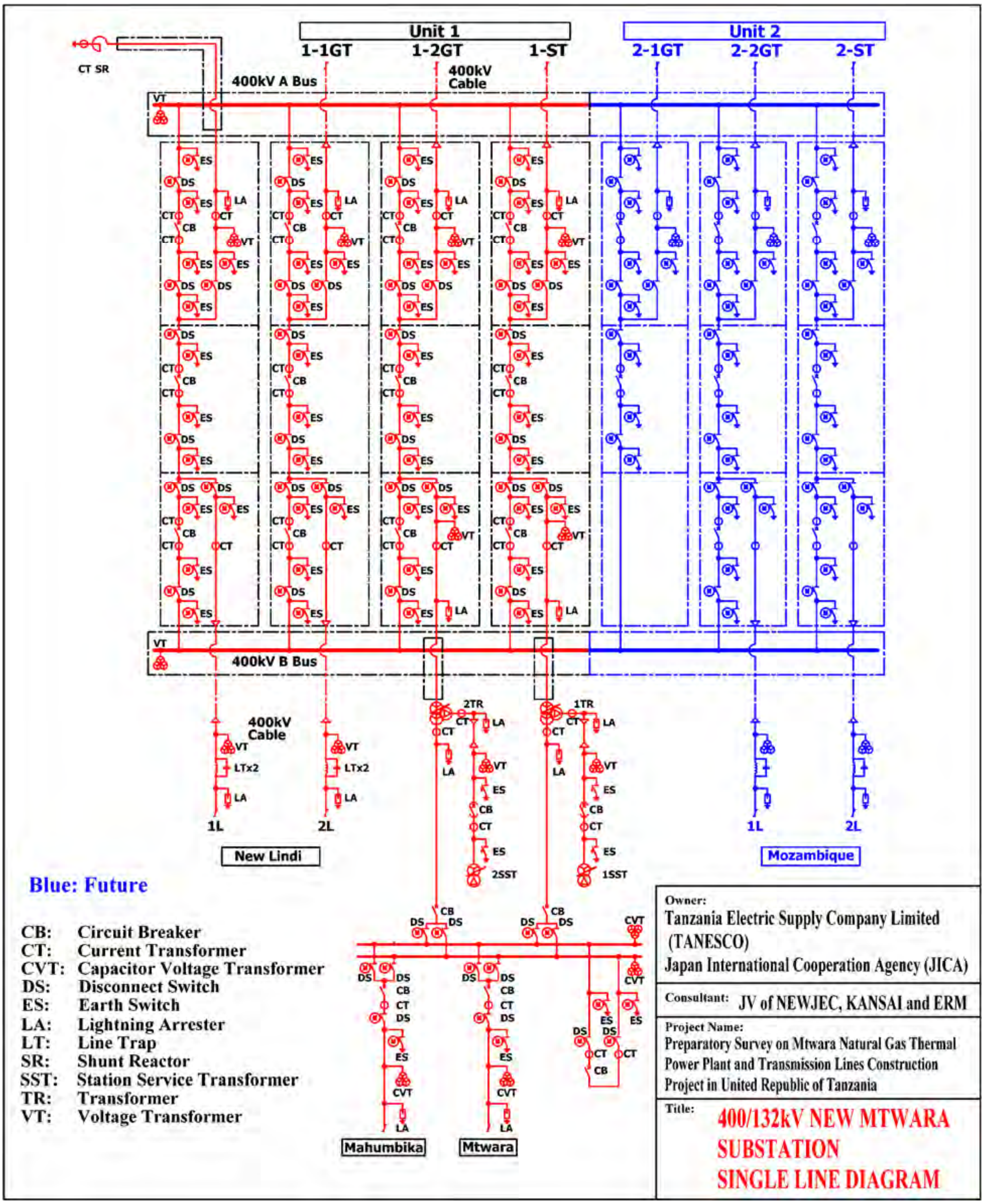
By adopting Full-GIS system to the 400kV New Mtwara Substation, bothering countermeasures against salt can be eliminated.

JICA Study Team has to consider the following for arrangement.

- Construction schedule including future plan to avoid dead equipment
- Cross of Cables
- CBF (Circuit Breaker Failure) in 1.5CB scheme to avoid tripping of transmission lines and generators at the same time.
- Adjacent area of the concerned transmission lines to avoid operation mistake.
- Flexibility for expansion and connection of 132 kV feeders.

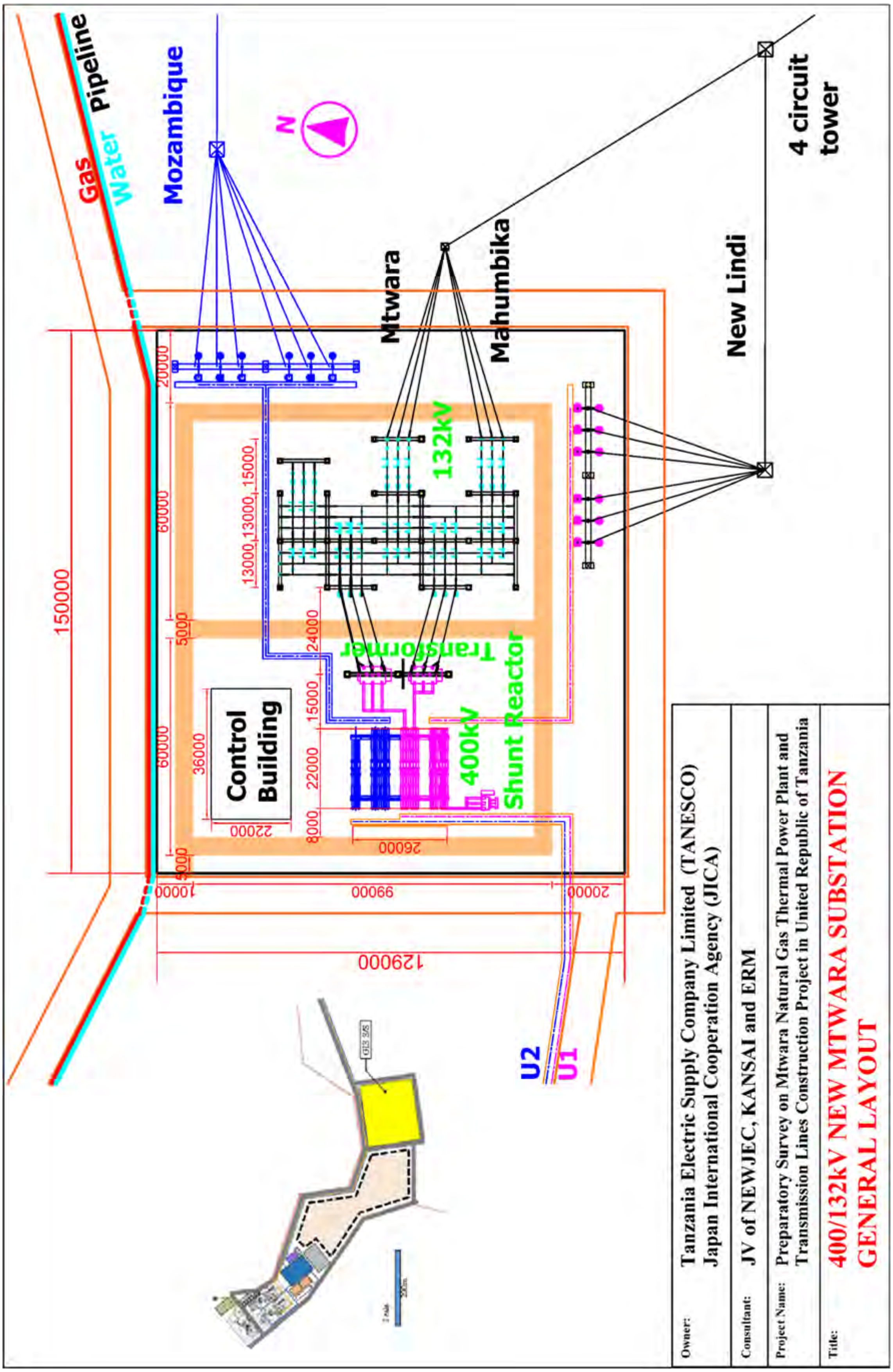
After studying the above, the following layout is proposed for 400kV New Mtwara Substation. The location of 400kV New Mtwara Substation, near the power station and 400kV transmission line towers, was determined by considering the total length of 400kV cables including Unit 2 and Mozambique interconnection.

The plot plan of 400kV New Mtwara Substation is shown in Figure 8-43 and Figure 8-44.



Source: JICA Study Team

Figure 8-43 Single Line Diagram of 400kV New Mtwara Substation



Source: JICA Study Team

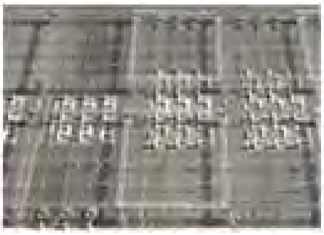
Figure 8-44 Layout of 400kV New Mtwara Substation

(3) 400kV New Lindi Substation

H-GIS and AIS are considered for 400kV New Lindi Substation. H-GIS is recommended for reliability in this Study because the 400kV New Lindi Substation is also an important base, and the other reasons are as follows.

- Reliability as 400kV bulk system
  Against lightning, rain, strong wind, and earthquake resistance
- Shared O&M
  Similar equipment with the New Mtwara Substation is required because unmanned New Lindi Substation will be operated from the New Mtwara Substation and one team will maintain both substations. Considering O&M cost, H-GIS is preferred.
- Severe pollution requirement
  AIS needs to be washed periodically because the standard creepage distance is set severe at 31 mm/kV throughout Tanzania.

Table 8-42 Comparison of Substation Type

	Hybrid-GIS		AIS	
Type of Substation				
Reliability	Less accidents due to few exposed and moving parts - Natural disasters such as wind, rain, and earthquake - Human injury	Excellent	Base	Good
Construction Period	6 month shorter	Excellent	Base	Good
Installation Space (400kV yard)	60% ($12,000m^2$)	Excellent	100% ($20,000m^2$)	Good
O&M	Less works for equipment maintenance	Excellent	washing insulator is needed	Fair
Safety	Less works at high place	Excellent	Base	Good
Tolerance to Pollution	Less exposed parts	Excellent	Base	Good
Construction Cost	100%	Fair	70%	Good

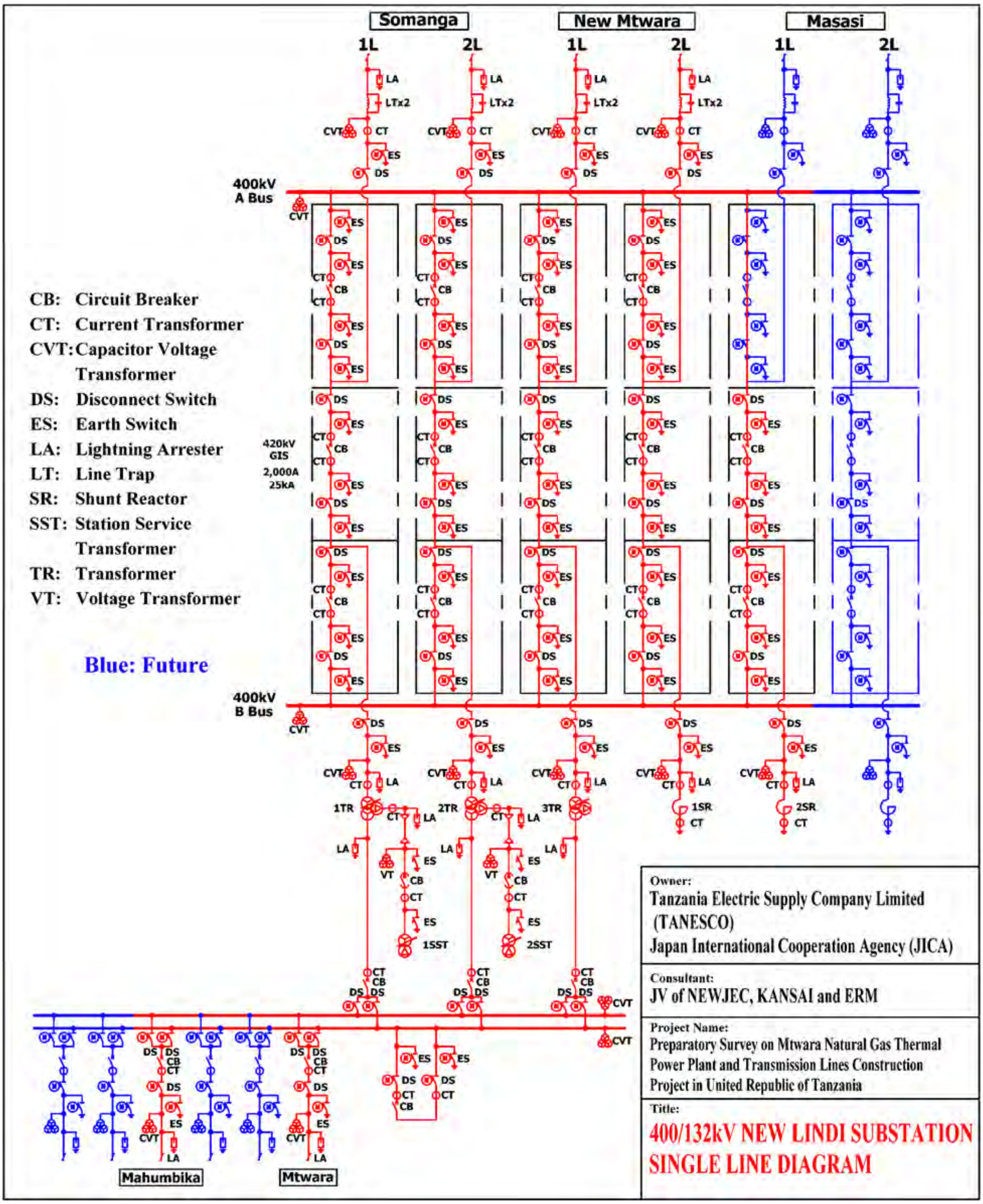
Source: JICA Study Team

The following points are considered for the design of 400kV New Lindi Substation.

- Six 400kV Feeders for Somanga, New Mtwara, and Masasi (Another future plan is possible to be included.) with 1.5CB scheme

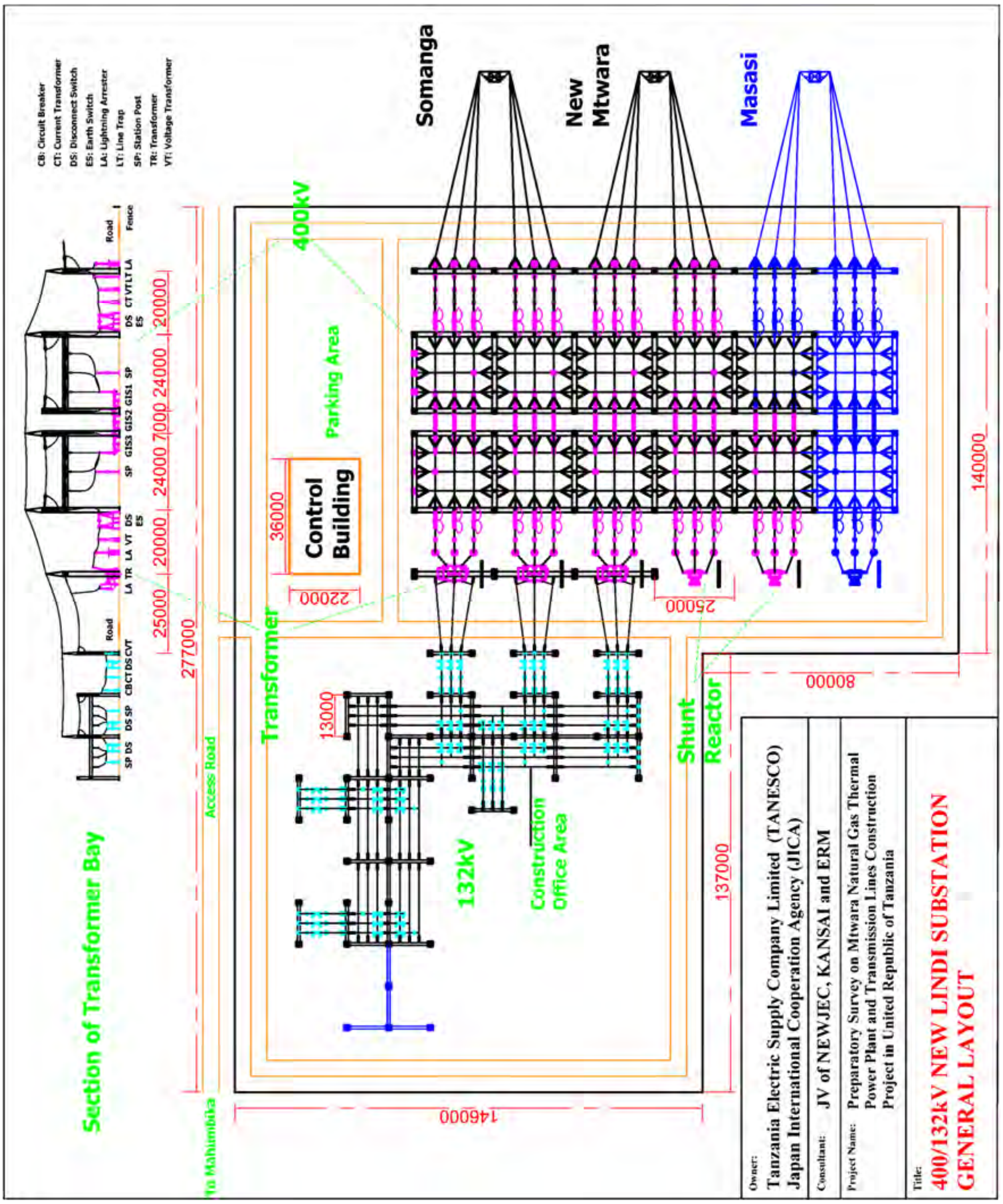
- 400kV switchgears shall be H-GIS. AIS may be alternative from financial point of view, provided that construction period is acceptable to extend six months.
- Three 400/132kV Transformers
- One 132kV bus coupler and six 132kV Feeders including the existing Mahumbika and Mtwara lines with two buses and 1CB scheme. (The number of feeders is subject to change. 132kV feeders may be arranged in the direction opposite to the gas pipeline, if it is difficult to set all transmission lines in the direction of the gas pipeline.)

The plot plans of 400kV New Lindi Substation are shown in Figure 8-45 to Figure 8-47.



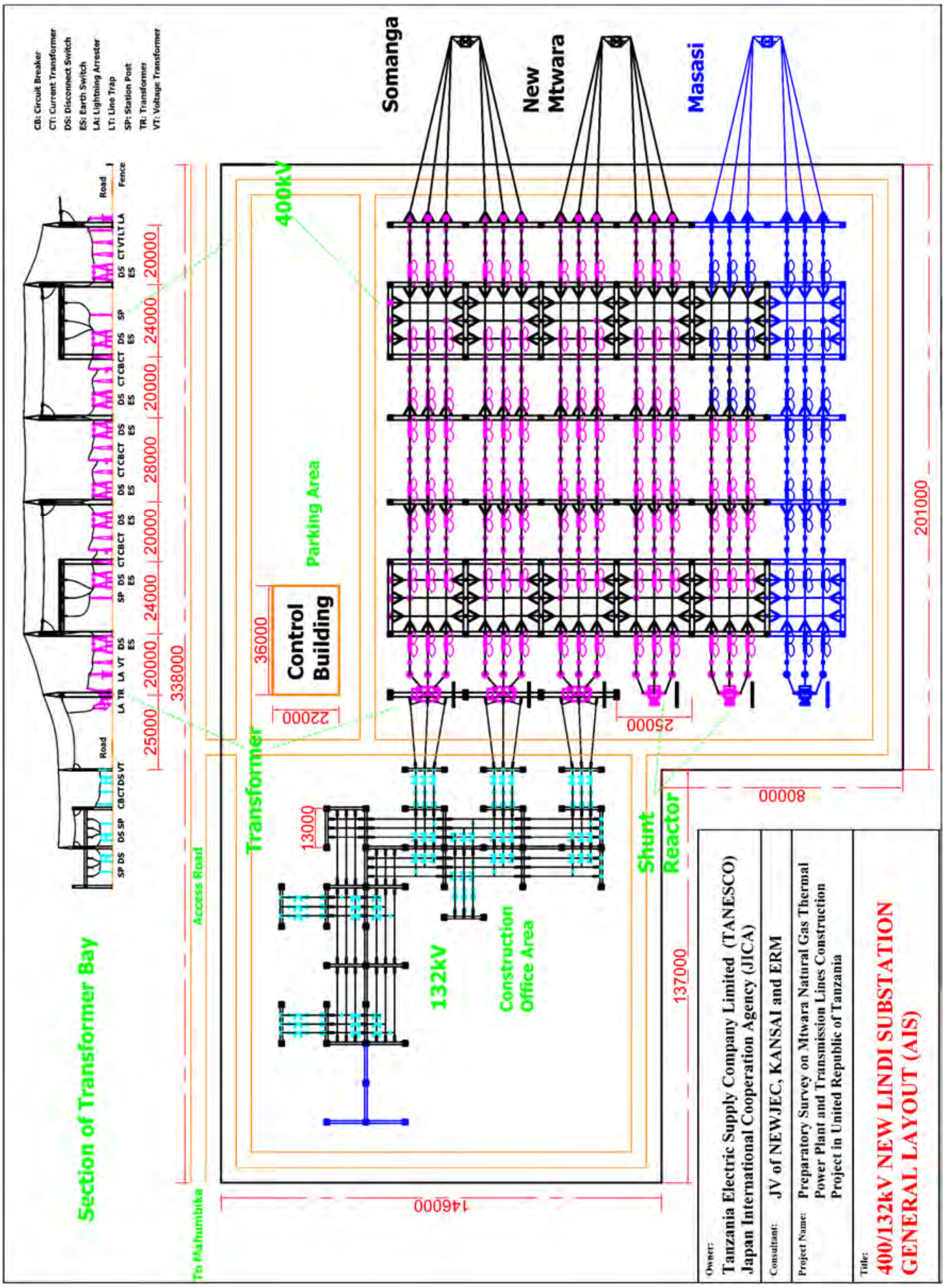
Source: JICA Study Team

Figure 8-45 Single Line Diagram of 400kV New Lindi Substation



Source: JICA Study Team

Figure 8-46 Layout of 400kV New Lindi Substation (H-GIS)



Source: JICA Study Team

Figure 8-47 Layout of 400kV New Lindi Substation (AIS)

(4) 400kV Somanga Substation

400kV Somanga Substation is being planned by another project. The cost of connection works, such as additional feeders and shunt reactors, is not included in the Project because they are confirmed to be included in another project based on information from TANESCO.

8.3.4 Reactor and Capacitor

In order to compensate for the capacitance or inductance of long distance transmission lines, it is necessary to install phase modifying equipment which connect to 400 kV transmission lines or bus. A direct connection to transmission lines can reduce the effect of transmission line fault. However, the required volume of compensation may change according to the change of power system.

The capacities are indicated in Table 8-43.

Table 8-43 Capacity of Reactor and Capacitor

Place	Line Name	Required Capacity	Facilities in this Project	Future Capacity
400kV New Lindi Substation	To Somanga	-110 MVar	Reactor 70Mvar*2	-50 to 80 Mvar (STATCOM)
	To New Mtwara	-30 Mvar		
400kV New Mtwara Substation	To New Lindi	-30 Mvar	Reactor 30Mvar*1	-

Source: JICA Study Team

8.3.5 Protection System

Protection systems are needed for main and back-up protection. Furthermore, in general, double group system is proposed for 400kV and extra high voltage system.

Table 8-44 Transmission Line Protection

Group	Line Name	Device Number
Group 1	Main	87L (Differential)
	Back-Up	21 (Distance) 67/67N (Transfer Trip) 50/51, 50N/51N
	Reclosing	25, 79
Group 2	Main	87L (Differential)
	Back-Up	21 (Distance) 67/67N (Transfer Trip) 50/51, 50N/51N
	Reclosing	25, 79

Source: JICA Study Team

8.3.6 Communication and SCADA System

The transmission lines between 400kV Somanga, New Lindi, and New Mtwara have two ground wires. At least, single OPGW (Optical Ground Wire) will be used. Back-up for the communication system is required for following reasons.

- 400kV system will be a bulk system in Tanzania
- Communication route has a long distance.
- There is no existing route (BTIP project has 230kV communication line).

Two methods are considered for the back-up system.

- Option 1: OPGW + OPGW
- Option 2: OPGW + PLC (Power Line Carrier)

PLC is old style, and the data transfer will be restricted. OPGW will cost an additional twenty (20) US dollars per meter. That means, about 6 million US dollars for three hundreds (300) kilometers. Although Option 1 is recommended. It will difficult to co-ordinate and secure communication using the PLC communication method between Kinyerezi and Somanga, as the distance is more.

The status of national grid is remotely monitored by the Supervisory Control and Data Acquisition (SCADA) system. This is already implemented in an independent grid at Mtwara and Lindi areas, and the micro SCADA system is adopted to the existing 132kV substations, in order to monitor and operate the facilities in the substations. However, it is suggested to construct a new communication system and place SCADA at the new 400kV substations which are connected to the central operation system.

In general, the SCADA system has monitoring, controlling and recording functions and these functions save operating and recording works as shown in Table 8-45. It is also expected to shorten the blackout time because we can analyze the accidents in detail.

Table 8-45 Basic Functions of the SCADA System

Item		Function
Monitoring Function	Monitoring	Display the operation state of substations such as open / close status of circuit breaker and disconnector, voltage, current, active power, reactive power in the single line diagram on the monitor screen.
	Alarm	Notify the operator of a fault in devices, protective device operation, automatic operation of devices and etc. with an alarm.
Control Function	Control	Perform remote operation such as opening / closing operations of circuit breakers and disconnect switchgears, increase / decrease operation of transformer taps, use / lock operation of protective relays and etc.
Record Function	Daily and Monthly Record	Record the operation information of substations such as voltage, current, active power, reactive power, and create a daily and monthly report.
	Event Record for Alarm or Operation	Record alarm and operation information with time series.

Source: JICA Study Team

8.3.7 Control Building

400kV New Lindi Substation is assumed to be unmanned and controlled from 400kV New Mtwara Substation. Both substations will have remote control functions at GCC (Grid Control Center). The following is the image of control building. JICA Study Team proposes a two-floor building, because 400kV substation will have 33kV cables and many underground control cables, and the cable treatment room will be secured on the ground floor.

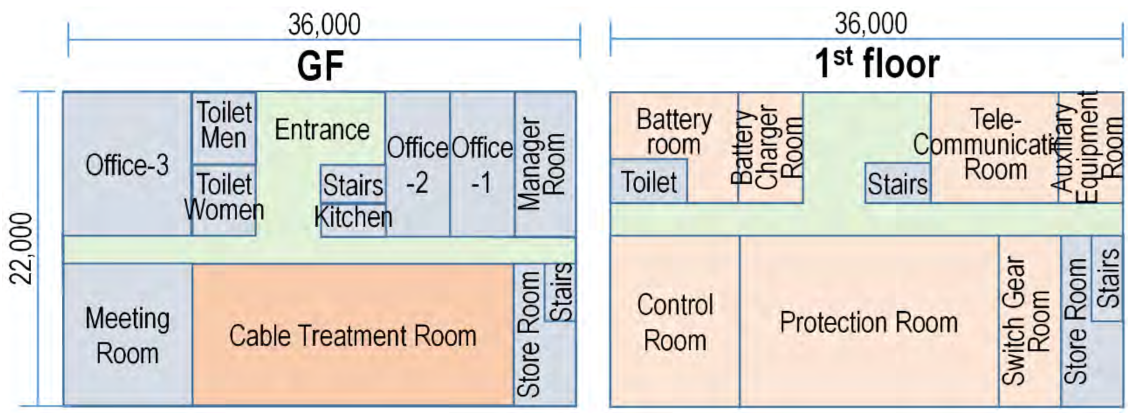


Figure 8-48 Sample of Control Building Layout

8.3.8 Fire Fighting System

Normal ABC fire extinguishers are equipped around the transformers in the existing 230kV and 132kV substations. On the other hand, at the Kinyerezi 2 power station, extinguishing water piping systems for each transformers are installed. The fire extinguishers are not suitable for the oil volume of 400kV transformer, as it is not possible to control/put out the fire. The fire wall can withstand only for two hours. A water system like Kinyerezi 2 will be required.

Furthermore, appropriate fire extinguishers and fire alarm will be installed in the main building.

8.3.9 Substation Facilities (final layout)

(1) Scope of 400kV New Mtwara Substation

(1)	400/132 kV 100MVA three phase transformers	2 sets
(2)	400kV three phase 30Mvar shunt reactors	1 sets
(3)	400kV Gas Insulated Switchgears (GIS) with one and a half CB scheme (1.5CB) for two transmission lines, two transformers, and three generators.	4 diameters
(4)	400kV Air Insulated Switchgears (AIS) for transmission line feeders	2 sets
(5)	400kV Power Cable	1 lot
(6)	132kV Air Insulated Switchgears (AIS) for bus with double bus single breaker scheme (1CB)	2 sets
(7)	132kV Air Insulated Switchgears (AIS) for bus couplers	1 sets
(8)	132kV Air Insulated Switchgears (AIS) for transformer feeders	2 sets
(9)	132kV Air Insulated Switchgears (AIS) for transmission line feeders	1 sets

(10)	33kV equipment	1	lot
(11)	Steel structure and supporting facilities	1	lot
(12)	Bus facilities including insulators, strings, and fittings	1	lot
(13)	Control system and SCADA system	1	lot
(14)	Protection system	1	lot
(15)	Communication System	1	lot
(16)	Earthing system	1	lot
(17)	Outdoor lightning protection system	1	lot
(18)	400V AC station service facilities including Diesel generators	1	lot
(19)	DC230V and 48V station service facilities	1	lot
(20)	MV power cables and accessories	1	lot
(21)	LV power and control cables and accessories	1	lot
(22)	Miscellaneous materials	1	lot
(23)	Spare parts and O&M tools	1	lot
(24)	Civil work	1	lot
(25)	Building work	1	lot

(2) Scope of 400kV New Lindi Substation (H-GIS)

(1)	400/132 kV 100MVA special three phase transformers	3	sets
(2)	400kV three phase 70Mvar shunt reactors	2	sets
(3)	400kV Hybrid Gas Insulated Switchgears (H-GIS) with one and a half CB scheme (1.5CB) for four transmission lines, three transformers, and two shunt reactors	5	diameters
(4)	400kV Air Insulated Switchgears (AIS) for bus	2	sets
(5)	400kV Air Insulated Switchgears (AIS) for transformer feeders	3	sets
(6)	400kV Air Insulated Switchgears (AIS) for shunt reactor feeders	2	sets
(7)	400kV Air Insulated Switchgears (AIS) for transmission line feeders	4	sets
(8)	132kV Air Insulated Switchgears (AIS) for bus with double bus single breaker scheme (1CB)	2	Sets
(9)	132kV Air Insulated Switchgears (AIS) for bus couplers	1	sets
(10)	132kV Air Insulated Switchgears (AIS) for transformer feeders	3	sets
(11)	132kV Air Insulated Switchgears (AIS) for transmission line feeders	2	sets
(12)	33kV equipment	1	lot
(13)	Steel structure and supporting facilities	1	lot
(14)	Bus facilities including insulators, strings, and fittings	1	lot
(15)	Control system and SCADA system	1	lot

(16)	Protection system	1	lot
(17)	Communication System	1	lot
(18)	Earthing system	1	lot
(19)	Outdoor lightning protection system	1	lot
(20)	400V AC station service facilities including Diesel generators	1	lot
(21)	DC230V and 48V station service facilities	1	lot
(22)	MV power cables and accessories	1	lot
(23)	LV power and control cables and accessories	1	lot
(24)	Miscellaneous materials	1	lot
(25)	Spare parts and O&M tools	1	lot
(26)	Civil work	1	lot
(27)	Building work	1	lot

(3) Scope of 400kV New Lindi Substation (AIS)

(1)	400/132 kV 100MVA special three phase transformers	3	sets
(2)	400kV three phase 70Mvar shunt reactors	2	sets
(3)	400kV Air Insulated Switchgears (AIS) with one and a half CB scheme (1.5CB) for four transmission lines, three transformers, and two shunt reactors	5	diameters
(4)	400kV Air Insulated Switchgears (AIS) for bus	2	sets
(5)	400kV Air Insulated Switchgears (AIS) for transformer feeders	3	sets
(6)	400kV Air Insulated Switchgears (AIS) for shunt reactor feeders	2	sets
(7)	400kV Air Insulated Switchgears (AIS) for transmission line feeders	4	sets
(8)	132kV Air Insulated Switchgears (AIS) for bus with double bus single breaker scheme (1CB)	2	Sets
(9)	132kV Air Insulated Switchgears (AIS) for bus couplers	1	sets
(10)	132kV Air Insulated Switchgears (AIS) for transformer feeders	3	sets
(11)	132kV Air Insulated Switchgears (AIS) for transmission line feeders	2	sets
(12)	33kV equipment	1	lot
(13)	Steel structure and supporting facilities	1	lot
(14)	Bus facilities including insulators, strings, and fittings	1	lot
(15)	Control system and SCADA system	1	lot
(16)	Protection system	1	lot
(17)	Communication System	1	lot
(18)	Earthing system	1	lot
(19)	Outdoor lightning protection system	1	lot

(20)	400V AC station service facilities including Diesel generators	1 lot
(21)	DC230V and 48V station service facilities	1 lot
(22)	MV power cables and accessories	1 lot
(23)	LV power and control cables and accessories	1 lot
(24)	Miscellaneous materials	1 lot
(25)	Spare parts and O&M tools	1 lot
(26)	Civil work	1 lot
(27)	Building work	1 lot