United Republic of Tanzania
Tanzania Electric Supply Company Limited

DATA COLLECTION SURVEY ON GAS THERMAL POWER GENERATION IN UNITED REPUBLIC OF TANZANIA

FINAL REPORT

December 2016

Japan International Cooperation Agency

NEWJEC Inc.
The Kansai Electric Power Co., Inc.

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16-094

Data Collection Survey on Gas Thermal Power Generation in United Republic of Tanzania
FINAL REPORT

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Abbreviations

Symbol	English
ACSR	Aluminum Cable Steel Reinforced
BOP	Balance of Plant
BLE	Bluetooth Low Energy
BRN	Big Results Now!
COD	Commercial Operation Date
DBSA	Development Bank of Southern Africa
DD	Detailed Design
EPC	Engineering, Procurement, Construction
EPRI	Electric Power Research Institute (USA)
FS	Feasibility Study
GE	General Electric Company
GoT	Government of Tanzania
GT	Gas Turbine
GTCC	Gas Turbine Combined Cycle
HRSG	Heat Recovery Steam Generator
IHI	IHI Corporation
IoT	Internet of Things
IPP	Independent Power Producer
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
KANSAI	The Kansai Electric Power Co., Inc.
LNG	Liquefied Natural Gas
LTSA	Long Term Service Agreement
M&D	Monitoring & Diagnostics
NEWJEC	NEWJEC Inc.
NSSF	National Social Security Fund
MHPS	Mitsubishi Hitachi Power Systems, Ltd.
MQTT	Message Queueing Telemetry Transport
MT Method	Mahalanobis-Taguchi Method
NEC	NEC Corporation
NOx	Nitrogen Oxides
ODA	Official Development Assistance
O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PSMP	Power System Master Plan (The Project for Formulation of Power System Master Plan in Dar es Salaam and Coast Region and Review of Power System Master Plan)
SMBC	Sumitomo Mitsui Banking Corporation
SN	Signal of Noise
ST	Steam Turbine
TANESCO	Tanzania Electric Supply Company Limited
TPSC	Toshiba Plant Systems & Services Corporation
TPDC	Tanzania Petroleum Development Corporation
XLPE	Cross - linked Polyethylene

Chapter 1 Preface

1.1 BACKGROUNDS OF THE PROJECT

Government of Tanzania (GoT) is planning the strategic short-term (2016 ~ 2020) and mid-term (2021 ~ 2025) power development program to increase national power generation capacity on large scale.

To achieve this crucial target, Tanzania Electric Supply Company Limited (TANESCO) asks Japan International Cooperation Agency (JICA) to provide Official Development Assistance (ODA) by which a 300MW class Gas Turbine Combined Cycle (GTCC) Plant and 400kV transmission lines from Mtwara to Somanga can be constructed.

In response to the request from TANESCO, JICA has started to scrutinize the feasibility of the construction of the 300MW class GTCC. JICA assign the consortium of NEWJEC Inc. (NEWJEC) and The Kansai Electric Power Co., Inc. (KANSAI) the consultant of the project, and dispatched them to Tanzania as JICA Study Team.

Although the main purpose of the project is the pre-feasibility study on the new power plant (300MW class GTCC), the following items are included as the scope of works;

1) Study on the operation and maintenance (O&M) systems of the existing gas-fired power plants, especially introduction plan of Internet of Things (IoT) system to the power plants

2) Study on the power development program of gas-fired power plants

3) Study on adoption of the low loss transmission lines for the 400kV transmission lines from Mtwara to Somanga

1.2 STUDY SCHEDULE

Study period is from the beginning of July 2016 till the end of December 2016, about 5 months' fast track program.

Date	July	August	September	October	November	December
Milestone	1st Site Investigation Inception Report	2nd Site Investigation	Draft Final Report			Final Report

During the study period, JICA Study Team carried out the site investigations twice with JICA and/or TANESCO.

(1) 1st Site Investigation (25 July 2016 ~ 29 July 2016)

The details are explained in Appendix I "1st Site Investigation Report". Major activities are 1) meetings with associated Tanzanian agencies and collection of questionnaires' answers from them, 2) the screening of the 9 candidate sites for the new power plant (the 300MW class GTCC) to narrow down them to 4 sites.

(2) 2nd Site Investigation (29 August 2016 ~ 9 September 2016)

The details are explained in Appendix II “2nd Site Investigation Report”. Major activities are 1) selection of the most feasible new power plant site among 7 candidate sites (originally 4 candidate sites, but 3 sites were added in the course of site reconnaissance), 2) study on gas supply and water supply for the new power plant.

1.3 OUTLINE OF THE STUDY RESULTS

The details of the site investigation results are explained in Chapter 5 ‘Site Investigation Results on the New Power Plant” of this report. The outlines of them are as follows;

- The best feasible site is ideal height above sea level, therefore the civil works at the site on large scale is not expected.
- The best feasible site is located at the edge of small peninsular surrounded by deep sea, therefore sea water cooling (once-through type) is adaptable for the steam turbine (ST) cooling that gives the highest plant efficiency among ST cooling systems.
- The intake channel for the ST can be utilized as an unloading 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 is transported by cargo ships with unloading cranes, therefore, any unloading facilities for the jetty seems not to be necessary.
- The East Coast of Tanzania is water scanty area, however the water supply project in Mtwara is ongoing that can supply enough water to the new power plant
- The gas pipeline from Mtwara to Dar es Salaam was completed and enough gas supply to the new power plant is expected.

As the results, the construction of the new power plant (the 300MW class GTCC) is judged to be feasible.

1.4 SCHEME OF THE PROJECT

The members of the project and their tasks are as follows;

Name	Responsibility	Company
Tetsuo SADA	Leader/Power plant development	NEWJEC
Hidenobu OKUDA	Power plant operation planning	KANSAI
Junji HIRANO	Power plant maintenance (1)	NEWJEC
Shingo SUZUKI	Power plant maintenance (2)	KANSAI

During the 1st Site Investigation, following JICA personnel jointed the JICA Study Team;

Name	Position	Company
Hiroshi TADOKORO	Senior Adviser	JICA
Tsunaki ITO	Officer	JICA
Rosina Apolei	Assistant Program Officer	JICA Tanzania office

During the 2nd Site Investigation, following JICA and TANESCO personnel jointed the JICA Study Team;

Name	Position	Company
Hiroshi TADOKORO	Senior Adviser	JICA
Abdallah Chikoyo	Planning Mechanical Engineer	TANESCO
Alex Gerald	Planning Electrical Engineer	TANESCO

Chapter 2 Operational Status and Maintenance System of the Existing Gas-fired Power Plants

2.1 SUMMARY OF EXISTING GAS-FIRED POWER PLANTS

TANESCO has six gas-fired power plants which have Gas Engine or Gas Turbine (GT) and the each output from their plants is small.

2.1.1 Features of Gas Engine and Gas Turbine

Maximum power demand of Tanzania is 988.27MW in 2015 and transmission capacity is also low. Therefore, if the plant with large single output capacity is connected to such a small power grid and trouble occurs at the plant, it is impossible to keep frequency of the power grid in proper range.

So, the single output capacity has to be decided in consideration of the power grid capacity of Tanzania.

Table 2-1 Allowable Maximum Output

Year	Allowable maximum output
2020	132MW
2025	236MW
2030	390MW

Sources: PSMP

According to “Formulation of Power System Master Plan in Dar es Salaam and Review of Power System Master Plan 2012 (PSMP)”, the future power grid capacity of Tanzania is assumed as shown in Table 2-1.

For example, the single output capacity of M701F Gas Turbine that is manufactured by Mitsubishi Hitachi Power Systems, Ltd. (MHPS), which is developed for power generation and called “Heavy Duty”, is 359MW. So, this Gas Turbine is too big to connect to the power grid of Tanzania in 2020. This is why Aero-derivative Gas Turbine, Heavy Duty Gas Turbine and Gas Engine which have small output are installed at power plants in Tanzania these days. Table 2-2 shows comparisons between Gas Engine and Gas Turbine.

Table 2-2 Comparisons between Gas Engine and Gas Turbine

	Aero derivative Gas Turbine	Gas Engine	Heavy Duty Gas Turbine
Major Inspection	<LM6000 Case> -Borescope Inspection (Per Six Month) -Hot parts Inspection (Per 25,000h) -Overhaul (Per 50,000h)	<KU30GIS Case> -Ignition plug (Per 2,000h) -Cylinder Cover Replacement (Per 4,000h) -Piston pull-out Inspection (Per 8,000h) -Factory Overhaul (Per 36,000h)	<SGT-800 Case> -Borescope Inspection (Per 10,000h) -Hot parts Inspection (Per 25,000 & 40,000h) -Overhaul (Per 60,000h)
O&M Cost	The operation cost is lower than Gas Engine because consumption of lubrication oil is less than Gas Engine.	The operation cost is higher than Gas Turbine because consumption of lubrication oil is more than Gas Turbine.	The operation cost is lower than Gas Engine because consumption of lubrication oil is less than Gas Engine.
Efficiency	The efficiency is lower than Gas Engine because the combustion temperature is lower than Gas Engine.	The efficiency is higher than Gas Turbine because the combustion temperature is higher than Gas Turbine.	The efficiency of this class is lower than Gas Engine because the combustion temperature is lower than Gas Engine.

Sources: JICA Study Team

2.1.2 Details of the Existing Gas-fired Power Plants

Table 2-3 shows the overview of the existing gas-fired power plants. Fig. 2-1 shows the photograph of exterior of the existing gas-fired power plant.

Table 2-3 Overview of the Existing Gas-fired Power Plants

Plant	Ubungo I	Tegeta	Ubungo II	Mtwara	Kinyerezi I	Somanga
Fuel	Gas	Gas	Gas	Gas	Gas	Gas
Units	12	5	3	9	4	3
Installed Capacity (MW)	102	45	105	18	158	7.5
Year Installed (Jan)	2007	2009	2012	2007	2016	2010
Gas Turbine / Gas Engine	Gas Engine	Gas Engine	Gas Turbine	Gas Engine	Gas Turbine	Gas Engine
Type	W20V34SG	W20V34SG	SGT-800	G3520C	LM6000PF	W6L32SG
Manufacturer	Wärtsilä	Wärtsilä	SIEMENS	Caterpillar	General Electric	Wärtsilä

Sources: JICA Study Team

(1) Ubungo I gas-fired power plant

The plant is composed of 6 gas engine units per a group. (No.1 Group: Unit 1 - Unit 6, No.2 Group: Unit 7 - Unit 12)
The total output of the plant is 102MW (8.5MW × 12). Fuel is supplied from Songo Songo gas field.

(2) Tegeta gas-fired power plant

The plant is composed of 5 gas engine units. The total output of the plant is 45MW (9MW × 5). The gas is supplied from Songo Songo gas field and the gas is supplied by different pipeline from that of Ubungo I, II.

(3) Ubungo II gas-fired power plant

The plant is composed of 3 simple cycle gas turbine units. The total output of the plant is 105MW (35MW × 3). Gas is supplied from Songo Songo gas field.

(4) Mtwara gas-fired power plant

The plant is composed of 9 gas engine units. The total output of the plant is 18MW (2MW × 9). Gas is supplied from Mnazi Bay gas field. This plant is constructed in order to satisfy the power demand in Mtwara and Lindi Regions, which are located in Southern part of Tanzania.

(5) Kinyerezi I gas-fired power plant

The plant is composed of 4 simple cycle gas turbine units. The total output of the plant is 158MW (44MW × 2, 35MW × 2). Each two unit has different output because those two units have chillers that cool down inlet air temperature to increase the gas turbine output. Gas is supplied from Mnazi Bay gas field.

(6) Somanga gas-fired power plant

The plant is composed of 3 gas engine units. The total output of the plant is 7.5MW (2.5MW × 3) and granted from World Bank. This plant is next to another Somanga power plant project mentioned in Section 4.1.8. Gas is supplied from Songo Songo gas field.

Ubungo I

Ubungo II

Mtwara

Kinyerezi I

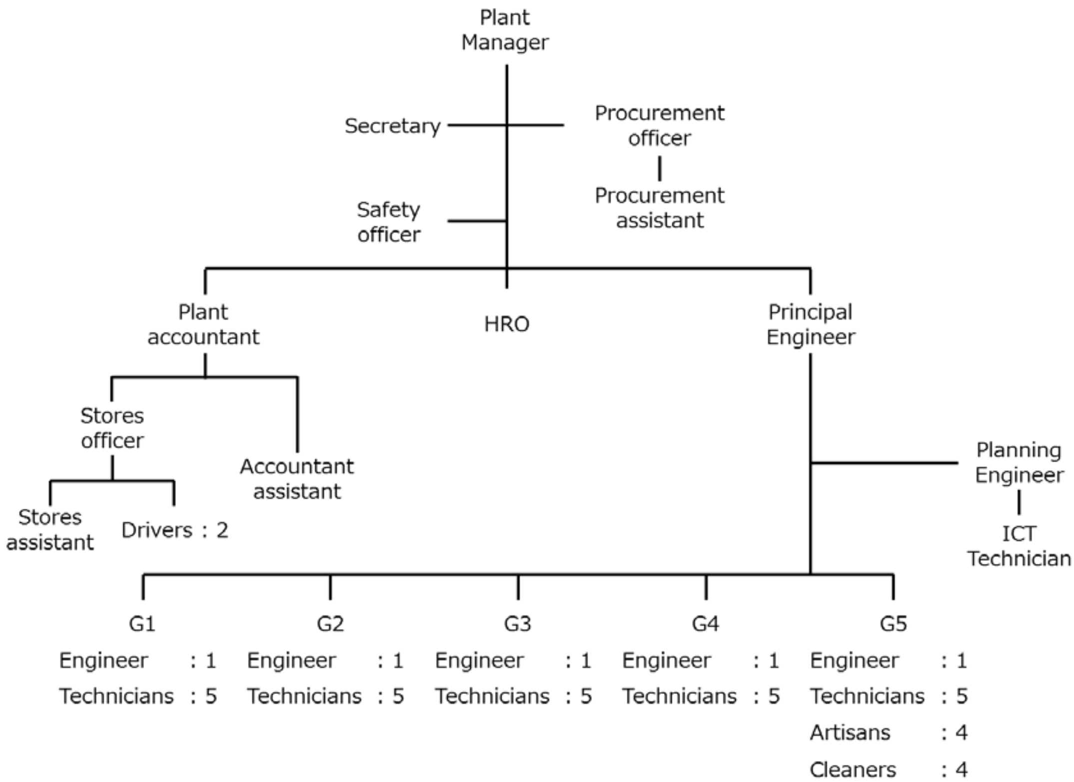
Sources : JICA Study Team

Fig. 2-1 Photographs of Exterior of the Existing Gas-fired Power Plants

2.2 STATUS OF PLANT O&M

2.2.1 Staff Organization

Fig. 2-2 shows staff organization of a power plant of TANESCO. There are four group for plant operation (Groups 1-4) and they work in three shifts of eight hours. There is a group for plant maintenance (Group 5).



Sources : JICA Study Team

Fig. 2-2 Staff Organization

2.2.2 Operation

The plant operation is not conducted by manufacturer, but is conducted by TANESCO. TANESCO also checks the operating data of the power plants. If they detect the data that is not normal, they consult with manufacturer and tackle the problem.

2.2.3 Maintenance

Regarding daily balance of plant (BOP) maintenance, TANESCO do maintenance with spare parts which are possessed by TANESCO. On the other hand, although TANESCO determine timing of implementation for Major Maintenance which is based on the manufacturer’s instruction manual, they outsource Major Maintenance to the manufacturer.

Table 2-4 shows Major Inspection interval and inspection content.

Table 2-4 Inspection Interval and Inspection Content

No	Inspection Interval	Inspection Content
A	10,000 hrs.	The Borescope Inspection of the combustor
B	25,000 hrs.	The combustor and GT 1st stage rotor blade Replacement
C	40,000 hrs.	The combustor and GT 1st ~ 3rd stage rotor blade Replacement
D	60,000 hrs.	Overhaul

Sources: JICA Study Team

2.3 PROBLEMS OF THE POWER PLANT MANAGEMENT AND COMPARISONS BETWEEN JAPANESE UTILITY FIRMS AND TANESCO

In Japan, the plant O&M are conducted on the basis of the law and regulations, for example "Electricity Business Act". Therefore, it is assumed that plant O&M are in the highest level in the world in terms of the stable power supply.

In this section, we reveal the problems of the power plant management of TANESCO, and suggest action items for pulling up the level of the power plant management by comparing with the power plant management system between Japanese utility firms and TANESCO

2.3.1 Main Cause of Forced Outage

On June 2016, Unit 1 of Ubungo II faced a forced outage because of abnormal noise. Engineers of manufacturer conducted borescope inspection and detect damage of the compressor blades from 6th stage to 15th stage. The starting point was a crack occurred in 5th stage. It is under the investigation for the root cause of the crack.

In addition, one unit of the Somanga Gas Power Plant (8MW, Gas Engine) is in long-term stop because of a damage and the root cause is also under the investigation. As it can be seen from these examples, it tends to take a lot of time for investigation of the damage and repair of equipment because negotiations with the manufacturers are not smoothly carried out.

On top of that, we heard from TANESCO that load fluctuation often causes forced outages. Therefore, TANESCO have to construct the power plant and have to be able to respond to demand fluctuations.

2.3.2 Main Reason for Low Load Factor

It is a reason for low load factor to use same fuel pipe line in Ubungo I and Ubungo II because enough fuel gas for full load operating is not supplied. Therefore, in order to utilize both of the Ubungo I and Ubungo II power plant effectively, it is required to increase fuel gas supply from Songo Songo gas field or connect the pipe line with the pipe line of Tegeta power plant.

2.3.3 Comparisons between Japanese Utility Firms and TANESCO

Table 2-5 shows action items which Japanese Utility Firms conduct for O&M of the power plant and the results whether TANESCO conducts same action for plant O&M.

Table 2-5 Comparisons between Japanese Utility Firms and TANESCO

1. Power Station

Japanese Utility Firms		TANESCO
Organization	Activities	Activities
Operation	Daily patrol inspection	
	- Record of daily patrol inspection	○
	Performance Check	
	- Intervals of performance check (Monthly/ Yearly)	×
	- Performance adjustments from actual condition to reference site condition	×
Maintenance	Subcontractors	
	- Exist of subcontractors permanently on site	×
	Scheduled maintenance	
	- Maintenance schedule is planned	○
	GT Maintenance	
	- Spare parts at site	×
Human Resources, Training	- On the job training	×
	- Class room training	×
	- Incentive system for employee’s proposal on performance improvement and cost cutting	×

2. Headquarter

Japanese Utility Firms		TANESCO
Organization	Activities	Activities
Technical Division	Remaining life assessment for major equipment	×
	Study on repair/ replacement method and its timing as the results of 1) maintenance and performance check results at power stations and 2) remaining life assessment results for major equipment	×
	Update of O&M manual	×
Planning Division	Long-term maintenance schedule	○
	Computerized inventory control of spare parts for all power stations	×
Training Center	Plant operation drill by simulators	×
	O&M drill of equipment by using models	×

○: Yes ×: No

Sources: JICA Study Team

2.3.3.1 Problems related to Operation

As shown in Table 2-5, TANESCO records the data of the power plant and confirm whether the data is normal.

However, they don't conduct performance check if the power plant condition is fit for purpose under same conditions.

There are few measuring points to be recorded because they have only Gas Engine and Gas Turbine.

But, if they install GTCC, the performance management will become complicated because there are a lot of data to be recorded and it is necessary to manage both of the topping cycle (gas turbine) and bottoming cycle (Heat Recovery Steam Generator (HRSG) + ST).

Therefore, it is important for TANESCO to acquire how to conduct the performance check for early detection of abnormal status as they will develop fossil-fired power plants including GTCC power plant from now on.

2.3.3.2 Problems related to Maintenance

TANESCO conducts Major Maintenance based on recommendation by the manufacturer in Gas Engine power plant. According to TANESCO, they have only a set of spare parts for Gas Engine (Manufacturer: Wärtsilä, Type: W20V34SG) because of lack of funds. The spare parts can be shared Ubungo I and Tegeta power plant because their Gas Engines are same. But managing of the spare parts between these two power plants would be a problem at the same time of major maintenance or troubles.

In Gas Turbine plants, Ubungo II, they do not have spares for hot spare parts of Gas Turbine. Therefore, it may take a long time to recover from troubles because they have to purchase hot parts from the manufacturer after trouble occurs.

In addition, it does not ensure even the budget to tackle troubles. Therefore, when it is required to purchase spare parts, they have to find remaining budget in the TANESCO and it is necessary to negotiate to purchase. Therefore, it takes a long time to purchase them.

2.3.3.3 Problems related to Human Resources, Training

In TANESCO, they have educational plan and training programs for the power plant staff members. However, according to the interview of the Somanga Gas Power Plant, we feel that more training of the staff members is required.

In addition, staff members of Somanga Gas Power Plant can acquire knowledge from Ubungo I staff members because the same Gas Engine are installed in Somanga Gas Power Plant and Ubungo I. From now on, it is going to start operation of the GTCC plant (Kinyerezi II) and it is necessary for bottoming cycle to carry out the water treatment. So, they have to acquire knowledge for water treatment of bottoming cycle. For the stable power plant operation and appropriate action at the time of trouble, it is necessary to build up the educational plan.

Chapter 3 IoT Status on Gas-fired Power Plants

3.1 IoT in Power Industry

3.1.1 IoT

IoT is a broad concept that everything is connected to Internet and communicates each other. This means not only people control things, but also things control other things. In the past, similar concept such as, ubiquitous, M2M came out, however, reason why IoT attract people's attention these days is that cheap sensors and information technology, such as cloud, big data, artificial intelligence become well improved to realize IoT.

IoT System is roughly divided into Device Layer, Network Layer, and Service Layer. Sensing technology in Device Layer is very important technology to operate IoT and various cheap sensors change information in reality into data in sensors. Those data are transferred in Network Layer by some communication protocol. The protocol used in device communication includes Bluetooth Low Energy (BLE) for IoT device communication, EnOcean by 920MHz radio wave. Moreover, asynchronous interactive and multipoint-to-multipoint communication protocol called Message Queueing Telemetry Transport (MQTT) is used for communication in Application Layer. The function in Service Layer is data collection, data storage, data processing. On data collection, data storage, we need to collect them in various form, and various span, and flexible system is required to meet such a mixed data. There are two systems for data processing, batch processing and real-time processing. For batch processing, distributed processing architecture, such as Apache Hadoop and Apache Spark are adopted. For real-time processing, distributed processing architecture, such as Apache Storm and Spark Streaming are adopted.

3.2 Remote Monitoring System by Manufacturer

Power station is a big system and many physical data (pressure, temperature, flow rate etc.) and control signals are used for its operation. From the past, it has been common for power plants to store and use these data for its troubleshooting. However, there is a trend featuring keyword "IoT" to make the active use of big data which has not been used effectively. "Active use" means "computer aided" monitoring and decision in contrast with maintenance process of alert issued by single threshold and decision based on experience of operator or maintenance staff so far. This computer aided monitoring and decision has following features:

(1) Setting threshold by computer automatically and flexibly

(2) Detecting hardly noticeable change for human: for instance, when the data is fluctuating randomly, it is difficult for operator how much the amplitude increase or decrease.

(3) Detecting very slow change hardly noticeable in limited time window: for instance, decrease of efficiency for a few years cannot be perceived without intentional comparison between major overhauls.

(4) Processing big data which is too enormous and extensive for men to handle practically

With the features above, we will realize aggressive maintenance no one could imagine in the past. This aggressive maintenance is called fault detection or fault diagnosis and it aims to find tiny indications before big trouble comes and prevent big trouble by quick response.

It is said that we can have following merits by storing and analyzing big operating data.

Reducing trouble risk: an alert is issued to users before the trouble grows and prompts users to quick response. This brings high reliability of facilities and prevents big trouble before it happens. Therefore, we can expect shorter downtime for maintenance.

Data Oriented Decision: Manufacturers collect data from the machines they sell all over the world, develop algorisms to find trouble indications and advise their customers about O&M. With this advice, the customers can make decisions based on not experience but data.

3.2.1 GE (General Electric Company)

GE is collecting data of over 1,600 generators from all over the world. The data size is 40 Tera-byte equivalents to 100,000,000 operating hours. In Monitoring & Diagnostics (M&D) Center in Atlanta, over 50 engineers are analyzing data. Monitoring service is available from Scotland, France, India as well as main Atlanta. GE has developed their original algorism based on physical phenomena and they can issue prompt alert for over 60 different trouble. GE says this service brings over 70 million USD cost-savings to their customers.

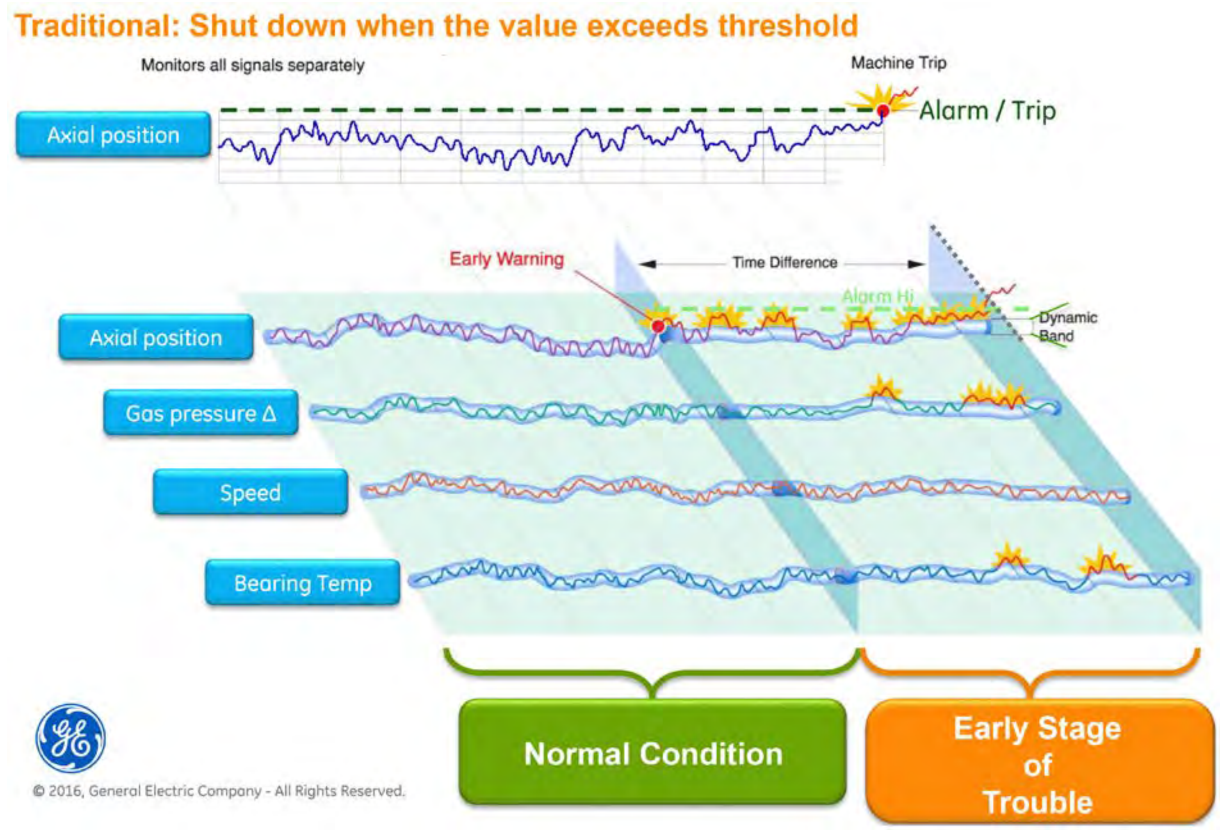
The feature of GE’s remote monitoring is that the service includes cyber security or remote tuning of Low Nitrogen Oxides (NOx) combustor in response to customer’s request.

GE gives their customers feedback which consists of on-site monitor by which GE analyses and assesses data on site, and monthly assessment report. The customers can make decisions about maintenance timing and scope using these feedbacks.

GE proposes “smart” power plant management through monitoring. In unexpected outage or unscheduled outage, the internal parts of each facilities degrade gradually and we suffer big repair cost and long down time for repair after the unexpected trip of facilities. In contrast to this, what GE call “smart” means to find some indication for trouble in early stage with many data from sensors and to avoid unexpected trip.

Finding indications in early stage will lead to shorter down time as the facilities would be repaired before their degradation becomes big as well as lead to smaller cost for repair as the cost for preventive maintenance is smaller than the cost for trip recovery. Similar approach is being implemented in other companies including Japan.

GE’s software for “smart” power plant management is Smart Signal. Conventional plant management system use limit value for each monitoring point and the facilities are shut down when the value exceeds the limit. Smart Signal develops prediction model from normal operating data by their original algorithm and it finds trouble indication by how far each data deviate from the prediction model.



3.2.2 MHPS (Mitsubishi Hitachi Power Systems, Ltd.)

(1) Remote monitoring center

MHPS's remote monitoring centers are located in Takasago, Hyogo, Japan, in Orlando, Florida state and in Manila, Philippines. In each remote monitoring center, experts are monitoring customer's sites 24 hours a day, every day. These centers have foreign staff and can communicate in English and Korean. They monitor 116 units (as of January 2016) and more than 20GW.

Country	Number of Unit	Country	Number of Unit
Britain	5	Singapore	6
Ireland	1	Australia	2
Spain	1	Japan	4
Qatar	8	Canada	2
Turkey	2	U.S.A	37
Israel	1	Mexico	14
Thailand	4	Puerto Rico	2
Malaysia	2	Colombia	2
Chile	2	Argentina	2
New Zealand	1	Korea	18

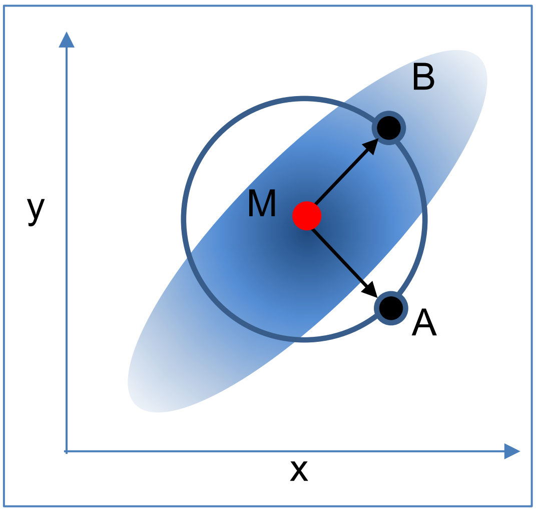
(2) Monitoring items

MHPS collects data of about 2,000 items per one gas turbine. Major items are in the table below.

Rotation speed	Output	Control signals
Combustion temperature	Fuel flow rate	Fuel valve position
Inlet temperature of air compressor	Inlet pressure of air compressor	Blade pass temperature
Inlet temperature of air compressor	Inlet pressure of air compressor	Exhaust gas temperature
NOx	Combustion oscillation	Shaft vibration
Metal temperature of bearing	Temperature of rotor cooling air	Temperature of disk cavity

It is possible for MHPS to add further monitoring items from plant as a whole including ST, HRSG, and generator.

(3) Fault detection by MT method



The approach by MHPS is using in its fault diagnosis has evolved from quality engineering and is called Mahalanobis-Taguchi (MT) Method. MT method defines normal data group as a unit space on the basis of multivariate data and determines whether or not the subject of the data is attributable to the population in the Mahalanobis distance. Mahalanobis distance quantifies the degree of difference between the sample data and target data. Let us think in two dimensions in order to understand intuitively. Assume sample groups (x, y) as shown below is the distribution which extends like an ellipse. When the center of gravity of the sample group is defined point M, point A and point B are same distance from point M. However, considering the distribution degree of data, in other words, measuring with respect to the minor axial length and major axis length of the ellipse, point A rather than point B is further away from the sample group. It is high possibility that point A does not belong to the sample group.

Merit of MT method is not to check many parameters at the same time whether they are out of normal range but to check only Mahalanobis distance for the diagnosis of whether the system is normal status.

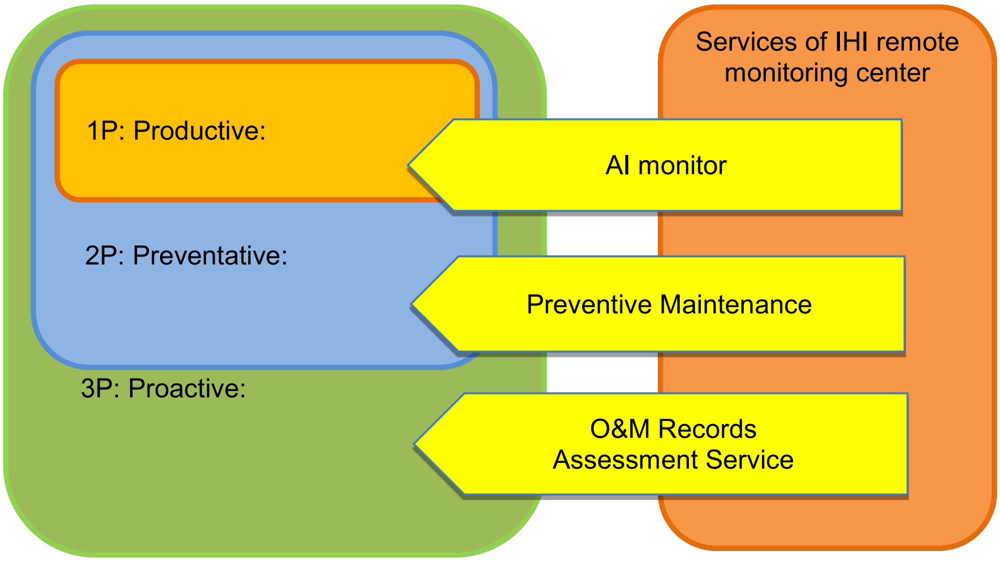
MHPS practically set unit space data from sample data which comes from the state plant operates normally and MHPS get the target data online and calculate and monitor Mahalanobis distance. When the Mahalanobis distance glows, MHPS judges any fault is coming.

Mahalanobis distance represents the number of parameters in a single indicator and it is necessary to investigate the cause when an abnormality occurs. However, calculating Signal of Noise (SN) ratio of each item and contribution ranking to Mahalanobis distance help us investigate distance contributor. This SN ratio ranking is just telling us which item is leading to the detection of fault and item itself is not a cause of fault. Therefore, experts should investigate what is the root cause for the abnormal behavior of the data.

3.2.3 IHI (IHI Corporation)

IHI is providing LM6000 as its main product in overseas. LM6000 is an Aero-derivative Gas Turbine developed by GE, but IHI manufactures a part of the gas turbine and assembles gas turbine package using LM6000 finished by GE. Therefore, IHI's LM6000 is considered as a kind of Japanese gas turbine.

IHI's remote monitoring service is called Total Productive, Preventative, Proactive Maintenance (T3PM) and its concept is shown in below. This concept includes three phases.



Source: IHI brochure

First phase is 1P: Productive and it means prompt action to customer's trouble. To achieve this phase, IHI provides remote monitoring tool called "AI monitor". IHI has a remote monitoring center (i-MOTS: IHI Global Monitoring and Technical Service Center) where IHI monitors gas turbine (LM6000) installed in their customer's sites. The center takes a role to collect and analyze the data automatically 24 hours a day, every day using "AI monitor" and issues alerts to its relevant divisions when trouble happens. On issuing an alert, representatives get together and discuss countermeasures then command their servicer to take necessary action. According to IHI, their target is to restart the gas turbine in three hours after the trouble happens.

Second phase is 2P: Preventative and it means preventive maintenance to keep facilities in good condition. The preventive maintenance is a concept that detection potential trouble from operation data shall prevent the facilities from serious troubles.

IHI's fault detection is firstly collecting data (real-time operating data, start and stop data, trip data) from customer's site through AI monitor, then automatically produces monitoring graphs such as trend graph, operating time trend graph, X-Y pattern graph. Then, the system analyzes the data and if it finds any fault, the system sends alert emails to representatives. IHI is trying to reduce customer's forced outage rate, improve reliability of generating facilities and meet the customer's satisfaction using their stored enormous operating data and records of trouble shooting. According to IHI, their gas turbine package achieve better result in reliability and availability than GE's gas turbine package thanks to their preventative maintenance activities.

Third phase is 3P: Proactive and it means support to make O&M plan for their customers. In particular, IHI consolidates the management of maintenance record at factory, maintenance record at site and operating data and assists customers to make operation plan and maintenance plan.

3.2.4 NEC (NEC Corporation)

NEC’s approach to fault detection is invariant analysis. Invariant analysis automatically makes relational expressions of invariant between two censors which is true in normal operation. And the system judge trouble sign when it finds the relational expression gets false.

NEC delivered fault detection system with invariant analysis to the Chugoku Electric Power Co., Inc.'s Shimane Nuclear Power Plant Unit 2 in June 2014. They analyzed stored plant operating data from 2011 to 2012 and judged whether the system could find any sign before the trouble occurs. The input plant data is over 2500 items including vibrations and temperatures of the Nuclear Power Plant. As a result, NEC verified effectiveness of the approach and installed it into training facilities as a trial then demonstrated with pseudo facility trouble that it can find any sign of trouble in advance.

Invariant analysis building up track records can be applied to fossil fuel fired power stations. NEC conduct experimental test at the Chubu Electric Power Co., Inc.'s Hekinan power plant and Joetsu power plant from 2014 to 2015 and they verified effectiveness of the approach for the coal-fired power plant and the Liquefied Natural Gas (LNG)-fired power plant.

3.3 PROPOSED SERVICE AND SITUATION

When we had a meeting with Kinyerezi I, they said that GE is now proposing O&M service to TANESCO and they have not signed the agreement yet. The table below shows the outline of O&M service proposed by GE.

Contract Term	2 years from COD (Commercial Operation Date)
Engineer Dispatch	GE dispatches two site engineers. Their role is usual O&M support.
Capacity Building	GE receives TANESCO staff as trainees to Houston. Training course has operation including start and stop of GTCC, usual maintenance and trouble shooting.
Remote Monitoring	GE monitors operation data at remote monitoring center in Atlanta.

3.4 IOT OF JAPANESE COMPANIES AND COMPARISON WITH KINYEREZI I

As mentioned on top of this chapter, many physical data (pressure, temperature, flow rate etc.) and control signals are used for its operation. And it has been very common in Japan for power plants to store and use these data for its troubleshooting. In recent years, Japanese power industry started a research on whether analyzing enormous stored data can find any signs of fault. Companies have various approach for fault detecting system and they show successful case. However, those systems have only a few track records and rating is not fixed.

JICA Study Team conducted an interview with TANESCO and Kinyerezi I plant managers and ask them what kind of IoT service is proposed to them. We found that Kinyerezi I had not yet received IoT proposal and we could not directly compare with what Japanese company usually do as IoT activity without the GE’s proposal. However, in Japanese manufacturer interview, we got some comments that GE’s IoT activity is almost same level as that of Japanese companies.

Chapter 4 Gas-fired Power Plant Development Plan in Tanzania – Challenges and Solutions

4.1 LATEST DEVELOPMENT PLAN

Tanzania has nine (9) gas-fired power plant development plans. The latest situation is as follows.

4.1.1 Kinyerezi I

(1) Kinyerezi I (original)

Kinyerezi I has four (4) simple cycle gas turbine units with GE's LM6000PF. Gross output is 150MW (44.3MW × 2, 35.94MW × 2). Each two unit has different output because those two units have chillers that cool down inlet air temperature to increase the gas turbine output. The rest of two units also have plans to install chillers in the future. Engineering, Procurement, Construction (EPC) contractor was Jacobsen Elektro (Norway). The project expected to start its operation in 2014, but it delays due to funding schedule delay. In October 2015, two units (35.94MW × 2) started their operations and the rest two started in January and February in 2016. Project cost was 183 million USD. The reason why the project did not choose GTCC but simple cycle, was that they put emphasis on due date of operation in addition to budgetary deficit and scarcity of water.

With regard to O&M, GE is proposing Long Term Service Agreement (LTSA), but is not signed yet. This LTSA proposal includes training course at Houston for TANESCO staff as well as remote monitoring service and two resident GE engineers' service.

(2) Kinyerezi I (extension)

Kinyerezi has an extension plan of 185MW simple cycle. The gas turbines are three (3) LM6000PF and they are under negotiation with Jacobson Elektro, expecting its operation in 2017. Project cost is 182 million USD. They have a plan to upgrade this simple cycle into combined cycle in the future, but they have not yet done detailed design and prepared budgets. When it changes into combined cycle, they would adopt air-cooled condenser because of scarcity of water.

4.1.2 Kinyerezi II

Kinyerezi II is the first GTCC in Tanzania. It has six (6) H25 gas turbines and consists of two 3-3-1 configuration units. Gross output is 240MW (GT: 30MW × 6, ST: 30MW × 2). Sumitomo Corporation is EPC contractor, MHPS provides gas turbine and Toshiba Plant Systems & Services Corporation (TPSC) covers the rest of work including civil. At the start of this project, they aimed to start its operation in December 2015, but the start of construction delayed due to budget schedule delay. In March 2015, loan agreement was signed and it started its construction in December 2015. Partial Commercial Operation Date (COD) will be in the beginning of 2018 and full COD will be within 2018. Project cost is 344 million USD and 85% of debt is funded from Japan Bank of International Cooperation (JBIC) and Sumitomo Mitsui Banking Corporation (SMBC) and 15% is funded from Development Bank of Southern Africa (DBSA).
They have not started any effective discussion on O&M.

They expect to use natural gas from Mnazi Bay and Songo Songo gas field same as Kinyerezi I. As for water, it will use the water for Kinyerezi complex as same as other Kinyerezi projects will do. However, the condenser of ST is air-cooled type because of scarcity of water.

4.1.3 Kinyerezi III Phases 1, 2

Kinyerezi III is a Public-Private Partnership (PPP) project developing by Shang Tan Power Generation Company, a joint company by Shanghai Electric Power Company (China) and TANESCO. 60% of its equity is funded by Shanghai Electric Power Company and 40% is by TANESCO. Gross output of each Phase 1 and Phase 2 is 300MW GTCC. Its expected COD was originally March 2016, but because of discussion between developer and GoT delays, now it has become a 2018 year-end. Project cost is 389.7Mil USD for the total of Phase 1 and Phase 2.

4.1.4 Kinyerezi IV

Kinyerezi IV is a power plant by Poly Group (China) and TANESCO under PPP scheme. Gross output was originally 450MW GTCC, but it reduces to 330MW. Discussion between the developer and GoT delays same as Kinyerezi III. Although its expected COD was originally June 2015, now it has become 2019. Project cost is expected to be 400Mil USD.

4.1.5 Somanga Fungu Phases 1, 2

Somanga Fungu project is being developed by Kilwa Energy Co. Ltd composed of two phases. In the Phase 1, simple cycle gas turbine will be installed and it will start generation as 210MW power plant. In the Phase 2, ST and HRSG will be added to make combined cycle and it will restart as 320MW power plant. Although the expected COD was April 2015, now it has become 2018 for Phase 1, 2019 for Phase 2.
In connection with this project, the country started 400kV transmission line between Dar es Salaam and Somanga Fungu and now the compensation of about half of the residents has been completed.

4.1.6 Mtwara

This project is developing under PPP scheme by Symbion Power and TANESCO. Feasibility Study (FS) was completed. TANESCO sent some comment on the FS report, but they have received no response and the discussion is suspended. Symbion aims to build simple cycle, however TANESCO has an intention to make combined cycle. In MOU, output was 600MW, but now the plan is 400MW. COD is scheduled in 2019.

4.1.7 Zinga

Zinga power project is also called Bagamoyo power project and is developing by Kamal Group (India) under Independent Power Producer (IPP) scheme. The power plant is planned in combined cycle and now is in FS phase. The output is 200MW. TANESCO sent some comments on FS report 2 years ago and TANESCO is reviewing new FS submitted by Kamal Group. COD is scheduled in 2020.

4.1.8 Somanga

Somanga power plant project is a pilot project under PPP scheme supported by World Bank. Originally, it is planned in Mkuranga, but later they moved to Somanga. It is planned in 300MW GTCC. The pre-FS was reviewed by Transaction Advisor K&M and full-FS was started. COD is scheduled in 2019.

4.1.9 Mkuranga

This project is funded by National Social Security Fund (NSSF) under PPP scheme. TANESCO, NSSF and Strategic Partner provides 10%, 20% and 70% of equity respectively. Strategic Partner is now under selection. Since FS is not completed yet, the equipment selection has not been done and plant configuration has not been determined. The output is 300MW and expected COD is 2019.

4.2 CHALLENGES AND SOLUTIONS

4.2.1 New Power Plant

GoT has developed a program called BRN (Big Results Now!). From 2013 through 2016, it was trying to develop the power capacity of 1,300MW. However, this program delays and is far away from program target due to delay of funding or negotiation with the developers.

Every power project at present is planned under IPP or PPP scheme. If this situation persists, it may cause some troubles on national grid operation. To wipe out this concern, it would be required to build power plants owned by TANESCO with the funds of ODA such as Japanese yen loan and to support the generation of the national grid to some extent.

Moreover, TANESCO is going to experience operation of ST in the Kinyerezi II GTCC and shall acquire water management and waste water management, which are not required in gas turbine or gas engine operation. Hence, it is desirable for TANESCO to have O&M agreement with the contractor until TANESCO engineer learn such O&M skills.

4.2.2 Existing Power Plant

Generally, existing power plants are operated carefully, TANESCO is well aware of the necessary maintenance on its power plants in order to maximize their performance and therefore funds and budget have to be allocated each year for maintenance of its infrastructures. However, the challenge is budget constraints to meet TANESCO plans both on new developments in line with national development plan and maintenance of existing power plants as scheduled.

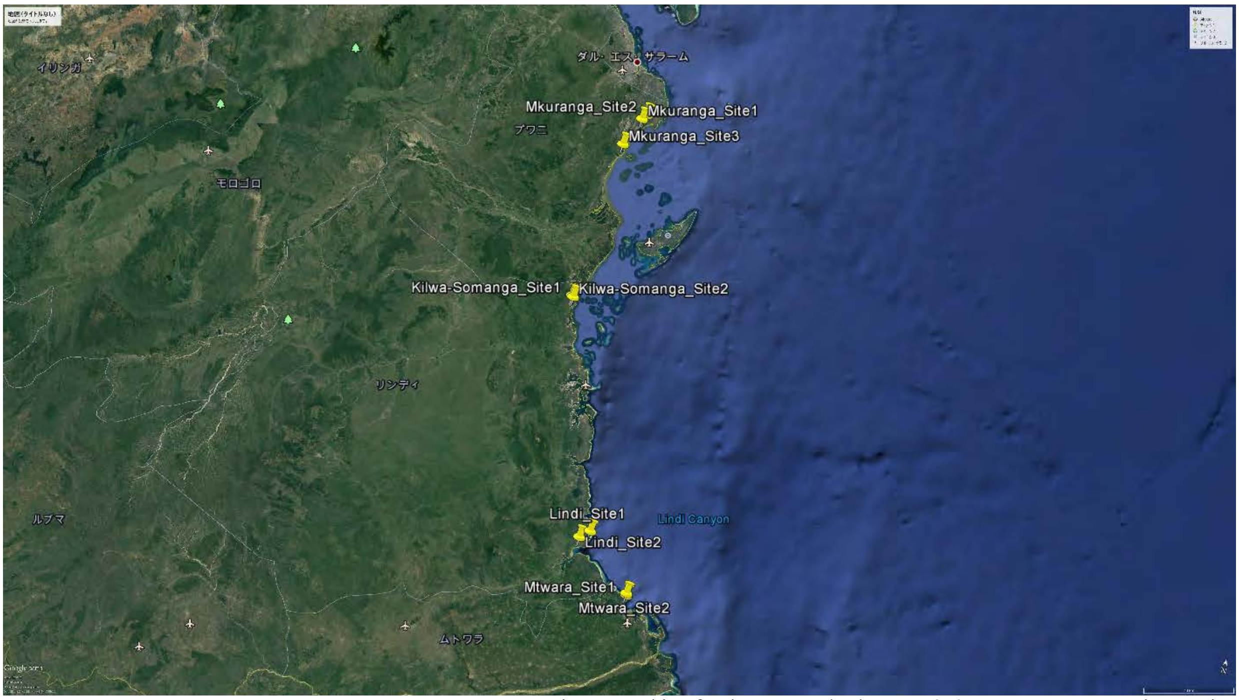
In addition, TANESCO was established with core business of generation, transmission and distribution. However they have less expertise on GTCC or ST because their main generation source is hydro, gas turbine and gas engine. It will become important to secure and train of proper engineers who can operate and maintain gas-fired power plants for the future gas-fired power development.

Chapter 5 Site Investigation Results on the New Power Plant

5.1 CANDIDATE SITES FOR THE NEW POWER PLANT

TANESCO carried out the Pre-FS on the construction of 250MW GTCC together with Mott MacDonald, etc. during October 27 ~ November 6, 2014 (refer to Appendix III).

Based on the study, 9 candidate sites for the construction of 250MW GTCC were selected along the east coast of Tanzania. Fig. 5-1 shows the locations of the candidate sites.



Sources: TANESCO "Site Earmarking for the proposed Mkuranga 250MW CCGT Power Plant Project

Fig. 5-1 Candidate Sites for the Construction of 250MW GTCC

5.2 SCREENING OF THE CANDIDATE SITES

To match the site investigation schedules of about 1 week, JICA Study Team narrowed 9 candidate sites down to 4 sites through the screening the candidate sites by 15 check items with TANESCO.

The screening results are shown in Table 5-1.

Table 5-1 Screening of the 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 from 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	

Source: JICA Study Team

As the results of the screening, Mkuranga 3 sites are excluded because the sites are not so near the seashore, which means that sea water cooling of ST is difficult. On top of that, according to TANESCO's information, these 3 sites are far from the main road and planned 400 kV transmission lines.

With regard to Kilwa-Somanga 2 sites, these sites are also excluded because though the distance from the gas valve station to the sites is the shortest, the sites are located in vast wetland designated as the sanctuary by Ramsar Convention.

As the results, Lindi 2 sites and Mtwara 2 sites are determined to be investigated.

5.3 EVALUATION OF THE INVESTIGATION RESULTS

(1) Results of Site Reconnaissance

The site reconnaissance was implemented during August 29 ~ September 2, 2016 (Around 1 week). In the course of site reconnaissance, Lindi 1 site and Mtwara 2 sites were additionally investigated, therefore, totally 7 sites were investigated. Table 5-2 shows the explanation on the investigated sites.

Table 5-2 Explanation on the Investigated Sites

	Name of Site	Explanation
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
	Mtwara New Site	The site that is found in the course of discussion with Mtwara Local Government
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

Fig. 5-2 shows the locations of site reconnaissance together with gas pipeline and its valve stations, water pipeline from the Ruvuma River and its intake point and water storage tanks

Ruvuma River

Sources: JICA Study Team

Fig. 5-2 Location Map on Reconnaissance Sites and Relevant Facilities

During the site reconnaissance, topography/ geology/ oceanography of sites, water supply prospect, lengths and conditions of access roads, distances from gas valve stations, heavy equipment unloading capacities of ports, human element around the sites, local power demand and environmental issues were investigated (total 10 items). Distances from the future 400kV transmission lines were excluded because its route is unclear for the time being.

Table 5-3 “Site Reconnaissance Results (Mtwara)” and Table 5-4 “Site Reconnaissance Results (Lindi)”. The bottom lines of these 2 tables show the overall ranking of the investigated sites. JICA Study Team, a JICA expert and TANESCO engineers agreed to select the Mtwara New Site as best feasible site to construct the new power plant (300MW class GTCC).

Table 5-3 Site Reconnaissance Results (Mtwara)

No	Item	Candidate Sites			
		Mtwara Site 1	Mtwara Site 2	Mtwara TANESCO Site 1	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.	Access 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 × 100 ton mobile crane, 1 × 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, Fertilizer, Gas treatment plant.			
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**

Sources : JICA Study Team

Table 5-4 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 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.	Access 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, Gold (small), Nickel, 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 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**

Sources : JICA Study Team

(2) Reasons of the Best Feasible Site

The major reasons why Mtwara New Site is selected as the best feasible site are as follows;

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

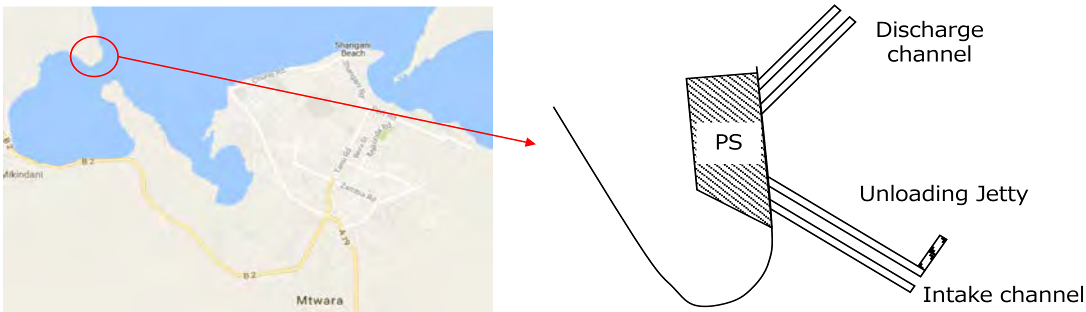
2) The site is located at the edge of small peninsular surrounded be deep sea, therefore sea water cooling (once-through type) is adaptable for the ST cooling that gives the highest plant efficiency among ST cooling systems. (Fig. 5-3 shows the comparison among ST cooling system).

3) The intake channel for the ST can be utilized as an unloading 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 is transported by cargo ships with unlading cranes, therefore, any unloading facilities for the jetty seems not to be necessary. (Fig. 5-3 shows the conceptual idea of the unloading jetty).

4) Environmental measures for nearby village are required during the construction stage and operation stage of the plant. However, the plant is gas-fired power station that is environmental friendly plant compared with the coal-fired plant. There are no environmental impact related to coal and ash. Expected impacts seem to be NOx, noise and vibration, but they can be solved to set the appropriate level at the plant boundary during the plant design stage.

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

Item	Sea water cooling	Cooling tower	Air-cooled condenser
Installation cost	High	Low	High
Efficiency of S/T	High	Medium	Low
Fresh water consumption	Almost 0	High	Almost 0
Space of land	Base	Almost same as sea water cooling	More vast
Land height above NSWL	4～5 m	No limitation	No limitation
Possibility of unloading Jetty	Yes	No	No
Notice 1	Hot water recirculation and heat accumulation have to be avoided	No notice	No notice
Notice 2	Mangrove forest area have to be avoided	No notice	No notice



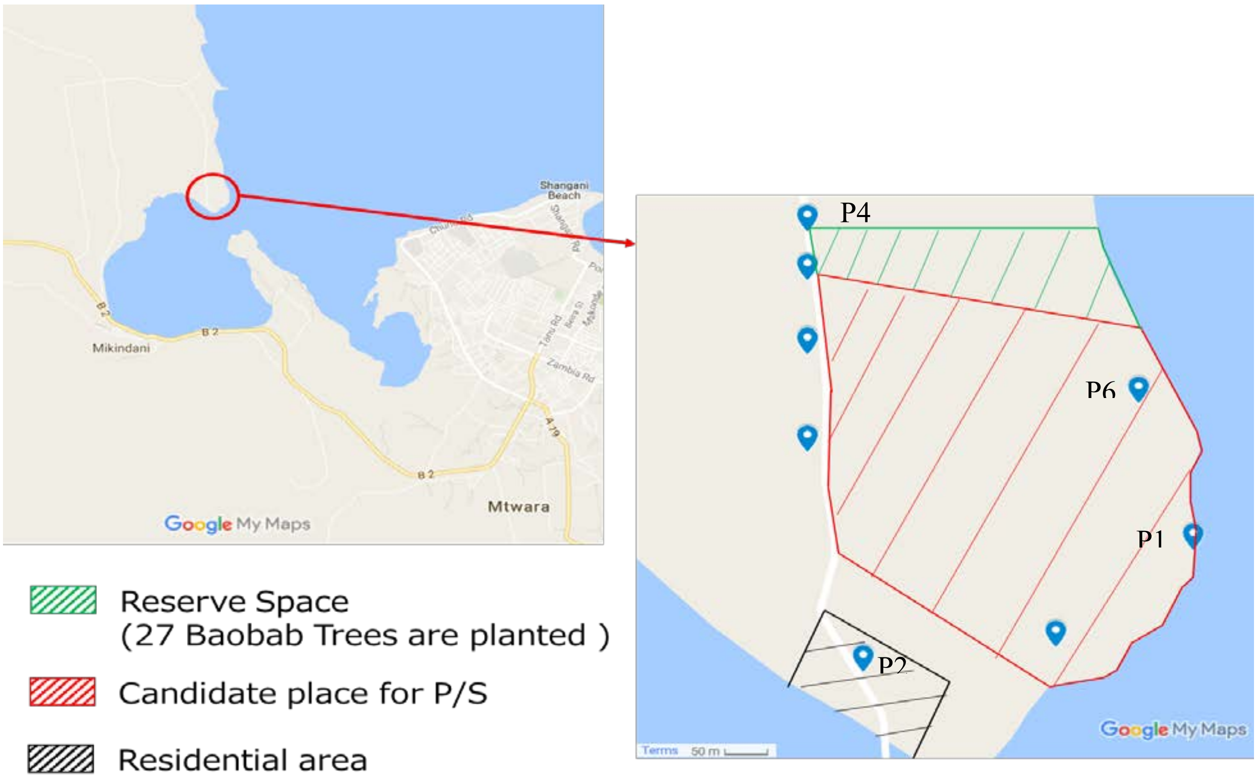
Sources: JICA Study Team

Fig. 5-3 Comparison among ST Cooling Systems and Conceptual Drawing on the Unloading Jetty

(3) Power Plant Area of the Best Feasible Site

Fig. 5-4 shows the power plant area of the best feasible site. The hatched lines marked in red shows the plant area, and the hatched lines marked in green shows the reserved space if the plant area is short though several Baobab trees are required to be cut.

The plot plans for 2 types of 300MW GTCC are studied in Chapter 6 of this report. As the results, the best feasible site is confirmed that the site is enough space to allocate a 300MW GTCC.



Sources: JICA Study Team (P1~6 shows the photographs No.)

Fig. 5-4 Power Plant Area

Photographs of each candidate sites during the site reconnaissance are shown in the following pages.

Mtwara Site 1

Baobab

Sea Shore

Fishing Activities (Small)

Land View

Mtwara Site 2

Sea Shore

Mangrove (Small)

Cattle Raiser

Village

Land View

Mtwara TANESCO Site

Land View

Land View

Mtwara New Site


Deep Sea


Sea Shore (P1)


Southern Edge Point (P2)


Baobab (P4)


Northern Edge Point (P6)

Lindi Site 1

Mangrove Forest

Sea Shore

Sea Shore

Land View

Lindi Site 2


Land View


Land View (Mangrove delta)

Former / Old DG Plant

Access Road

Lindi New Site

Land View

Eclipse of the Sun @1st September

Big Mangrove Forest

Outcrop of rock

Chapter 6 Study on the New Gas-fired Power Plant

6.1 NECESSITY OF THE NEW GAS FIRED POWER PLANT

In Tanzania, considering the future strong power demand, bold power development plan has been studied. Prospective power plant would be owned by TANESCO, IPP and PPP. According to the JICA's ongoing study "Power System Master Plan (PSMP)", all of the power development plans currently in progress are the IPP and PPP projects. In the case that national grid is dominated by the IPP and PPP, there is a possibility that flexibility of the power supply may be lost due to contractual binding (Power Purchase Agreement: PPA). Therefore it is better that power plants which owned by TANESCO should bear a certain portion of power supply of the national grid.

The study of the necessity on the construction of the 300MW class GTCC in Mtwara district is describe below. The following four locations could be considered as power-consuming area.

(1) Power transmission to Dar es Salaam, the largest power-consuming area

Dar es Salaam is about 500km far from Mtwara. Even the use of high-voltage transmission line of 400kV, transmission loss might be considerably large. So, this case may not be the preferred choice. In addition, Kinyerezi gas-fired power complex, currently under development, is expected to cover the power demand in Dar es Salaam.

(2) Power demand in the Mtwara and Lindi area

Table 6-1 is the expected power demand in the area.

Table 6-1 Power Demand in the Mtwara and Lindi Area

Power demand		Remarks
Dangote cement company	90MW	In Mtwara industrial park. Already installed 45MW private power generation facility.
LNG Production Plant	100MW	TANESCO's estimation
Graphite	45MW	There are three companies (30MW, 5MW, 10MW).Two companies have issued power supply request letter to TANESCO.
Water supply project in Mtwara and Lindi area.	6MW	
Rural Electrification project	84MW	
Nickel	6MW	
Cement	5MW	Lindi area
Fertilizer factory	3MW	
Total	**339MW**	

Sources: Interviews from TANESCO by JICA Study Team.

Table 6-1 shows that there is a possibility to consume the amount of power generated in this project only in Mtwara and Lindi area.

In addition, not included in the above table, there is a plan of the Mtwara Corridor Project (Economic Corridor connecting Tanzania, Mozambique, Malawi and Zambia). So, there is a possibility of more electricity demand in future.

On top of that, Mtwara local government is working on the construction of industrial park and aggressively attracting the enterprises. If power supply is ensured, it could be expected more companies to build factories in the park.

As mentioned in chapter 4, Symbion (USA) is planning to build 400 to 600MW GTCC in the Mtwara. But the plan now goes nowhere fast. Therefore, it is desirable that this project (the 300MW class GTCC) makes an important role to meet the forthcoming power demand ahead of the Symbion.

(3) Power supply to Mozambique

MOU of the project has been concluded. As currently both parties are in the process of seeking approval for the development and execution of the project and soliciting financing for carry out full feasibility study and finally implementation of the project.

(4) Power Supply to Western Area from Mtwara

Songea (town at upper stream of the Rovuma River) has electricity demand, but there is no transmission line, and 220kV transmission line is under construction from Makambako to Songea which is expected to be completed in 2018.

6.2 SPECIFICATIONS OF THE PROJECT

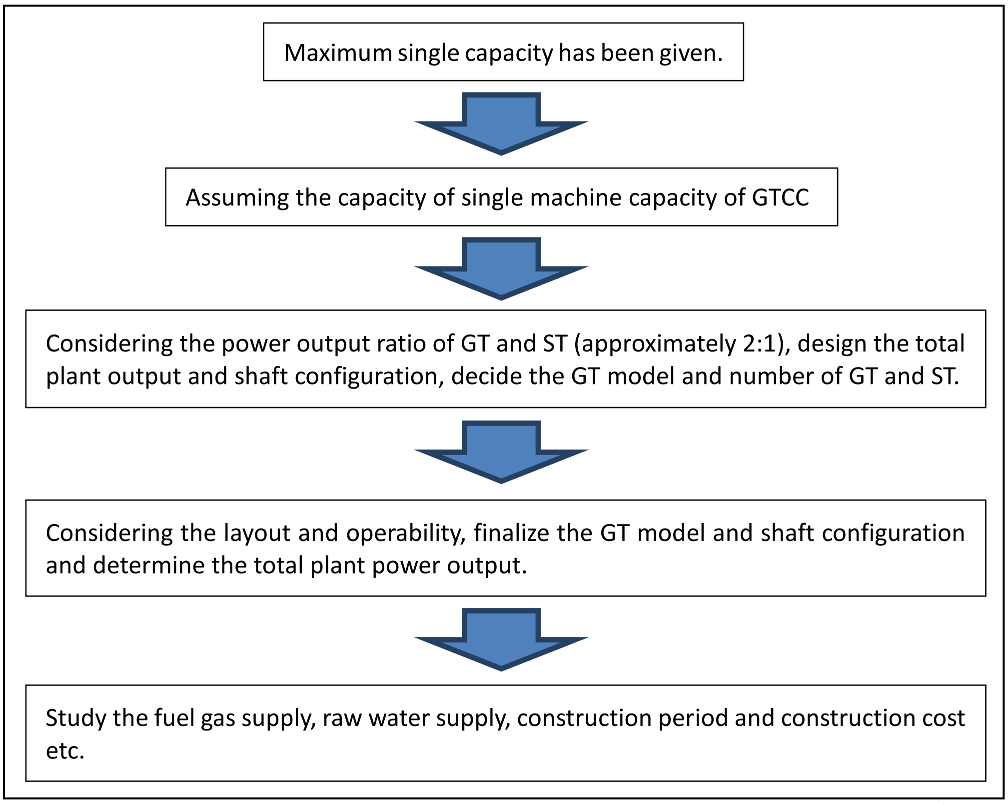
In the PSMP, study of the maximum allowable machine capacity of single power generation facilities have been made. Maximum allowable machine capacity means the maximum single machine capacity which would not make power grid to operate in the out of operational limits when the machine drop offs.

As of now, maximum single machine capacity in Tanzania is Kihansi hydro power 60MW. And in the future the maximum single machine capacity would be 132MW in 2020, and 236MW in 2025 respectively.

In the case of GTCC, there are generators for gas turbine and ST. So, each of the single machine capacity must below the maximum single capacity but the entire plant capacity can be much greater.

(1) Specification of selection flow

In the study of power plant equipment, decision of main specification is shown below.



Sources: JICA Study Team

Fig. 6-1 Flowchart of GTCC Power Plant Specification Selection

(2) Study of Gas turbine specification.

Grid frequency in Tanzania is 50Hz. According the Gas Turbine 2016 Performance Specs., typical models fit in this project is shown in table below.

Table 6-2 GTCC (1on1)

Supplier	Model	Gross output (ISO base)	Net generation efficiency (ISO base)
GE/IHI	LM6000PF	59.0MW	54.9%
	LM6000PF+	71.2MW	55.9%
	LM6000PG	74.2MW	52.2%
	LMS100PA+	135MW	51.5%
	LMS100PB+	128.8MW	52.4%
SIEMENS	SGT-800 (2010)	71.4MW	55.1%
	SGT-800 (2015)	74.1MW	55.6%
MHPS	H-25 (42)	120.2MW	52.8%
	H-100 (110)	157.5MW	54.4%

Sources: Gas Turbine World 2016 Performance Specs.

GE/IHI has a number of gas turbine models. In the GE/IHI models, we select LM6000PF+ as it is the highest efficiency model. About the SIEMENS model, only 2 models gas turbine fit the maximum single machine capacity, so we select SGT-800 (2015) as it has better efficiency of them.

In the case of MHPS, model H-100 (110) has the better efficiency of them, so we select this model.

Table 6-3 shows study result of each gas turbine models.

There is no much difference in the efficiency of each GTCC models, but construction prices (USD/kW) are much different. (Efficiency difference between Table 6-2 and Table 6-3 is due to number of gas turbine and ST.) The price of power generation facilities may change time to time, because of supplier's speculative bid and the market conditions (buyers' market of sellers' market).

Refer to the Gas Turbine World, which is objective data that has been recognized worldwide, model H-100 (110) could build more than 40MW capacity of LM6000PF+ at the same price.

About the maintenance, LM6000PF+ could swap whole gas turbine to repaired one and bring back whole gas turbine to the maintenance factory in turn. This could keep the power plant high availability.

On the other hand, SGT-800 and H-100 (110) conduct the maintenance on the site. It could transfer maintenance ability to TANESCO staff and create employment opportunities in Tanzania.

If H-100 (110) is adopted, the number of GTs, HRSGs and STs are smaller than the cases of GE/IHI and SIEMENS. Therefore, the maintenance burden seems to be lighten up.

Table 6-3 GTCC Comparison of Each Supplier

Old model

Candidate model in this project

Supplier		MHPS		GE / IHI*		SIEMENS	
Model		(3×H28) × 2	2×H110	2×LM6000PF	(2×LM6000PF+) ×2	(2×SCC-800)×2	(2×SCC-800)×2
Launch		1988	2013	1997	2016	2000	2015
Feature	Type	Heavy Duty		Aero derivative		Heavy Duty	
		Fit for Base load		Fit for Peak load		Fit for Base load	
	Ambient temperature characteristics	Base		Relatively large decrease in the output and efficiency by the temperature rise (Using chiller is standard)		Base	
Specs (GTW)	Output [MW] (ISO base)	253.2	324	113	285 / 275	287.2	300
	Efficiency [%] (ISO base)	51.6	55.9	53.6	56.1 / 55.3	55.4	56.2
	GTW USD/kW (Standard bare bone price)	-	780	1,097**	923**	930	810**
Maintenance	Number of GT	6	2	2	4	2	4
	Overhaul interval	Base		Peak load operation: Longer Base load operation: Little bit shorter		Base	
	Maintenance scheme	Exchange of spare parts on the site		Change hole gas turbine (roll-in, roll-out) (Sent to maintenance factory)		Exchange of spare parts on the site	
	Reliability	Base		Higher		Base	
	Maintenance cost	Base		Higher		Base	
	Technical transfer to local	There is opportunity of OJT		There is no opportunity of OJT		There is opportunity of OJT	
	Employment opportunity at local	Yes		No		Yes	
Track Record	in Africa	Tanzania Kinyerezi II	No	Mozambique Maputo	No	Uninvestigated	Uninvestigated
	in all over the world	a number of track record in Japan and all over the world	Now, only in Japan	a number of track record in Japan and all over the world	In Thailand	Uninvestigated	Uninvestigated

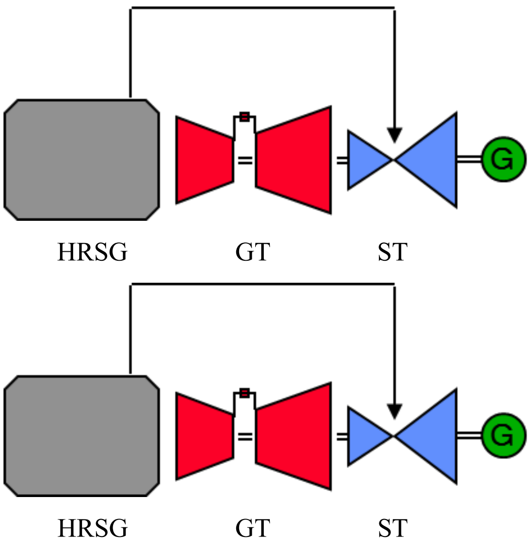
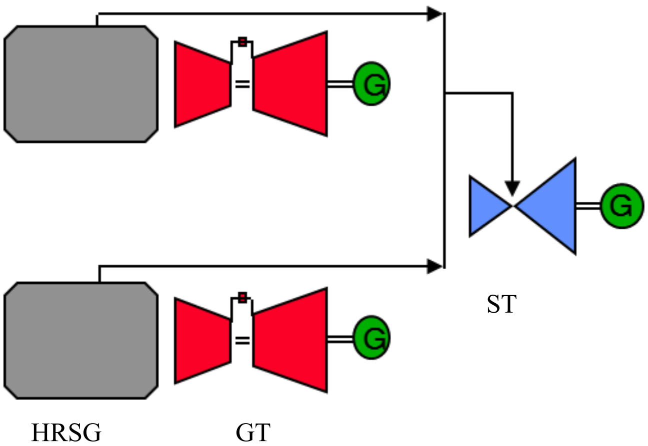
* Output and efficiency of GE/IHI is different because bottoming cycle (HRSG+ST) design is not same.
** Estimated values by JICA Study Team

Sources: JICA Study Team

(3) Study of shaft configuration

To construct GTCC, it is necessary to consider about the configuration of shaft. Shaft configuration could be divided into single-shaft and multi-shaft type. Single-shaft type only has one generator. Gas turbine, ST and generator are connected in one shaft. On the other hand, multi-shaft type has two or more gas turbine and only one ST, each turbine has its generator.

Features of single-shaft type are that time of start-stop is short and that high efficiency in the intermediate load range. About the multi-shaft type, efficiency at full load is higher than single-shaft type so this type of configuration often operates as the base load power supply.

Shaft configuration	Configuration figure	Feature
Single-shaft	1on1 ×2 units  Gas turbine, ST and generator are connected in one shaft.	- System configuration is simple. - Construction costs tend to be less expensive. - Better operability compared to the multi-shaft.
Multi-shaft	2on1 ×1 unit  Gas turbine and ST are connected to generator separately.	- Full load efficiency is better than single-shaft. (Because ST efficiency is better than single-shaft, due to grow in size of ST.) - It can proactively operate by gas turbine only. And connect HRSG and ST later.

Sources: JICA Study Team

Fig. 6-2 Comparison of Single-Shaft and Multi-Shaft GTCC

In this project, we adopt multi-shaft GTCC because it could proactively operate only gas turbine.

(4) Steam turbine condenser cooling system

Candidate site is close to the coast, so seawater is available for cooling the ST condenser and to cool the auxiliary cooling water. In this project we adopt seawater cooling system. Table 6-4 shows comparison of cooling system as a reference.

Table 6-4 Cooling System Comparison

Item	Sea water cooling	Cooling tower	Air-cooled condenser
Installation cost	High	Low	High
Efficiency of ST	High	Medium	Low
Fresh water consumption	Almost 0	High	Almost 0
Space of land	Base	Almost same as sea water cooling	More vast
Land height above NSWL	4 ~ 5m	No limitation	No limitation
Possibility of unloading Jetty	Yes	No	No
Notice 1	Hot water recirculation and heat accumulation have to be avoided	No notice	No notice
Notice 2	Mangrove forest area have to be avoided	No notice	No notice

Source: JICA Study Team

6.3 GAS SUPPLY PLAN

According to the PSMP, gas field at Mnazi Bay has been connected to Dar es Salaam by 532km pipeline (diameter 36 inch) in July 2015. In this project, gas could be supplied through 20km pipeline from gas valve station No.1.

As PSMP is still studying on gas supply and demand balance in future, we will conclude this item during next FS stage.

6.4 SUPPLY OF RAW WATER

About raw water supply, Mtwara-Ruvuma River water supply project is being planned. (Chapter 5 in detail) The project now is waiting for MOF (Ministry of Finance) approval. After approval, construction work is expected to be completed in two and half year. Water supply will rise in stages, and in 2021 the first operating year of the project, the water supply would be 50,000m^3/day. On the other hand, water demand of the project is only 300m^3/day. The Mtwara water authority declared that the use of water for the project is totally no problem.

As described in Chapter 5, Fig. 5-2, there is a water storage tank near the Mikindani, and the project could get water from the tank by around 10km of water pipeline.

6.5 SITE PLOT PLAN

Fig. 6-3 and Fig. 6-4 show the plot plan in case of GE/IHI (2 × LM6000PF+) × 2, and in case of MHPS 2 × H-110 in the Mtwara new site which describes in Chapter 5.

Sources: JICA Study Team

Fig. 6-3 Plot Plan of GE/IHI (2 ×LM6000PF+) ×2

Sources: JICA Study Team

Fig. 6-4 Plot Plan of MHPS 2 × H-110

6.6 EXPECTED TIME SCHEDULE OF THE PROJECT

This Pre-Feasibility Study was substantially completed in October 2016. After the pre-Feasibility Study, the following works are envisaged to complete the Project.

1) Proceed to Feasibility Study
2) Loan Agreement with GoT
3) Select of the Consultant and the Contractor.
4) Construction works.

If we follow the JICA standard procedure to proceed with the Project, the COD on or before 2021 that TANESCO wants seems to be difficult. Therefore, we will discuss with TANESCO to find the appropriate/necessary countermeasures to meet the TANESCO's requirement during next FS stage.

Chapter 7 Study on Transmission Line

7.1 CONFIRMATION OF TRANSPORTING POWER CAPACITY IN MIDDLE TERM PLANNING

(1) The present situation of national grid system in Tanzania

Concerning to the present situation of national grid system in Tanzania, the national grid system planning was presented in the theme of "Overview of Electricity Regulation in Tanzania" at the "1st Partnership Exchange USAID/ NARUC/ East Africa Regional Regulatory Partnership" held on Oct. 21st in 2014. That is mentioned in Fig. 7-1.

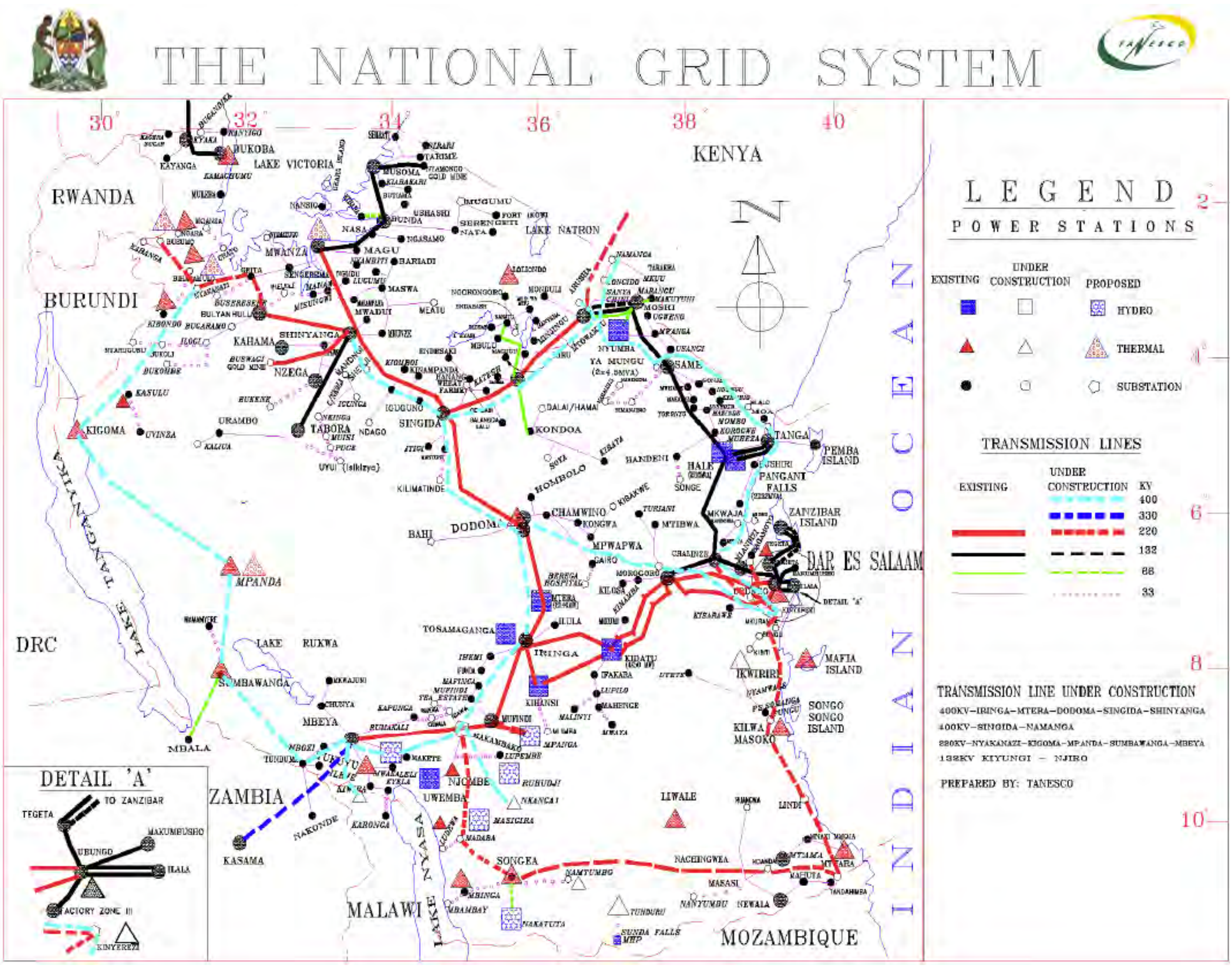


Fig. 7-1 National Grid System (2014) in Tanzania (Africa Regional Conference, 2014)

Additionally, in the progress report 3 of "National grid system Master Plan establish and renewable support project (2nd year): PSMP" reported in March, 2016, the national grid system plan informed by TANESCO in Sep., 2014 is shown in Fig. 7-2.

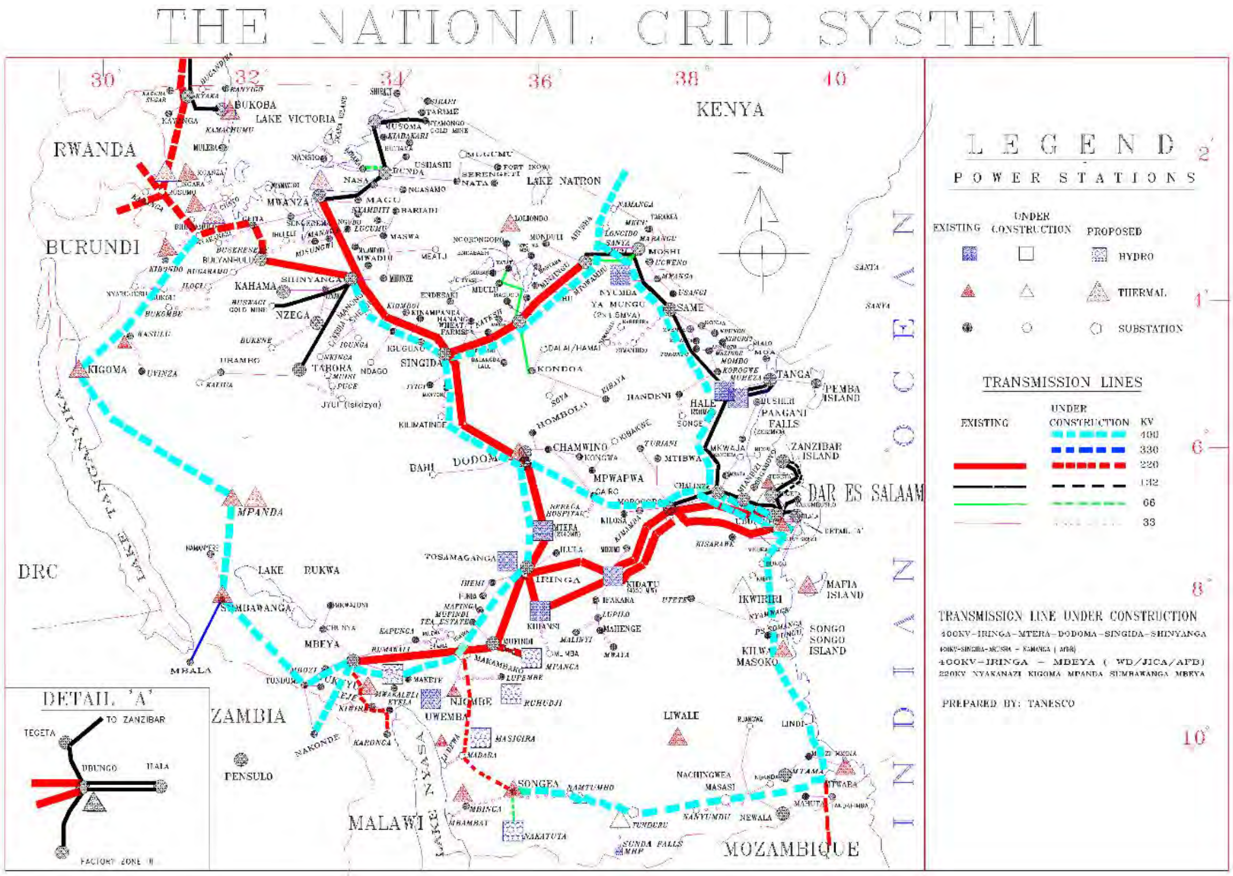


Fig. 7-2 National Grid System (2014) in Tanzania (PSMP, 2016)

Regarding these planning systems, the national grid system is operated by the maximum operation voltage of 220kV in 2014. Based on the newest national grid system mentioned in Fig. 7-2, the installation of 400kV transmission lines has started but operation is planned in 2020.

(2) Middle range planning of transmission line system in Tanzania

According to the progress report 3 of PSMP (2nd year) reported by JICA team in March, 2016, the system diagram is shown in the 5 year step planning from 2015 to 2040. The system diagram at 2015 and 2020 are shown in Fig. 7-3, Fig. 7-4 respectively. Additionally, the system diagram from 2025 to 2040 are shown in Reference 1.

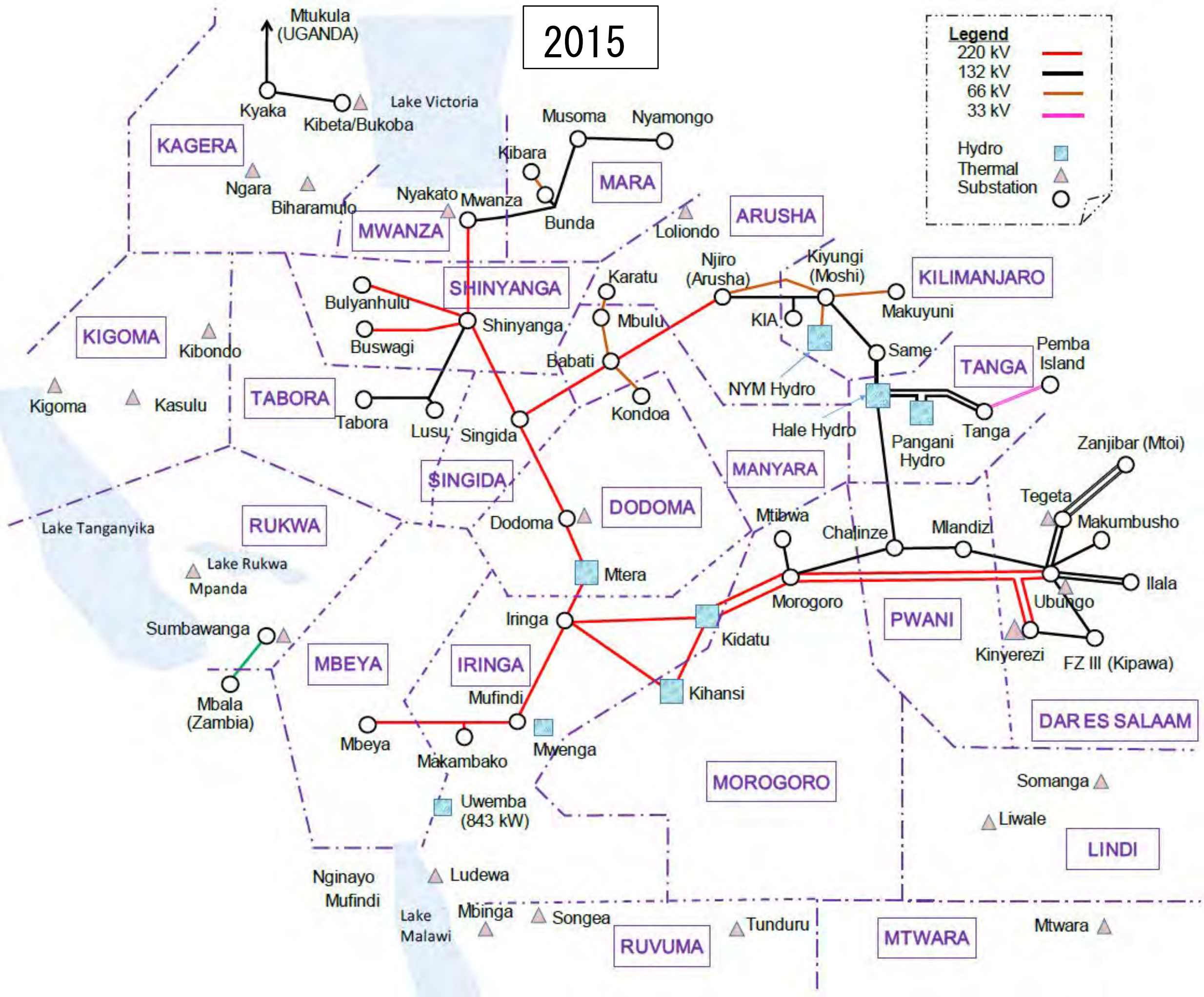


Fig. 7-3 System Diagram at 2015

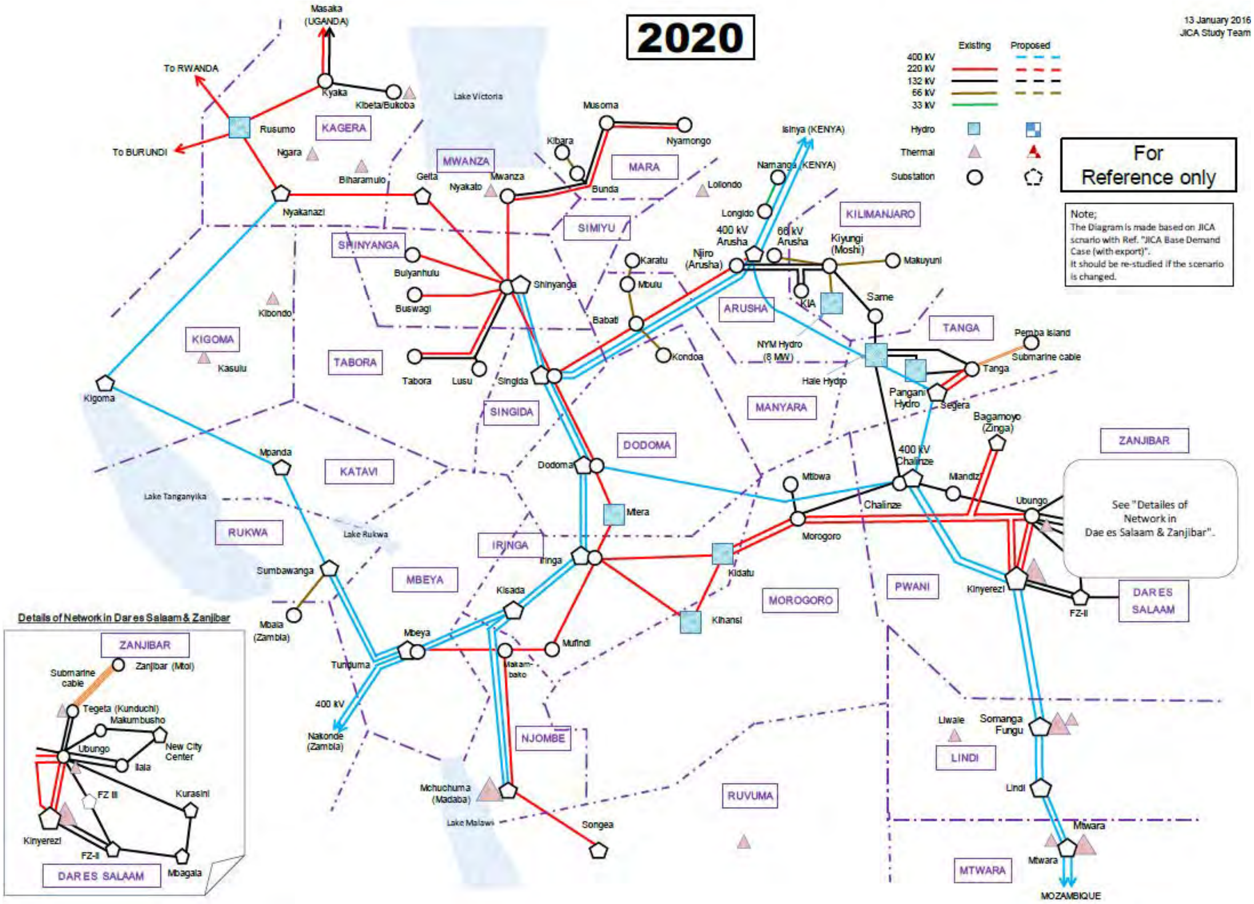


Fig. 7-4 System Diagram at 2020

On the other hand, according to the Final Full Feasibility Report - R05 (Volume I - Report) "Kenya-Tanzania Power Interconnection Project FS, Detailed Design (DD) and Preparation of Tender Documents" in June, 2012 by RSW International Inc., the scenario against 400kV transmission system as shown in Reference 2 is mentioned as below.

1) Establish the back born of 400kV transmission system

TANESCO said, 400kV back born transmission system planning shall be established for the international system connection between Kenya with northern system of Singida ~ Isinya (Kenya) and Singida ~ Shinyanga, southern system of Singida ~ Dodoma ~ Iringa.

2) Planning of installation and rising up to 400kV

・The year of 2015	International connection to Kenya (Isinya ~ Arusha)	400kV operation
	Arusha ~ Singida	220kV operation
	Singida ~ Shinyanga	220kV operation
・The year of 2020	Arusha ~ Singida	400kV rising up
	Singida ~ Shinyanga	400kV rising up
・The year of 2025	Singida ~ Iringa	400kV rising up
・The year of 2035	Babati	400kV rising up

Regarding to the above plan, 400kV operating will be started at Kinyerezi in 2020.

(3) Target transmission line in this project

The 300km length of 400kV transmission line from Mtwara to Somanga Fungu completed until 2021 ~ 2022 is studied as shown in Fig. 7-5.

This transmission line has the duty of transporting the power mentioned as below, and is indispensable to the national grid system.

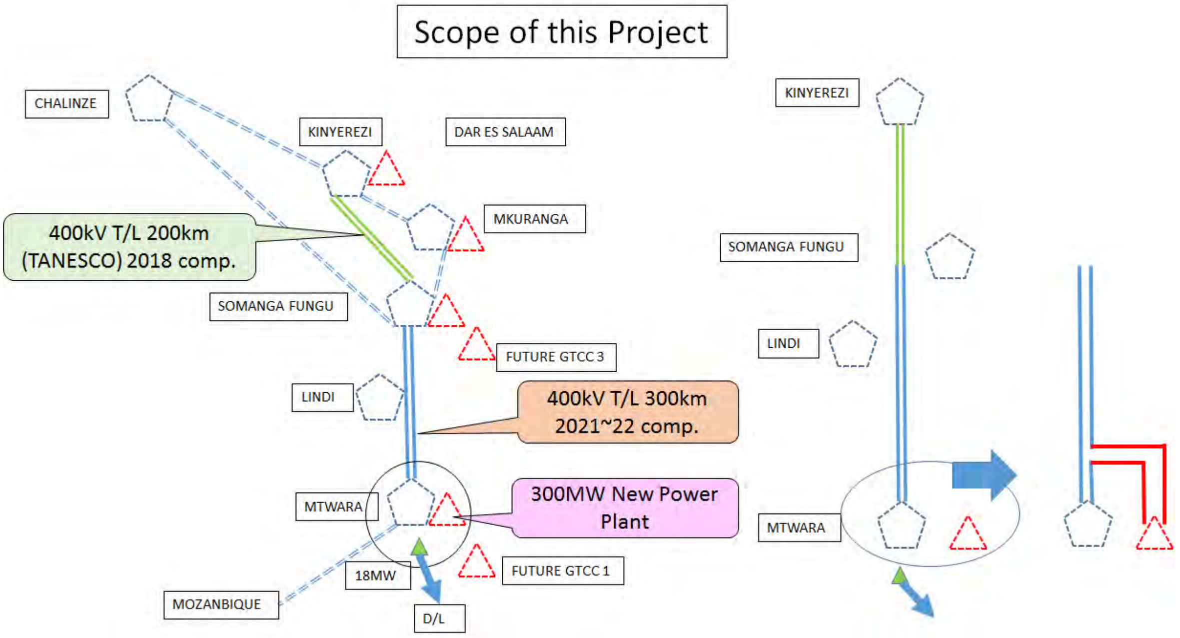
1) Transport the southern thermal power connect to Mtwara in 2025 to the northern demand area (Dar es Salaam) via Somanga Fungu ~ Kinyerezi.

Additionally, this transmission line will be connected to the constructing 200km, 400kV transmission line from Kinyerezi to Somanga Fungu which will be completed in 2018.

2) Transport the domestic power to Mtwara for the international connecting power to Mozambique.

① After 2030, Western hydro power is transported to Mtwara via Lindi completed in 2025.
② Huge thermal power connected to Somanga Fungu is transported to Mtwara.

Additionally, the target transmission line will be constructed through the route near by the pipe line route as shown in Fig. 7-6.



Sources: JICA Study Team

Fig. 7-5 Target Transmission Line in this Project

Source: TANESCO "Site Earmarking for the proposed Mkuranga 250MW CCGT Power Plant Project

Fig. 7-6 Gas Pipe Line Planning

(4) Yearly trend of power capacity considered on this project in the national grid system department

The considering transmission line will be connected from Mtwara supplied 300MW by IPP thermal power near Mtwara to Somanga Fungu connecting point. This power will be carried to Kinyerezi via Somanga Fungu connection point. Moreover, Mtwara has the function of the 400kV international grid system connecting point to Mozambique.

In 2020, Somanga Fungu will be adopted to this transmission line, and 300MW IPP thermal power will be constructed near Somanga Fungu.

In 2025, at the point of 50km distance far from Mtwara, the thermal power station named Future CGT1 (starting 200MW) will be constructed.

In 2030, southern route 400kV transmission line which carry a hydro power will be connected to Lindi.

In 2035, at the point of 50km distance far from Somanga Fungu, the thermal power station named Future CGT3 (starting 430MW) will be constructed.

In 2040, at the Future CGT1 (final 1,100MW) and Future CGT3 (final 6,110MW) additional power plants will be constructed.

Thus, the power capacity on this considering transmission line will be changed year by year, so maximum power capacity now is assumed 300MW for study of this transmission line.

Additionally, it shall be revised the maximum power capacity in the future.

7.2 STUDY ON CONDUCTOR SIZE AND NUMBER OF BUNDLED FOR 300KM LENGTH OF 400KV TRANSMISSION LINE

According to the progress report 3 of PSMP (2nd year) reported by JICA team in March, 2016, the specification of existing and future 220kV ~ 400kV transmission line are showed in Table 7-1 and Table 7-2. In addition, according to the Pre-FS draft report of "A DOUBLE CIRCUIT 400kV TRANSMISSION LINE FROM MTWARA TO SOMANGA" (Appendix IV), twin bundled Bluejay was recommended instead of triple bundled Flint, because of the transfer capacities and electric field strength ratio (Emax/Ec) as shown in Table 7-3. Moreover, one of the important consideration like as corona discharging influence is studied in next section.

On the other hand, standardization is the important element. In fact, the Bluejay is being used on other parts of the 400kV transmission system that are currently under co-ordination and/or construction. Standardization is desirable since it reduces the amount of holding spare required for ongoing maintenance of the network.

Table 7-1 Used Conductor for Existing Transmission Line according to Voltage

Voltage	Kind of conductor	Name of conductor	Cross section area (mm^2)	Power capacity (MVA)	Remarks
220kV	ACSR*1	Bluejay	565	333	
		Bison	350	207	
		Pheasant	644	362	
		Rail	483	303	
132kV	ACSR	Wolf	150	74	
		Hawk	241	121	
		Tiger	130	66	
	XLPE*2		300/400	143	Submarine cable
			95	52	
66kV	ACSR	Wolf	150	37	
		Rabbit	50	18	

*1 ACSR : Aluminum Cable Steel Reinforced
*2 XLPE : Cross-linked Polyethylene

Table 7-2 Specification of 220kV ~ 400kV Transmission Line

Parameter	400kV		220kV
Conductor	ACSR	ACSR	ACSR
Code Name	Bluejay	Bluejay	Bluejay
Size (MCM/mm^2)	1,113 / 564	1,113 / 564	1,113 / 564
No. of Circuit & Type	2-cct. Vert.	2-cct. Vert.	2-cct. Vert.
No. of Cond. per Phase	4	2	2
Current/Conductor (Amp)	1,092	1,092	1,092
① Full Rating (MVA)	3,026	1,513	832
②Normal Rating (MVA) = ① x 80%	2,421	1,210	666
③Emergency Rating (MVA) = ② x 120%	2,905	1,453	799

Table 7-3 Power Transfer Capacity and Electric Field Calculations

	Bundle Mass (kg/km)	Diameter (mm)	X_L (Ω/km)[1]	Power Transfer Capacity [SIL] (MW/circuit)[1]	E_{MAX} (kV/m)	E_C (kV/m)	E_{MAX}/E_C
Twin Bluejay	3,740	31.98	0.2943	569	17.78	18.71	0.950294
Triple Bluejay	5,610	31.98	0.2568	652	14.28	18.71	0.763228
Quad Bluejay	7,480	31.98	0.2326	720	12.15	18.71	0.649385
Twin Flint	2,062	25.13	0.3019	554	21.73	19.21	**1.131182**
Triple Flint	3,093	25.13	0.2618	639	17.40	19.21	0.905778
Quad Flint	4,124	25.13	0.2364	708	14.77	19.21	0.768870

Note (1): These values are approximations based upon the assumptions described above.

Source: USAID Pre-FS Relating to a 2 circuit 400kV T/L from MTWARA to SOMANGA

According to Table 7-2, 2/ 4 bundled Bluejay is selected for the study of this project.

(1) Comparison of corona discharging influence according to size and number of conductor

Against the 400kV transmission line, the problem of corona discharging environmental influence is occurred. The limiting value of noise caused by corona discharge is recommended by Electric

Power Research Institute (EPRI) reports of "AC Transmission Line Reference Book, 200kV and over, Third edition, 2005" and "ESKOM standards in South Africa" as mentioned below.

a. More over 43mm of diameter for twin bundled conductor
b. More over 25mm of diameter for triple bundled conductor

Because the electric gradient which is satisfied with the above condition is not cleared, electric gradient on three kinds of conductors i.e. FRINT, TERN, DRAKE are calculated by using equation (1) ~ (3) based on the recommended value of 25mm diameter for three bundled conductors. And limited value of corona audible noise level is suggested to 52.5dB (A). The relation between diameter and number of bundled conductors which is cleared this limited value are mentioned below.

The electric gradient (G) for random direction can be calculated by equation (1).

$$G = \frac{0.4343 \cdot E \cdot \left(1 + \frac{2(n-1)\cdot r}{a} \sin\frac{\pi}{n} \cdot \cos\theta\right)}{n \cdot r \cdot log\left\{n \cdot r \cdot \left(\frac{a}{2\sin\frac{\pi}{n}}\right)^{n-1}\right\}^{1/n}} \quad [kV/cm] \quad \text{.......................................} (1)$$

$$D = \sqrt[3]{D_{ab} \times D_{bc} \times D_{ca}} \quad [m] \quad \text{..} (2)$$

$$E = V/\sqrt{3} \quad [kV] \quad \text{..} (3)$$

Here,	G	:	Electric gradient on conductor surface for random direction	(kV/cm)
	E	:	Voltage against ground	(kV)
	V	:	Nominal voltage	(kV)
	r	:	Radius of conductor	(cm)
	D	:	Equivalent phase to phase distance	(cm)
	Dab・Dbc・Dca	:	each phase to phase distance	(cm)
	a	:	conductor spacing	(cm)
	n	:	Number of bundled conductors	(Nos)
	θ	:	Angle between direction of max. Electric gradient and random direction of electric gradient (0≤θ≤90)	(degree)

The maximum electric gradient (Gmax) can be obtained in the case of θ=0 degree. The result is shown in Table 7-4.

Table 7-4 Comparison of Maximum Electric Gradient for Each about 25mm Diameter Conductors

Name of conductor		FLINT	DRAKE	TERN
Diameter	mm	25.17	28.14	27
Unit weight	kg/m	1.028	1.628	1.334
Cross section of Aluminum	mm^2	375	402.56	403.77
Cross section of Core	mm^2	0	65.44	27.83
Total cross section	mm^2	375	468	431.6
Linear expansion	*/°C			
Modulus	kg/mm^2			
Minimum breaking load	kN			
DC resistance	Ω/km (20°C)	0.0774	0.0717	0.0715
Current capacity (in catalog)	A	577	615	610
AC resistance coefficient				
AC resistance	Ω/km (20°C)	0.087772	0.081308	0.081081
Current capacity	A			
Number of bundled conductors		3	3	3
Conductor spacing	m	0.4	0.4	0.4
AB phase to phase distance	m	13	13	13
BC phase to phase distance	m	13	13	13
CA phase to phase distance	m	26	26	26
Geometrical Mean Distance GMD	m	16.37897	16.37897	16.37897
Geometrical Mean Radious GMR	m	0.159099	0.165126	0.162865
Inductance value	mH/km	0.943478	0.936042	0.938799
Reactance value	Ω/km	0.296402	0.294066	0.294932
Limited transporting length	km	931.4156	938.8145	936.0575
Voltage drop	kV	13.12546	12.37266	12.35665
Electric gradient on conductor	kV/cm	14.63839	13.35236	13.81347
Power loss	MW	2.735425	2.533979	2.526911

Sources: JICA Study Team

According to Table 7-4, because the value of 14.65kV/cm is obtained for FRINT nearest to 25mm diameter, limited value of 14.65kV/cm shall be adopted for the electric gradient condition to select the conductors.

Additionally, in Japan, 15.5kV/cm is recommended for 50dB (A) of corona audible noise as mentioned in Reference 3.

(2) Study of corona discharge occurred on some kind of conductor and each number of bundled conductors for 400kV transmission line of this project.

According to Table 7-1 to Table 7-3, 2/4 bundled Bluejay are selected by TANESCO for the specification of 400kV transmission line.

Addition to Bluejay some kind of equivalent 25mm diameter, 3/4 bundled conductors are selected and calculated the electric gradient for each conductors. The selected conductors are Hawk, Zebra and Garnet. The result is shown in Table 7-5.

According to Table 7-5, 2/4 bundled Bluejay, 4 bundled Hawk and 3/4 bundled Zebra and Gannet are cleared the limited value of 14.65kV/cm.

Table 7-5 Comparison of Maximum Electric Gradient for Each Study Conductors

Name of conductor		Bluejay	Bluejay	Bluejay	Zebra	Zebra	Zebra	Hawk	Hawk	Gannet	Gannet
Diameter	mm	31.98	31.98	31.98	28.62	28.62	28.62	21.77	21.77	25.76	25.76
Unit weight	kg/m	1.866	1.866	1.866	1.621	1.621	1.621	0.9751	0.9751	1.3633	1.3633
Cross section of Aluminum	mm^2	565.49	565.49	565.49	428.9	428.9	428.9	241.65	241.65	338.26	338.26
Cross section of Core	mm^2	38.9	38.9	38.9	55.6	55.6	55.6	39.19	39.19	54.9	54.9
Total cross section	mm^2	604.39	604.39	604.39	484.5	484.5	484.5	280.84	280.84	393.16	393.16
Linear expansion	*/°C										
Modulus	kg/mm^2										
Minimum breaking load	kN	127.66	127.66	127.66	131.9	131.9	131.9	81.84	81.84	110.31	110.31
DC resistance	Ω/km (20°C)	0.0511	0.0511	0.0511	0.0674	0.0674	0.0674	0.1195	0.1195	0.0854	0.0854
Current capacity (in catalog)	A	745	745	745	636	636	636	451	451	553	553
AC resistance coefficient											
AC resistance	Ω/km (20°C)	0.057947	0.057947	0.057947	0.076432	0.076432	0.076432	0.135513	0.135513	0.096844	0.096844
Current capacity	A										
Number of bundled conductors		4	3	2	4	3	2	4	3	4	3
Conductor spacing	m	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
AB phase to phase distance	m	13	13	13	13	13	13	13	13	13	13
BC phase to phase distance	m	13	13	13	13	13	13	13	13	13	13
CA phase to phase distance	m	26	26	26	26	26	26	26	26	26	26
Geometrical Mean Distance GMD	m	16.37897	16.37897	16.37897	16.37897	16.37897	16.37897	16.37897	16.37897	16.37897	16.37897
Geometrical Mean Radious GMR	m	0.275836	0.172319	0.079975	0.268287	0.166059	0.075657	0.250551	0.151586	0.261317	0.160333
Inductance value	mH/km	0.829259	0.927514	1.089369	0.834809	0.934914	1.100469	0.848487	0.953152	0.840073	0.941933
Reactance value	Ω/km	0.260519	0.291387	0.342235	0.262263	0.293712	0.345722	0.26656	0.299441	0.263917	0.295917
Limited transporting length	km	1059.705	947.446	806.678	1052.659	939.9467	798.5413	1035.69	921.9619	1046.063	932.9429
Voltage drop	kV	9.376653	9.715233	10.27297	11.47525	11.82021	12.39069	18.16904	18.52971	13.78974	14.14074
Electric gradient on conductor	kV/cm	10.34109	12.03484	14.65429	11.30229	13.1689	16.07965	14.1545	16.52739	12.31294	14.36
Power loss	MW	1.354459	1.805946	2.708919	1.786508	2.382011	3.573016	3.167474	4.223298	2.263617	3.018156

Sources: JICA Study Team

(3) Transmission distance according to maximum power capacity under stable power grid

Because of long length transmission line and large power capacity, operation of power grid will become unstable. So power capacity shall be limited.

The power capacity using long length transmission line is calculated by equation (4) ~ (8) related to the line inductance and limited angle of power phase.

$$\text{Pmax} = \frac{V^2}{X \times L_d} \sin\theta \quad [MW] \quad \cdots\cdots (4)$$

Here, Pmax : Maximum power capacity (MW)
V : Transmission Voltage (kV)
X : Reactance of conductor (= 2πfL × 10^{-3}) (Ω/km)
L : Inductance of conductor (mH/km)
Ld : Line length (km)
θ : Limit angle of receiving power phase (under 15 deg.) (deg.)

The inductance of multi bundled conductor can be calculated by equation (5) ~ (8).

$$\text{L} = \left(\frac{0.05}{n} + 0.4605 \log\left(\frac{GMD}{GMR}\right)\right) \quad \left[{}^{mH}/_{km}\right] \cdots\cdots (5)$$

$$\text{GMD} = \sqrt[3]{D_{ab} \times D_{bc} \times D_{ca}} \quad [m] \cdots\cdots (6)$$

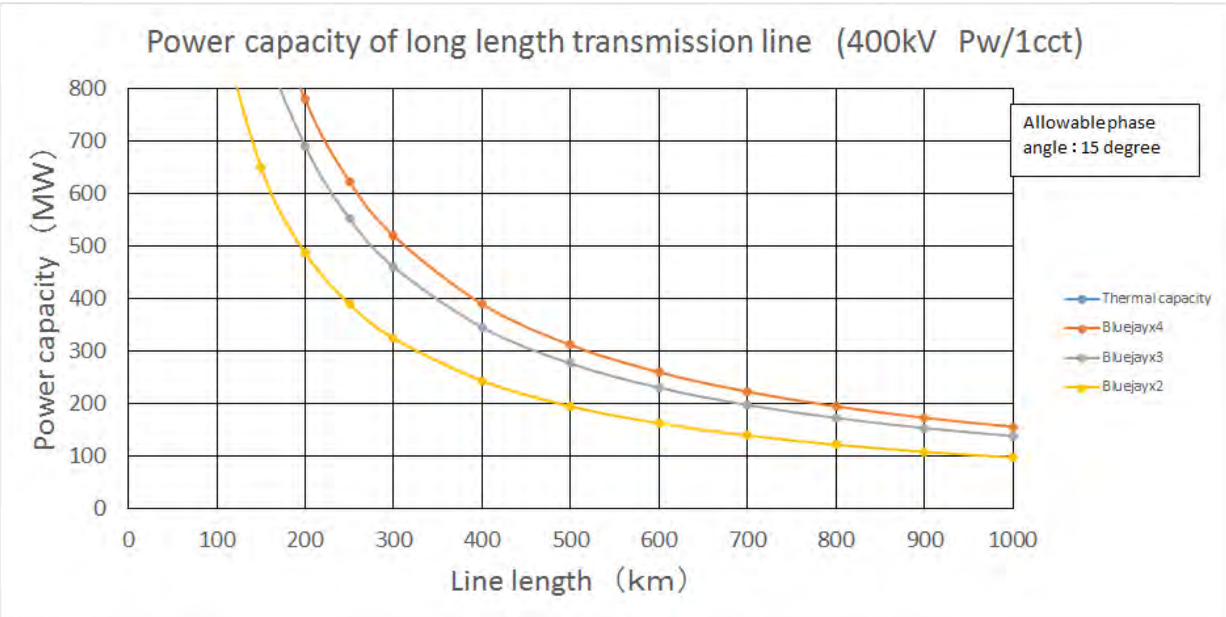
$$\text{GMR} = \text{K} \cdot \sqrt[n]{r \cdot a^{n-1}} \quad [m] \cdots\cdots (7)$$

$$K = \sqrt[n]{\frac{n}{\left\{2sin\left(\frac{\pi}{n}\right)\right\}^{n-1}}} \quad \cdots\cdots(8)$$

Here,	L	:	Inductance of multi bundled conductors (mH/km)
	GMD	:	Geometrical mean distance (m)
	GMR	:	Geometrical mean radius (m)
	Dab・Dbc・Dca	:	each phase to phase distance (m)
	n	:	Number of bundled conductors (Nos)
	r	:	Radius of conductor (m)
	a	:	Conductor spacing (m)

As mentioned Table 7-5, the inductance of 2/ 3/ 4 bundled each kind of conductors are shown. Each inductance is influenced by not conductor diameter but number of bundled conductors. So, the inductance of each number of bundled conductors is obtained as 1.09mH/km for 2 bundled, 0.94mH/km for 3 bundled and 0.83mH/km for 4 bundled.

The possible line length for TANESCO's 400kV Bluejay transmission line is calculated as shown in Fig. 7-7.



Sources: JICA Study Team

Fig. 7-7 Characteristic of Transmission Distance according to Maximum Power Capacity of Bluejay

According to Fig. 7-7, for example, in the case of transmitting 300MW, possible length are obtained 320km for 2 bundled and 510km for 4 bundled. Additionally, in the case of using 2 circuit transmission line, it is equal to one circuit transmitting 300MW at the one circuit fault, so same condition is appeared as mentioned the above.

Considering these conditions, 2 bundled conductors can be transmitted 300MW enough to 300km distance from Mtwara to Somanga Fungu. However, at the first operation, Somanga Fungu will not be constructed, so it has to transmit more over 200km to Kinyerezi.

Considering the above conditions, 4 bundled conductors shall be necessary to transmit 300MW to

500km distance from Mtwara to Kinyerezi through Somanga Fungu.

(4) Study of voltage drop

In the long length transmission line, the voltage drop at receiving point is occurred according to the self-impedance and power capacity. The voltage drop is calculated by equation (9).

$$\nu = \sqrt{3}(R_{AC} \cdot I \cdot \cos\theta + X \cdot I \cdot \sin\theta) \cdot l$$

$$= \sqrt{3}\left(R_{AC} \times \frac{P}{\sqrt{3}V_R} + X \times \frac{Q}{\sqrt{3}V_R}\right) \cdot l$$

$$= \frac{1}{V_R}(P \cdot R_{AC} + X \cdot Q) \times 10^3 \cdot l \qquad [kV] \text{..........} (9)$$

Here,	ν	:	Voltage drop	(kV)
	Vr	:	Receiving point voltage	(kV)
	P	:	Effective power	(MW)
	Q	:	Reactive power	(MVar)
	cosθ	:	Power factor	
	RAC	:	AC resistance of conductor	(Ω/km)
	X	:	Reactance of conductor	(Ω/km)
	l	:	Line length	(km)

The voltage drop for 300km length of each kind of conductor and number of bundled conductors are calculated and shown in Table 7-5 as mentioned before. These voltage drop are the range from 9 to 19kV, then at the one circuit fault, these voltage drop become twice as 18 to 38kV. If the allowable voltage drop for 400kV class is assumed to be 10% of 400kV, the voltage drop is satisfied under 40kV, so no limitation is recognized to power capacity and line length. However, in the case of transmitting to the distance of 500km to Kinyerezi via Somanga Fungu, It will be concerned about a voltage drop.

7.3 SPECIFICATIONS OF LOW LOSS CONDUCTOR

(1) Application of Low Loss Conductor (LL-ACSR)

In the case of introduction of low loss conductor, wind load and tensile force of conductor shall be not exceed design load corresponding to tower design for twin-bundle Bluejay. Therefore, low loss conductor shall be equivalent outer diameter and current capacity to conventional Aluminum Cable Steel Reinforced (ACSR) Bluejay conductor. Standard design of towers corresponding to twin-bundle ACSR Bluejay conductor is applicable to twin-bundle low loss conductor. Furthermore, transmission loss will be reduced after the start of operation when design condition has secured as mentioned above. So that the benefit can be surely obtained.

(2) Feature of Low Loss Conductor

Low loss conductor is one of ACSR, stranding up trapezoidal aluminum strands. Area of aluminum conductor has high occupancy compare with conventional conductor. Furthermore, steel core has adopted high strength steel core to reduce occupancy of steel core from overall cross section area. So that weight of conductor will be reduced. AC resistance of low loss conductor is smaller than conventional conductor in the case of using same outer diameter as the result of increment of aluminum section area. Therefore, transmission loss has reduced.

In the case of equivalent AC resistance between low loss conductor and conventional conductor, outer diameter and unit weight of low loss conductor are smaller than conventional conductor. There is possibility of downscale support structure.

(3) Specifications of Low Loss Conductor

Low Loss conductor is designed as for secure the current capacity of conventional Bluejay supposed in TANESCO and equivalent unit weight of conventional Bluejay (equivalent dip) and equivalent diameter of conventional Bluejay (equivalent wind pressure) and free size conductor. In this study, the case of equivalent unit weight of conventional Bluejay (equivalent dip) should be considered. The reason to adopt same unit weight as conventional conductor, it is expected that the safety factor of withstand load become larger than conventional conductor because of reducing a wind load with small diameter of low loss conductor, then maximum tension and dip shall be same as standard design of tower corresponding to conventional conductor which avoid changing basic line design conditions.

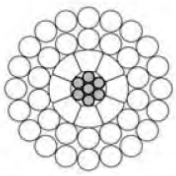
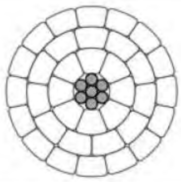
On the other hand, considering the multi-bundled small size low loss conductors, there is no possibility because of the diameter of 25mm over is required in accordance with the value less than 14.64kV/cm of electric gradient on conductor surface.

For example, 3 bundled of Gannet and Zebra can be considerable against the twin bundled Bluejay. Against the 4 bundled Bluejay, 6/ 8 bundled small size conductor is available but out of consideration.

However, in the case of large power capacity will be required, study of small conductor is undeniable.

The equivalent unit weight design of low loss conductor already studied by another project as shown in Table 7-6.

Table 7-6 Example of Low Loss Conductor

Description		Unit	LL-ACSR/AS 510mm^2	LL-ACSR/AS 610mm^2
Construction		Nos/mm	34/3.875 - AL 8/TW*1 - AL 7/2.1 - 14EAS*2	16/TW*1 - AL 11/TW*1 - AL 8/TW*1 - AL 7/2.1 – 14EAS*2
Nominal Diameter		mm	29.59	29.59
Min. breaking load		kN	116.1	126.5
Cross sectional area	AL	mm^2	514.4	610.7
	Core		24.25	24.25
	Total		538.7	635.0
Nominal weight		Kg/km	1600	1867
DC Resistance at 20 deg. C		Ohm/km	0.0558 **[93]**	0.0471 **[79]**
Modulus of electricity		GPa	66.7	65.9
Co-efficient of linear expansion		/^{o}C	21.7 x 10^{-6}	21.9 x 10^{-6}
Current capacity (AC Resistance)	at 956A	A (Ω/km)	956A (0.0743) at 87.3^{o}C	956A (0.0617) at 81.3^{o}C
	Maximum		988A (0.0749) at 90^{o}C	1073A (0.0635) at 90^{o}C
Sag at 350m	at 956A	m	12.10m at 87.7^{o}C	11.78m at 82.5^{o}C
	Maximum		12.20m at 90^{o}C	12.11m at 90^{o}C
Cross sectional view		-		

Notes:
*1: TW: Trapezoid wire
*2: AS: Aluminum clad steel wire

-Calculation condition-

For Sag-Tension	For Current Capacity
(1) Maximum working tension: Not exceed 40% RTS Wind velocity: 40 m/s at 25^{o}C (2) Everyday tension: Not exceed 23% RTS Wind velocity: still air at 30^{o}C Critical condition is (1) or (2) sever Span length: 350m	+ Ambient temperature: 40^{o}C + Wind velocity: 0.5m/s + Wind direction: Right angle + Solar radiation: 0.1W/cm^2 + Acsorptivity of conductor surface: 0.6 Calculation method: In accordance with JCS 0374

Source: Technical Sheet of conductor manufacturer

According to Table 7-6, the power loss of Bluejay and low loss conductor (LL-610) which is equivalent weight of Bluejay is calculated by the equation (10) ~ (16) using the parameters as diameter, AC resistance and so on selected in Table 7-6.

$$P_l = 3 \cdot \left(\frac{I}{n}\right)^2 \cdot R_{AC} \cdot n \times 10^{-6} \cdot L$$
$$= 3 \cdot I^2 \cdot \frac{R_{AC}}{n} \cdot L \qquad [MW] \text{..........}(10)$$

$$I \quad = \frac{P}{\sqrt{3} \cdot V \cdot \cos\theta} \times 10^3 \qquad [A] \text{..........}(11)$$

$$R_{AC} = \beta_1 \cdot \beta_2 \cdot R_{DC} \cdot \{1 + \alpha(T - 20)\} \qquad [\Omega/km] \text{..........}(12)$$

Here,	Pl	:	Power loss	(MW)
	P	:	Power capacity	(MW)
	I	:	Loading phase current	(A)
	L	:	Line length	(km)
	V	:	Nominal voltage	(kV)
	RAC	:	AC resistance	(Ω/km)
	n	:	Number of bundled conductors	(Nos)
	RDC	:	DC resistance (at 20 °C)	(Ω/km)
	β1	:	Skin effect coefficient	
	β2	:	Iron loss coefficient	
	α	:	Thermal resistance coefficient	(/°C)
	T	:	Temperature of conductor	(°C)

Skin effect coefficient

$$\beta_1 = 0.99609 + 0.018578x - 0.030263x^2 + 0.020735x^3 \text{..........}(13)$$

$$x = 0.01 \frac{D_1 + 2D_2}{D_1 + D_2} \sqrt{\frac{8 \times \pi \times f \times (D_1 - D_2)}{(D_1 + D_2) \times R_{DC}}} \text{..........}(14)$$

D1	:	Diameter (mm)
D2	:	Diameter of core (mm)
f	:	Frequency (Hz)

Iron loss (Even number of aluminum layer)

$$\beta_2 = 1$$

Iron loss (Odd number of aluminum layer)

$$\beta_2 = 0.99947 + 0.028895x - 0.0059348x^2 + 0.00042259x^3 \text{.....}(15)$$

$$x = \frac{I}{A_{AL}} \text{..........}(16)$$

I	:	Phase load current (A)
A_{AL}	:	Cross section of conductor (mm^2)

note) Repetition calculation will be necessary because of β_2 include the phase load current

The calculating result is shown in Table 7-7.

Table 7-7 Comparison of Power Low Loss for Bluejay and Low Loss Conductor (LL-610) (In the case of 300km length)

Name of conductor		LL610	LL610	LL610	Bluejay	Bluejay	Bluejay
Diameter	mm	29.59	29.59	29.59	31.98	31.98	31.98
Unit weight	kg/m	1.867	1.867	1.867	1.866	1.866	1.866
Cross section of Aluminum	mm^2	610.7	610.7	610.7	565.49	565.49	565.49
Cross section of Core	mm^2	24.25	24.25	24.25	38.9	38.9	38.9
Total cross section	mm^2	634.95	634.95	634.95	604.39	604.39	604.39
Linear expansion	*/°C						
Modulus	kg/mm^2						
Minimum breaking load	kN	126.5	126.5	126.5	127.66	127.66	127.66
DC resistance	Ω/km (20°C)	0.0471	0.0471	0.0471	0.0511	0.0511	0.0511
Current capacity (in catalog)	A	1207	1207	1207	745	745	745
AC resistance coefficient							
AC resistance	Ω/km (20°C)	0.053411	0.053411	0.053411	0.057947	0.057947	0.057947
Current capacity	A						
Number of bundled conductors		4	3	2	4	3	2
Conductor spacing	m	0.4	0.4	0.4	0.4	0.4	0.4
AB phase to phase distance	m	13	13	13	13	13	13
BC phase to phase distance	m	13	13	13	13	13	13
CA phase to phase distance	m	26	26	26	26	26	26
Geometrical Mean Distance GMD	m	16.37897	16.37897	16.37897	16.37897	16.37897	16.37897
Geometrical Mean Radious GMR	m	0.270531	0.167915	0.076929	0.275836	0.172319	0.079975
Inductance value	mH/km	0.833143	0.932692	1.097136	0.829259	0.927514	1.089369
Reactance value	Ω/km	0.261739	0.293014	0.344675	0.260519	0.291387	0.342235
Limited transporting length	km	1054.765	942.186	800.9672	1059.705	947.446	806.678
Voltage drop	kV	8.879735	9.222777	9.789437	9.376653	9.715233	10.27297
Electric gradient on conductor	kV/cm	11.00291	12.81581	15.63619	10.34109	12.03484	14.65429
Power loss	MW	1.248435	1.66458	2.496871	1.354459	1.805946	2.708919

Sources: JICA Study Team

According to the Table 7-7, three possible studying cases are selected with considering the power loss of low loss conductor are lower than Bluejay's one. These case are mentioned below.

(1) Together with 4 bundled conductors
(2) Together with 2 bundled conductors
(3) 2 bundled Bluejay and 3 bundled low loss conductors

However, in the case of 500km line length, only together with 4 bundled conductor will be compared, because of considering the power loss of 500km line length as shown in Table 7-8.

Table 7-8 Comparison of Power Low Loss for Bluejay and Low Loss Conductor (LL-610) (In the case of 500km length)

Name of conductor		LL610	Bluejay
Diameter	mm	29.59	31.98
Unit weight	kg/m	1.867	1.866
Cross section of Aluminum	mm^2	610.7	565.49
Cross section of Core	mm^2	24.25	38.9
Total cross section	mm^2	634.95	604.39
Linear expansion	*/°C		
Modulus	kg/mm^2		
Minimum breaking load	kN	126.5	127.66
DC resistance	Ω/km (20°C)	0.0471	0.0511
Current capacity (in catalog)	A	1207	745
AC resistance coefficient			
AC resistance	Ω/km (20°C)	0.053411	0.057947
Current capacity	A		
Number of bundled conductors		4	4
Conductor spacing	m	0.4	0.4
AB phase to phase distance	m	13	13
BC phase to phase distance	m	13	13
CA phase to phase distance	m	26	26
Geometrical Mean Distance GMD	m	16.37897	16.37897
Geometrical Mean Radious GMR	m	0.270531	0.275836
Inductance value	mH/km	0.833143	0.829259
Reactance value	Ω/km	0.261739	0.260519
Limited transporting length	Km	527.3824	529.8523
Voltage drop	kV	29.59912	31.25551
Electric gradient on conductor	kV/cm	11.00291	10.34109
Power loss	MW	4.161451	4.514865

Sources: JICA Study Team

Considering the above, the comparison case between Bluejay and Low loss conductor are shown in Table 7-9.

Table 7-9 Comparison Case between Bluejay and Low Loss Conductor

		Low loss conductor					
		Line length 300km			Line length 500km		
		2 bundled	3 bundled	4 bundled	2 bundled	3 bundled	4 bundled
Bluejay	2 bundled	○	○	---	---	---	---
	4 bundled	---	---	○	---	---	○
Comparison case		Comparison case ①			Comparison case ②		

Sources: JICA Study Team

7.4 COMPARISON OF LIFE CYCLE COST

(1) Calculation of power loss

In the base of the trend of power capacity, the power loss and it's conversion cost of conventional conductor and low loss conductor are calculated by equation (17) ~ (18), then the 50 years of life cycle cost are compared each other.

$$\text{Power loss } \mathrm{Qy}\left[{}^{\mathrm{kWH}}\!/_{km}\right] = \mathrm{P} \times (0.3\mathrm{f} + 0.7\mathrm{f}^2) \times 8760 \quad \text{..................... (17)}$$

$$\text{Power loss cost} \quad = \textstyle\sum_y^n \left[{}^{C_1 \cdot Q_y}\!/_{(1+i)^y}\right] \quad \text{............................... (18)}$$

Here,	P	:	Power capacity	(MW)
	C1	:	Unit cost of thermal power	(Yen/kWh)
	f	:	Load factor	(%)
	i	:	Interest	(%)
	y	:	Trend years	(year)

The recommended equation by Buller-Woodrow (Reference-1) is to be used for the calculating equation of power loss. The power loss cost is calculated by the equation conversing from trend cost to present cost.

Reference-1 : F. H. Buller and C. A. Woodrow, "Load factor equivalent hours values compared -----", Electrical World, Jul. 1928"

(2) Study of unit cost and material cost of conductors

For each conductors mentioned before, the unit price which is conversed with the rate of aluminum cross section area are shown in Table 7-10.

Table 7-10 Unit Cost of Each Conductors (including shipping to Tanzania)

Kind of conductor	FOB unit price (Yen/km)		CIF unit price (Yen/km)		Remarks
	JPY	Foreign	JPY	Foreign	
Bluejay	810	490	910	550	Unit price of Aluminum 1,750$/Mt Applied rate of Aluminum cross section
LL-610	770	770	870	870	
LL-510	700	700	800	800	
Zebra	620	370	720	430	
Garnet	490	295	580	350	
Hawk	350	210	440	265	

Sources: JICA Study Team

Because of the unit price of conductor is influenced by the unit price of aluminum, its trend of unit price of late years are investigated in the IMF home page. The trend of unit price for aluminum is shown in Reference 4.

It is confirmed that the aluminum unit price has been kept 1,750$/Mt without a big change after 3/4 quarter 2016.

The material cost of the target for comparison of each conductor and number of bundled conductors are calculated as shown in Table 7-11 for line length 300km and 500km each other.

Table 7-11 Material Cost of Each Conductors

(Unit: Million Yen)

Kind of conductor	Number of bundled conductor	Comparison case ① (300km)	Comparison case ② (500km)	Remarks
Bluejay	2	1,852	----	
	4	3,704	6,174	
LL-610	2	2,911	----	
	3	4,366	----	
	4	5,821	9,702	

Sources: JICA Study Team

Additionally, the material cost is calculated by using the conductor length obtained a 1.05 times of line length

About the various parameters for material cost calculation, the value as mentioned below are adopted while referring the example as shown in Table 7-12 mentioned in the Final Full Feasibility Report - R05 (Volume I - Report) "Kenya-Tanzania Power Interconnection Project FS, DD and Preparation of Tender Documents", June, 2012 reported by RSW International Inc.

Electric power rate	:	10 Yen/kWh
Load factor	:	75%
Interest	:	1%
Trend years	:	50 years

Table 7-12 Each Kind of Parameter for Calculating the Power Loss Cost

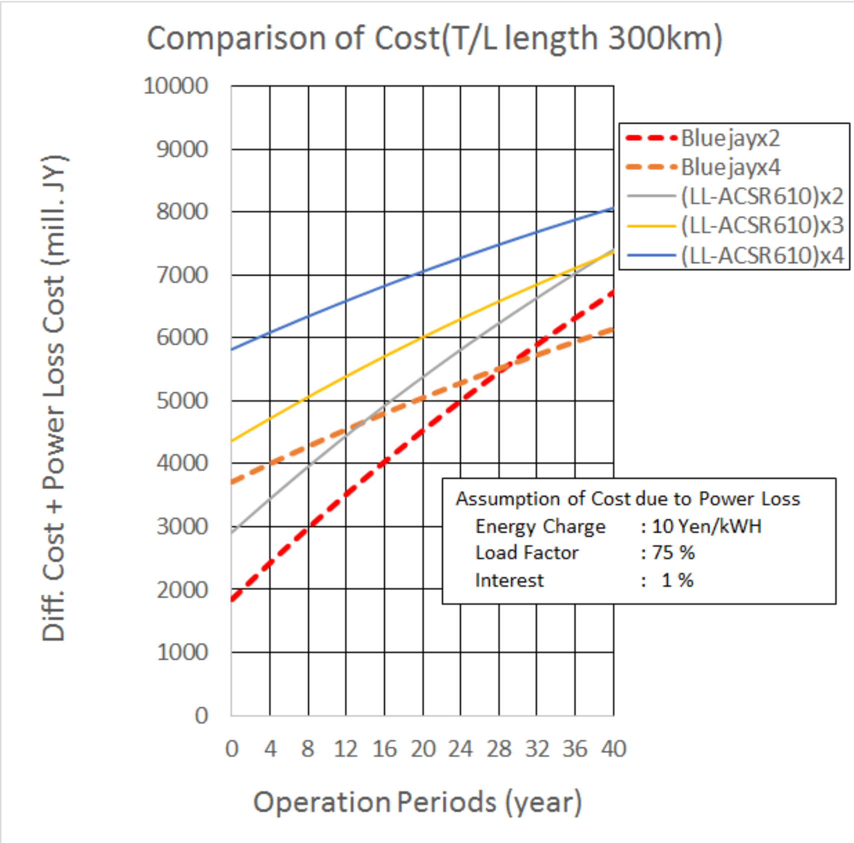
7.2.2 Value of Losses

The power transfer of the interconnection was considered during optimizing studies to evaluated losses for each line configuration. The cost of losses was evaluated based on assumptions given below:

Projected life of line :	23 years
Initial operating voltage :	400 kV
Final operating voltage :	400 kV
Power factor :	0.95
Load factor :	0.75
Discount rated :	10 %
Inflation rate :	0 %
Present cost of energy (US$/kWh) :	0.094
Fixed charge rate on generating capacity :	10 %
Cost of installed generating capacity (US$/kW) :	218
Fixed charge rate of conductor :	10%

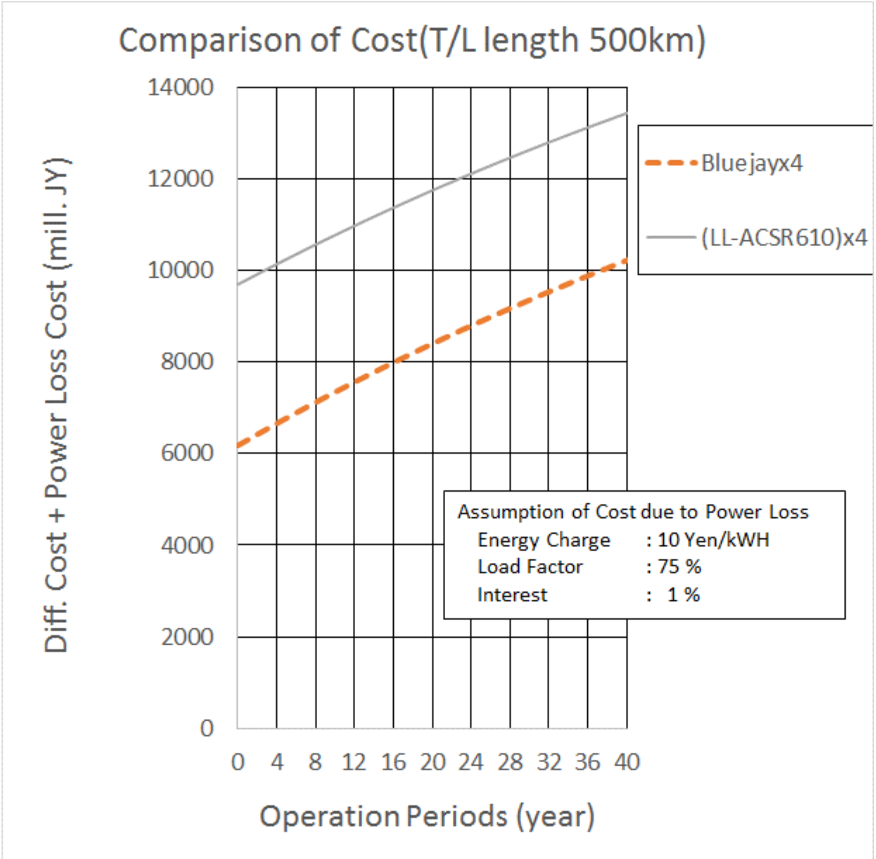
Source: Final Full Feasibility Report (Volume I) on Kenya-Tanzania Power Interconnection Project (2012) by RSW

Considering the material cost for each conductor as shown in Table 7-11 to the initial cost, year trend of power loss cost is calculated as shown in Fig. 7-8 and Fig. 7-9.



Sources: JICA Study Team

Fig. 7-8 Comparison of Cost between Bluejay Conductor and LL-ACSR610 (low loss) Conductor (300km)



Sources: JICA Study Team

Fig. 7-9 Comparison of Cost between Bluejay Conductor and LL-ACSR610 (low loss) Conductor (500km)

7.5 SELECTION OF OPTIMIZED LOW LOSS CONDUCTOR

(1) According to the comparison of cost as shown in Fig. 7-8 and Fig. 7-9, it is cleared that the no low loss conductor which can be recovered the cost up of the conductors for minimum duration of years is existing.

(2) It is the reason that the 400kV transmission line has an advantage of low loss because of the low current and high voltage when the same power capacity is transported.

(3) Additional reason is the large initial cost difference. For this reason, it will be necessary the long term of years for recovering by the power loss cost.

7.6 CONDITION OF PREQUALIFICATION

(1) Fabrication

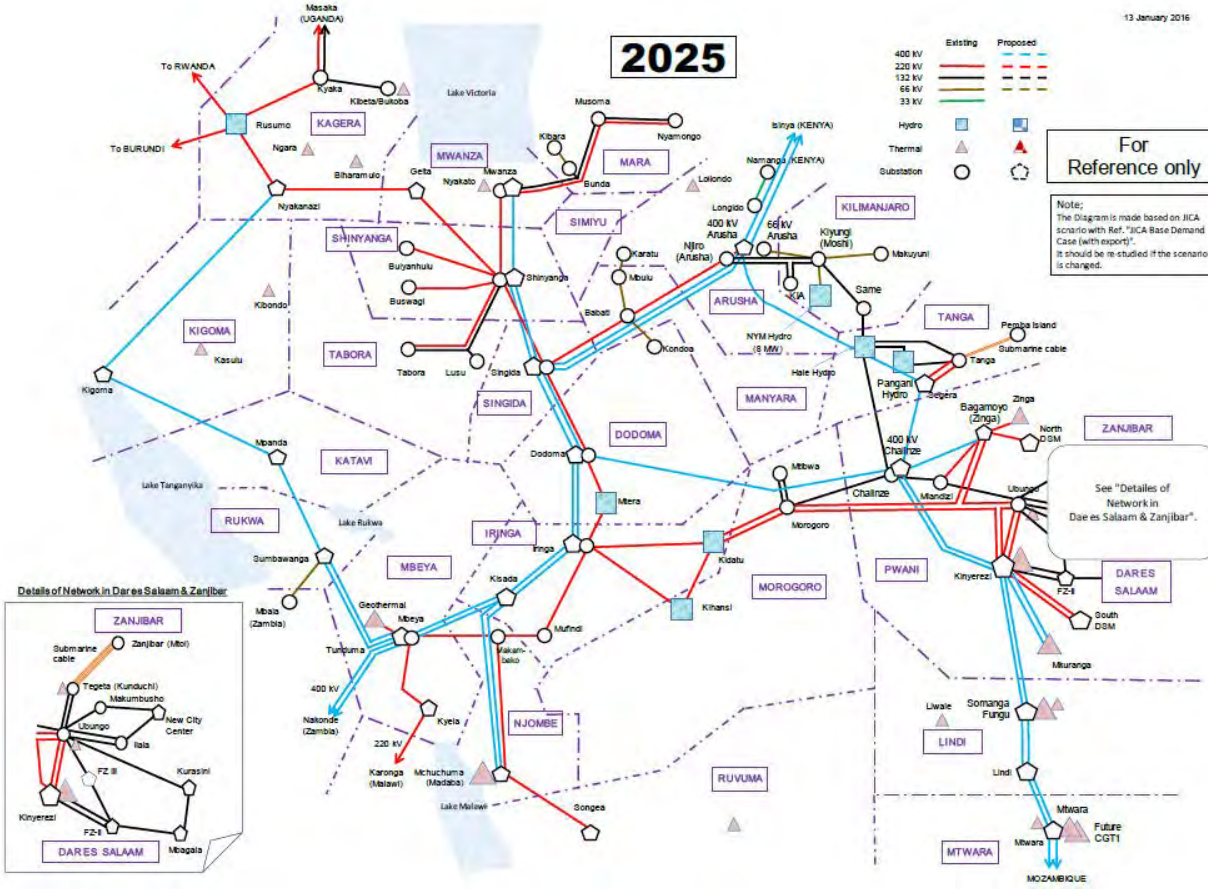
a. Capacity	:	1,000 ton/month over
b. Incoming Order	:	100 km/month over

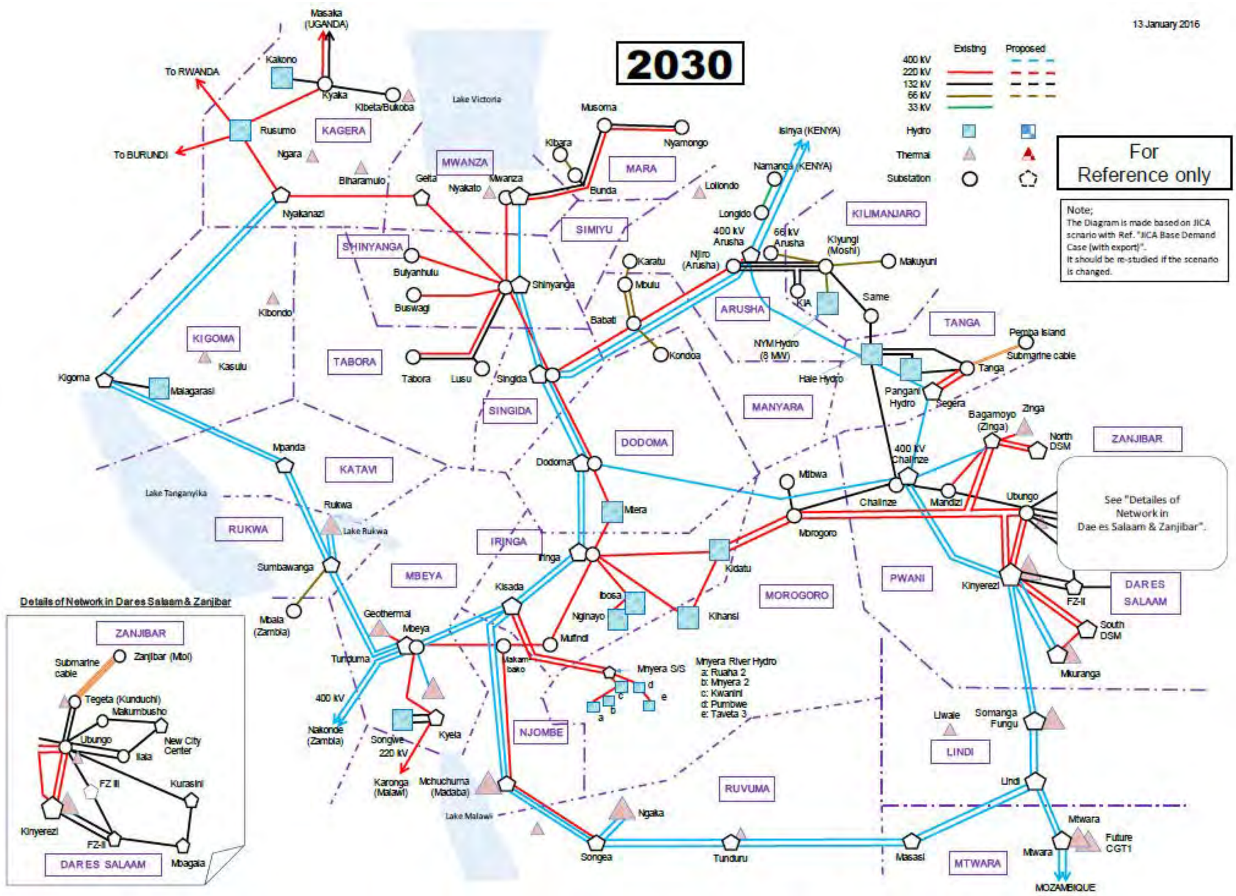
(2) Technical Capabilities

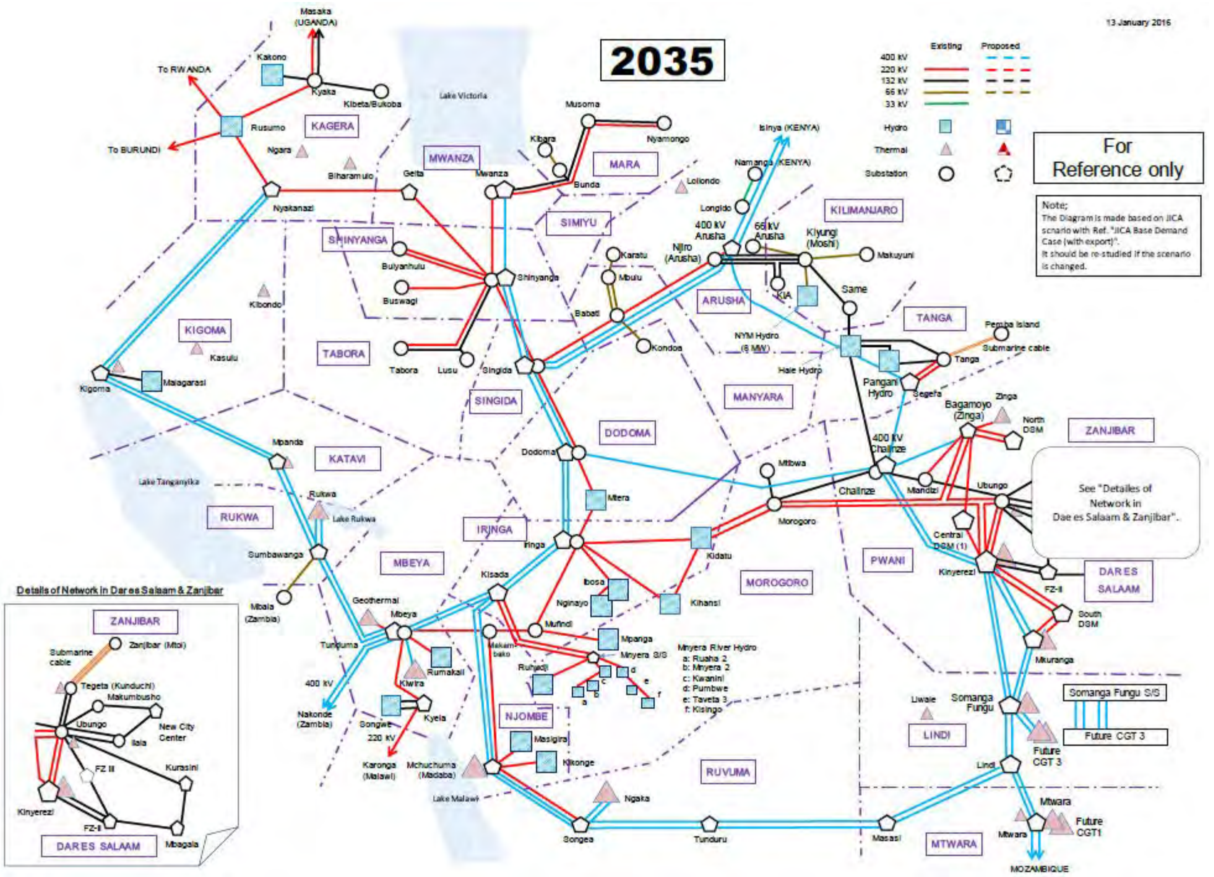
a. Delivery Record	:	2,000 km over, with user certificate
b. Fabrication Experience	:	30 years and more
c. Strength of steel core	:	1,960 MPa, Galvanized steel wire
	:	1,770 MPa, Aluminum clad steel wire

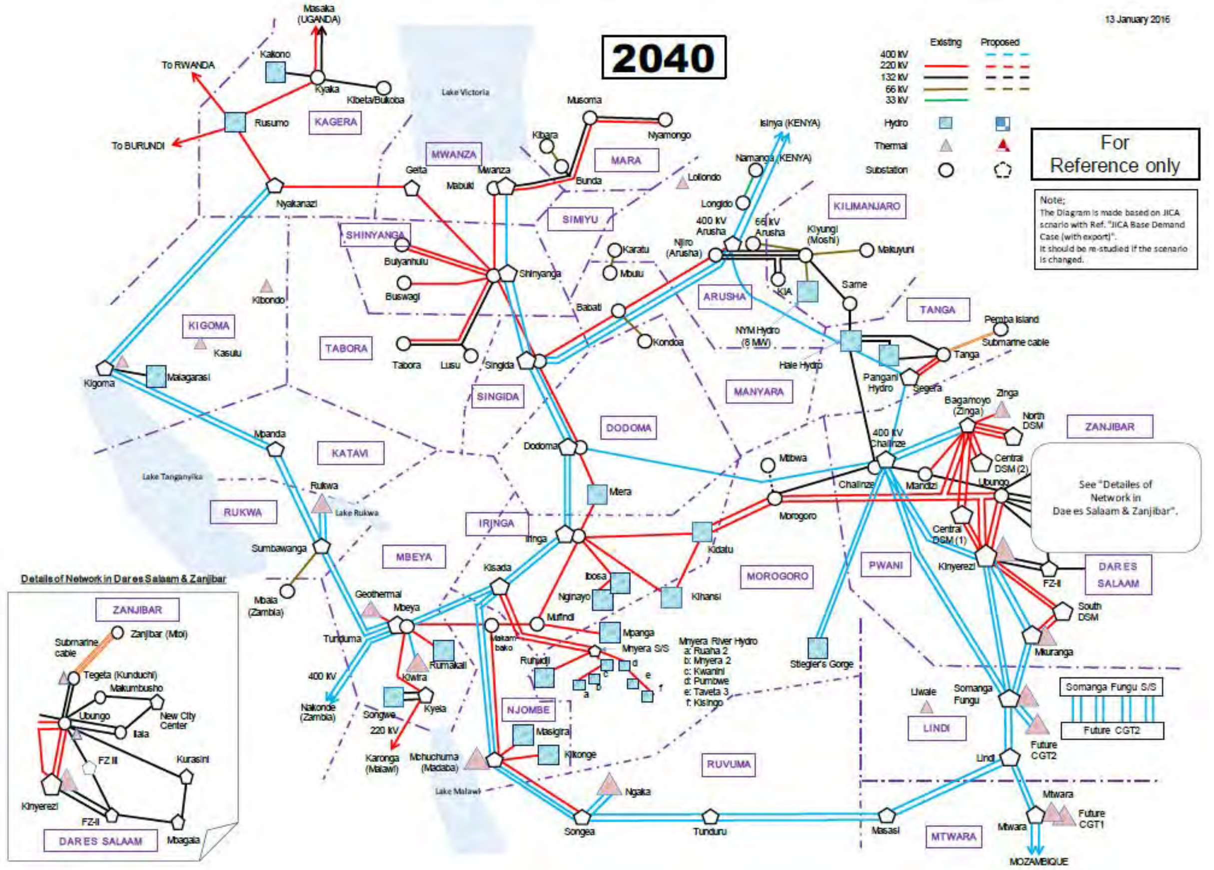
Reference 1

5 year trend of system diagram




2030
13 January 2016
For Reference only
Note;
The Diagram is made based on JICA scnario with Ref. "JICA Base Demand Case (with export)".
It should be re-studied if the scenario is changed.
Existing
Proposed
400 kV
220 kV
132 kV
66 kV
33 kV
Hydro
Thermal
Substation
Details of Network in Dar es Salaam & Zanjibar
See "Detailes of Network in Dae es Salaam & Zanjibar".


2035
13 January 2016
For Reference only
Details of Network in Dar es Salaam & Zanjibar


2040
13 January 2016
For Reference only
Details of Network in Dar es Salaam & Zanjibar

Reference 2

The scenario about 400kV transmission system installing

TANESCO is planning the addition of a new 400 kV switchgear at its existing Singida 220/33 kV substation. The existing substation is located in the town of Singida at an altitude of 1511 m.

- Arusha to Singida as well as backbone plan by TANESCO shall be operated at 220 kV from commissioning;
- Operating voltage of Singida to Arusha and Singida to Shinyanga shall be switched to 400 kV in 2020;
- Remaining of backbone (Singida to Iringa), shall be switched to 400 kV in 2025.

The Kenyan and Tanzanian systems were seen to perform satisfactorily under normal conditions. No branch overloads were detected and voltages remained within the prescribed limits. The un-switchable line reactors are as follows:

- 18.15 MVAr at each end of 400 kV Singida-Babati-Arusha transmission line when operated at 220 kV;
- 18.15 MVAr at Singida line end of 400 kV Singida-Shinyanga transmission line when operated at 220 kV;
- 22.69 MVAr at Dodoma line end of 400 kV Singida-Dodoma transmission line when operated at 220 kV;
- 40 MVAr at each end of 400 kV Arusha-Isinya transmission line.

There is also additional need for switched bus shunt reactors at the following substations:

- 75 MVAr at 220 kV Singida substation including existing shunt reactors;
- 75 MVAr at 220 kV Shinyanga substation;
- 75 MVAr at 220 kV Dodoma substation.

- The Singida–Isinya 220kV/400kV system for year 2015

  For year 2015, 400 kV double circuit transmission line from Singida to Arusha is operated at 220 kV and 400 kV transmission line from Arusha to Isinya is operated at its design voltage. The existing Singida-Babati-Arusha 220 kV transmission line is connected in parallel with the new 400 kV Singida-Arusha transmission line. A 400/220/33 kV autotransformer with 500 MVA capacity is modelled at Arusha substation. This in fact consists of two 250 MVA autotransformers operated in parallel. Refers to Figure EMTP- 1 below for details;

- The Singida–Isinya 400kV system for year 2020

  For year 2020, the 400 kV double circuit transmission line from Singida to Arusha is operated at 400 kV and a 400/220/33 kV autotransformer with 200 MVA capacity is added to the model at Singida substation. This in fact consists of two 100 MVA autotransformers operated in parallel. Refers to Figure EMTP-2 below for details;

- The Singida–Isinya 400kV system 2035

  For year 2035, a new 400/220/33 kV autotransformer with 200 MVA capacity is added to the model at Babati substation. This in fact consists of two 100 MVA autotransformers operated in parallel. Refers to Figure EMTP-3 below for details;

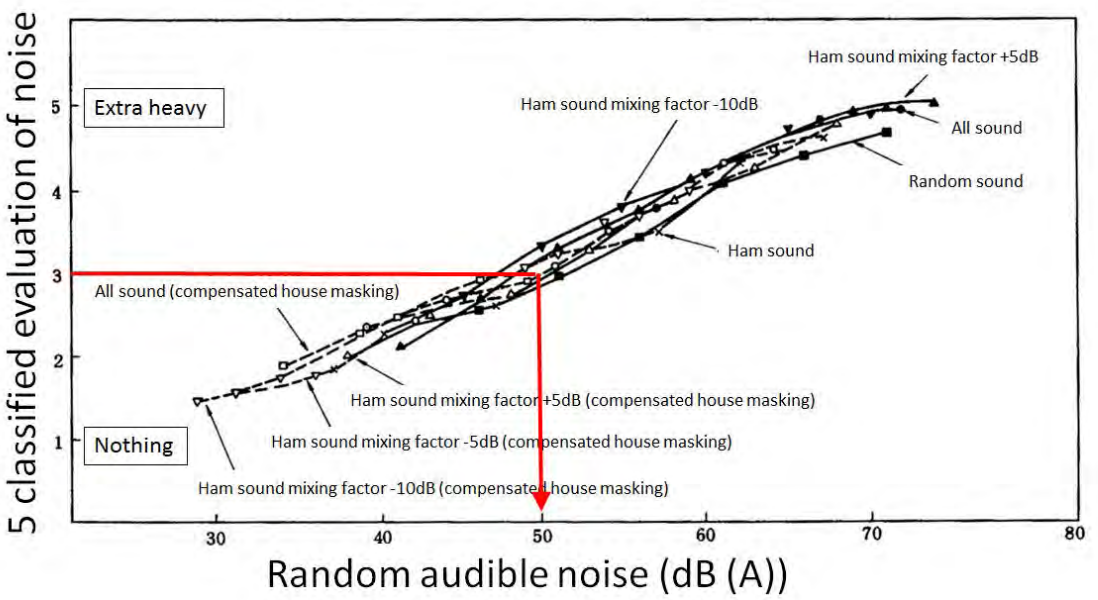
  The system that was modeled for year 2035 includes the addition of a 400/220 kV substation at Babati. It is not clear at the present time, when this substation will be required but its effect on the SPAR performance and on the shunt and neutral reactors sizing must be analysed.

(Reference) Final Full Feasibility Report -R05 (Volume I - Report) ”Kenya-Tanzania Power Interconnection Project FS, DD and Preparation of Tender Documents” , June 2012, reported by RSW International Inc.

Reference 3

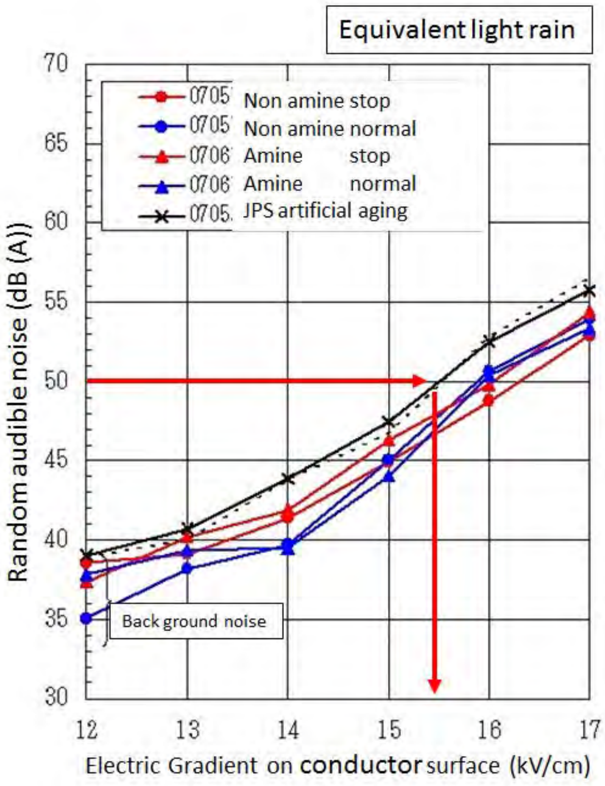
Limitation of electric gradient on conductor surface accordance with corona audible noise

In the case of crossing over the 50dB (A) of corona audible noise, the problem will be occurred as shown in Fig. 1. When electric gradient on conductor surface cross over 15.5kV/cm, more over 50dB (A) of corona noise will be generated as shown in Fig. 2.



Sources: Technical Sheet of conductor manufacturer

Fig. 1 Noise level according to corona noise level

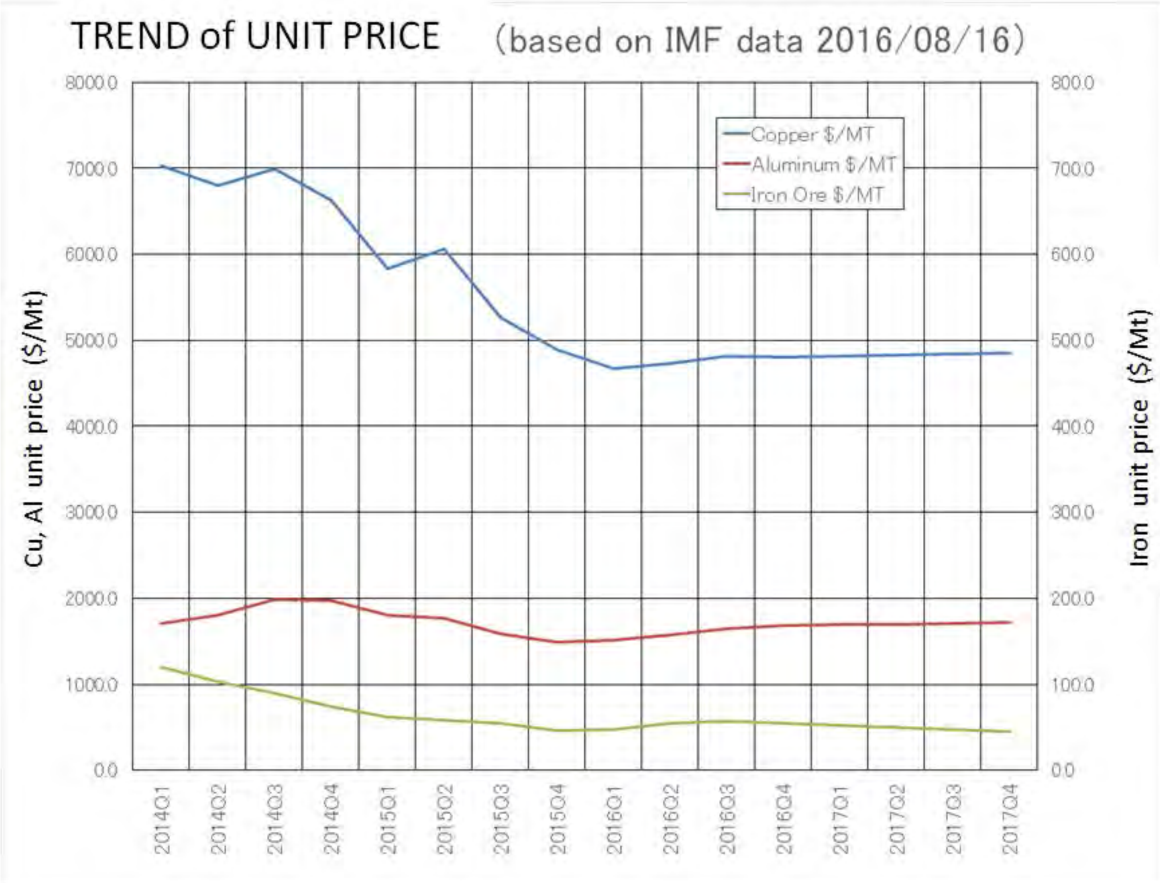


Sources: Technical Sheet of conductor manufacturer

Fig. 2 Relation between electric gradient on conductor surface and random audible noise level

Reference 4

Trend of late years unit price for material of metal



Chapter 8 Official Support for Development of the Gas-fired Power Plant and Possibility to adopt the Japanese Yen Credit

8.1 EXPANSION OF THE POWER PLANTS

TANESCO has only diesel engines, gas turbines of simple cycle as thermal power plants up to now in Tanzania that are small as ten thousands of kW/single machine capacity. GoT plans to construct power plants on large-scale in order to build up the power industries with high investment efficiency from now on. TANESCO is now in financially difficult time, and the budget for the construction of power plants cannot be secured without ODA by developed countries.

The demand of electricity in Tanzania is growing at a very fast rate and hence the need to develop power generation and transmission infrastructures to meet the fast growing demand. It is necessary to mobilize fully public funds and/or private funds to develop the power infrastructure. Therefore, GoT is going to utilize the outside funds to construct the power plants such as financial aid from the developed countries and/or private funds. However, the private companies will avoid high risk projects which require large funds.

Therefore, for the power project that requires huge amounts of budget and is difficult for private sector to enter, Japanese yen credit should be adopted to develop it. In particular, it is necessary to shift power plants from the simple cycle to the combined cycle aiming large capacity power plants, and moreover it is preferable to include the construction of transmission lines. The project can be a highly effective power plant by which basis of power infrastructure is formed in Tanzania.

8.2 EXPERIENCE OF O&M

Japanese power industry starts from so-called conventional power generation technology using the boiler and the ST, and proceeds to combined cycle power generation technology from about 20 years ago. Therefore, boiler water treatment technology, which is essential technology for the conventional power generation, can be utilized for combined cycle power plant operation.

On the other hand, Tanzania has only simple cycle of the gas engines and gas turbines, and they have no operation of ST and no experience of water treatment. When the first combined cycle power plant is introduced such as Kinyerezi II GTCC, it is easily envisaged that TANESCO needs the outside support in terms of operation of ST and the water treatment because the trainings by the contractor during the commissioning stage and the guarantee period are not enough for TANESCO staff to master the O&M of the GTCC.

According to the interview at the existing power plants, Kinyerezi I has received a suggestion of long-term service agreement (LTSA) from GE. However, the cases that unit 1 of Ubungo II stops long time by damage of a compressor blade and one gas engine in Somanga - Fungu is also left for long time after breaking down, show TANESCO cannot get manufacturer’s enough support in terms of O&M agreement because of budgetary deficit and lack of man power who are skillful in maintenance of power generation facilities. Because of these circumstances, some concerns remain in terms of O&M in Tanzania that is going to own the combined cycle power plant without the ST operation and water treatment experience.

Therefore, it is desirable to support the combined cycle driving skill of TANESCO by Japanese yen credit in order to successfully operate the Kinyerezi II GTCC constructed by All-Japan firms and to expand combined cycle power generation in Tanzania from now on. Specifically speaking, it is recommended that “Technical cooperation project” targeted for Kinyerezi II GTCC commence and the project conduct the OJT and classroom lectures at the site as well as invite engineers of TANESCO to Japan and give them technical lessons.

8.3 NECESSITY OF TRANSMISSION LINE FROM SOMANGA TO MTWARA

The thermal power of 300MW planned to construct in Mtwara shall be transported to Kinyerezi via Somanga Fungu because of the large power demand in Dar es Salaam. Regarding to the above transmission line, the 400kV transmission line constructed until 2020 is reported in PSMP (2016).

Chapter 9 Conclusions and Recommendations

9.1 EXISTING GAS-FIRED POWER PLANT

The existing gas-fired power plants in Tanzania are simple cycle power plant with small gas engine or gas turbine. We compared the operations in these power plants with those in Japanese utility firms and found that they conduct daily patrol inspection and make maintenance plans in accordance with manufacturer's recommendation, but they do not conduct performance management in order to detect facility trouble or efficiency degradation.

The performance management for simple cycle is simpler than combined cycle and we propose to make a system of performance management to maximize the plant's ability in the existing gas-fired power plants. The system of performance management would be applied to future GTCC plants in Tanzania.

In addition, we found that training of plant staff is not enough. There is no consecutive and scheduled program for plant staff to improve their skills. This may be a concern when GTCC plant comes on line as it needs water quality management.

In order to support the development of the gas-fired power plants of Tanzania in the future, it is desirable to carry out the technology transfer of the performance management and O&M by dispatching engineers with experience of the combined cycle by using the mechanism of ODA.

9.2 NEW GAS-FIRED POWER PLAN

JICA Study Team found the best feasible site for the construction of 300MW class GTCC power plant after the site reconnaissance in Mtwara region. The feasible site is located at a tip of small peninsula and is surrounded by deep sea. The site can use seawater for its ST condenser cooling that gives the highest plant efficiency among ST cooling systems. The water intake channel for seawater is available as a jetty for heavy equipment unloading. Therefore, it is unnecessary of land transportation of heavy equipment, widening and pavement of access roads, and on top of that, it can solve the issue of resettlement of residents along the access road. Recently, it is a common transport that cargo ships have crane equipment that can load and unload the heavy equipment. Therefore, any unloading facilities for the jetty are not required.

The best feasible site is a flat land above sea level 4 ~ 5m, therefore, during the construction of power plants, civil works at the site on large scale seems to be unnecessary. Moreover, east coast of Tanzania faces water shortage, however Mtwara has a big water project in which water comes from the Ruvuma River, and the best feasible site seems to be able to get enough water. As for gas, the gas pipeline has already existed and enough gas will be provided to the new site. In conclusion, the construction of the new gas-fired power plant (300MW class GTCC) is judged to be feasible.

In Mtwara and Lindi region, local business is booming and there is a plan of economic corridor with neighbor countries. We can expect Mtwara and Lindi region to consume 300MW power in the future. But, in Mtwara, TANESCO has a plan to acquire vast area of land for the future gas-fired power complex with Symbion (PPP). It is important for the new project to provide power to local area ahead of the PPP project.

This project is pre-FS and it is required to proceed to FS stage soon. Main investigation items in FS stage are as follows:

1) Power demand forecast for the new gas-fired power plant
2) Weather observation at site
3) Geological Survey, Terrain Survey including boring
4) Simulation analysis of thermal diffusion based on sea depth, sea current speed & direction and temperature
5) Expansion plan of the site (if TANESCO requests)
6) Fuel supply plan
7) Water supply plan
8) Detailed specifications of power plant
9) Construction Schedule
10) Construction Cost Estimation
11) Economic/ Financial analysis
12) Environmental Impact Assessment

9.3 TRANSMISSION LINE PLAN

For transporting from the southern power of 300MW generated by the new GTCC power plant in Mtwara to the northern demand area of Kinyerezi via Somanga Fungu, it is suggested that the 300km length, 400kV transmission line consists of Bluejay double/ quadra bundled conductors be the most suitable .

It is studied whether the Low Loss conductor can be adoptable to the above transmission line instead of Bluejay conductor. As the results, there are no available low loss conductors because of the reason mentioned below.

a. The phase current on 400kV power system is small value amperes, so even a normal conductor’s power loss becomes small.

b. The low loss conductor’s unit cost is more than twice of normal conductor’s one, so the cost merit given by the different of power loss cost will not be obtained.

APPENDIX I

1st Site Investigation Report
(25 ~ 29 July 2016)

Data Collection Survey
on
Gas Thermal Power Generation
in
United Republic of Tanzania

1st Site Investigation Report
(25 ~ 29 July 2016)

8 August 2016

Japan International Cooperation Agency

NEWJEC Inc.
The Kansai Electric Power Co., Inc.

1. Preface

JICA is conducting two (2) Master Plans, i.e. Power System Master Plan and Natural Gas Master Plan in Tanzania. Reflecting these Master Plans, JICA decided to set up this project. The project is fast track program (start in mid-July, finish in mid-October).

JICA Study Team is scheduled to visit Tanzania twice. This report explains the 1st site investigation results (25 ~ 29 July).

Members and schedule are shown in Table 1 and Table 2, respectively.

Table 1 Members of JICA Study Team

Name	Position	Company
Hiroshi Tadokoro	Senior Adviser	JICA
Tsunaki Ito	Officer	JICA
Rosina Apolei	Assistant Program Officer	JICA Tanzania office
Tetsuo Sada	Leader/Mechanical Engineer	NEWJEC
Junji Hirano	Mechanical Engineer	NEWJEC
Hidenobu Okuda	Ditto	Kansai Electric Power
Ryosuke Ishii	Electrical Engineer	NEWJEC

Table 2 Schedule

Date	Day	Activity
25 July	Mon	10:00-11:00 Meeting with JICA 14:00-16:00 Meeting with TANESCO for Interview
26 July	Tue	09:00-11:30 Site Visit on Ubungo I & II Power Plant 12:00-14:00 Site Visit on Kinyerezi I Power Plant 14:10-14:45 Site Visit on Kinyerezi II Power Plant (Under construction)
27 July	Wed	11:00-12:00 Meeting with MEM 13:00-14:00 Meeting with TANESCO
28 July	Thu	10:00-11:00 Meeting with TPDC
29 July	Fri	10:00-12:00 Wrap-up meeting with TANESCO 15:00-16:30 Meeting and Reporting to JICA Tanzania

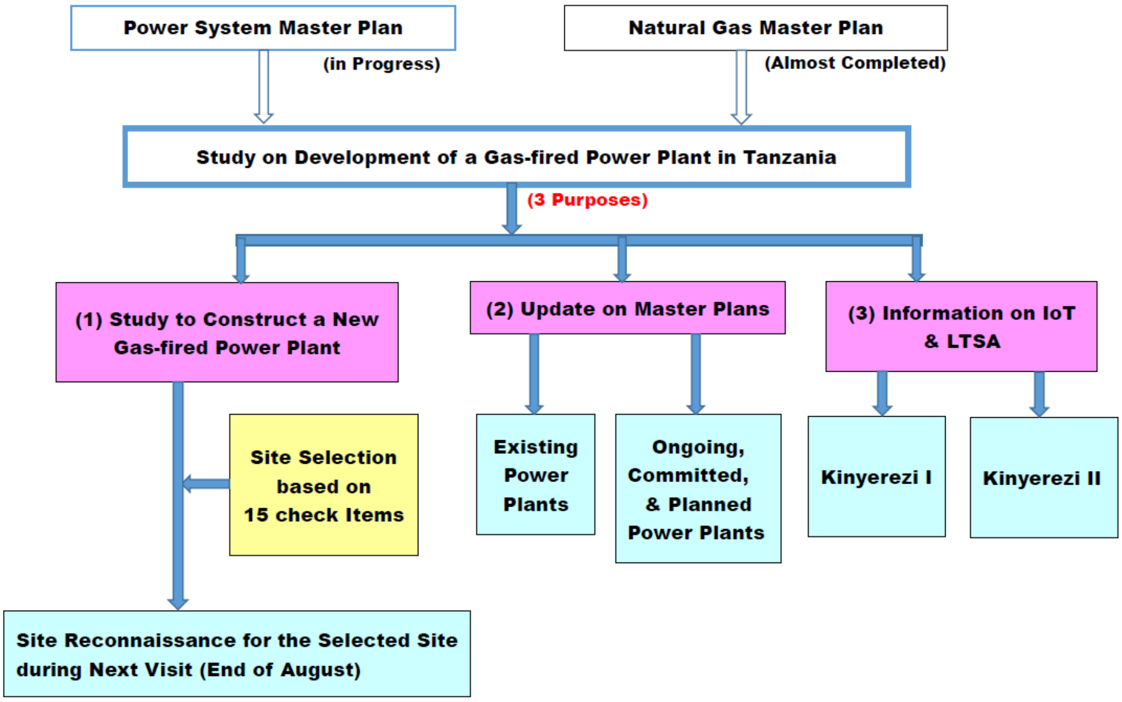
*Ubungo I is Gas Engine Power Plant

2. Purpose of the Project

Table 3 explains the project. There are three (3) major purposes:

(1) Study to construct a new gas-fired power plant
(2) Update on Master Plans
(3) Information on IoT & LTSA

Table 3 Purpose of the Project



3. Study to construct a new gas-fired power plant

TANESCO carried out the site investigation for nine (9) candidate sites between 27th October until 6th November 2014.

By discussing with TANESCO and by using 15 check items, JICA Study Team try to narrow nine (9) candidate sites down to 3,4 sites that allow JICA Study Team to inspect the sites in one (1) week.

Table 4 shows discussion results. As the result, four (4) sites (Mtwara Site 1 & 2 and Lindi Site 1 and 2) are selected to conduct site reconnaissance during next visiting period (tentatively 29 August ~ 3 September 2016).

Table 4 Screening of Sites (29/July/2016)

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 from 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**	

4. Update on Master Plans

Through the courtesy of TANESCO, we have visited Ubungo II and Kinyerezi I. This is the summary of our site visit.

4-1 Existing Power Plant (Ubungo II)

We have visited Ubungo II. We found out that the plant is well organized and kept things in tidy. The unit 1 of the plant has been suffered by Forced outage from 26/June /2016. SIEMENS inspectors from Sweden conducted bore scope inspection on 25-28/July/2016 and the root cause of the Forced outage is unclear now. The repair of unit 1 will be done within this year. Table 5 shows the investigation results of Ubungo II.

4-2 Ongoing, Committed & Planned Power Plants (Kinyerezi I & II)

(1) Kinyerezi I

We have visited Kinyerezi I. We found out that the plant is well organized and kept things in tidy. The feature of the plant is that they use chiller for Unit 1 and 2 for inlet cooling. The inlet cooling is good technology to bring up output. They have a plan to install the chiller for Unit 3 and 4 in the future at the same time with Kinyerezi I Expansion. Table 5 also shows the investigation on results of Kinyerezi I.

Table 5 Findings of Site Visit

	Ubungo II	Kinyerezi I
Commercial Operation Year	Apr 2012 (First COD) June 2012 (Full COD)	Oct 2015 (First COD) Mar 2016 (Full COD)
Output	SGT-800 × 3 (43MW × 2, 35MW × 1)	LM6000PF × 4 (44MW × 2, 35MW × 2)
Gas Source	✓ Mnazi Bay (Songo Songo Gas Field in the past)	✓ Mnazi Bay
Site Visit Date	26/July/2016	26/July/2016
Operation	✓ Unit 2 & 3 are in full-load operation. ✓ The control room is kept in order and easy for monitoring.	✓ Jet Fuel is stored (3750 m^3 × 2 tanks) at site in case fuel gas is not available. ✓ Chiller for inlet cooling is equipped. ✓ Gas Turbine Filter's different pressure often increase. It may be sand from nearby construction site.
Maintenance	✓ Daily maintenance is done by Ubungo II. ✓ The unit 1 of the plant has been suffered by Forced outage from June/2016 and bore scope inspection was conducted on 25-28/ July/2016. It is long time comparing our experience. ✓ The each of pipes for water, gas etc. are distinguished by color to avoid human error.	✓ In gas turbine room, there are hoist crane for easy maintenance. ✓ Workshop is kept in order and easy for maintenance.

	Ubungo II	Kinyerezi I
Capacity Investment	✓ Unit 2 & 3 were upgraded into 43MW. Unit 1 will be upgraded in Nov/2016. ✓ Under study for change into GTCC.	✓ Chiller for Unit 3 & 4 in the future.
Site Management	✓ Things are well organized and put in order. ✓ Culture of Safety first is penetrated. The plant has fire-fighting equipment including fire water tank, fire hydrant system.	✓ Things are well organized and put in order. ✓ Culture of Safety first is penetrated. The plant has fire-fighting equipment including fire water tank, fire hydrant system.

*Kinyerezi III & IV seem not to proceed well

(2) Kinyerezi II

We have visited Kinyerezi II construction site. The plant is GTCC power plant with 6 H-25 Gas Turbines and 2 Steam Turbines. The construction started in March/2016 and constructed about 100 piles. The site has 300m×260m area and moreover they have acquired laydown area.

5. Information on IoT & LTSA

We have discussed with TANESCO regarding Remote Monitoring for Kinyerezi I. Remote Monitoring is one of the GE's Industrial Internet tools.

According to TANESCO, Kinyerezi I has no Remote Monitoring Service by GE. They monitor the plant by themselves at Control Room and they will receive advice from GE when some trouble happens.

However, TANESCO and GE are under discussion on O&M for future. TANESCO got proposal from GE and it includes dispatch of two GE engineer to the site.

6. Photos

Ubungo II Power Plant

 Site View	 Evacuation Plan
 GT (#1)	 GT (#3)
 GT (#1: Inspection)	 Meeting

Kinyerezi I Power Plant

Site View

GT (#4)

Work Shop

Control room

Raw & Fire Water Tank (+Fire engine)

Chiller pipes

Kinyerezi II Power Plant
(Under construction)

Site View (Piling)

Office (Under construction)

Kinyerezi I & II (Aerial view)

Meeting Snaps

Ubungo II (26/July)

Kinyerezi I (26/July)

MEM (27/July)

TPDC (28/July)

TANESCO (29/July)

TANESCO (29/July)

APPENDIX II

2nd Site Investigation Report
(29 August ~ 9 September 2016)

Data Collection Survey
on
Gas Thermal Power Generation
in
United Republic of Tanzania

2nd Site Investigation Report
(29 August ~ 9 September 2016)

8 September 2016

Japan International Cooperation Agency

NEWJEC Inc.
The Kansai Electric Power Co., Inc.

1. Preface

JICA study team has conducted 1st stage investigation during 25 ~ 29 July 2016, in which candidate sites for a 300 MW class GTCC were narrow 9 sites down to 4 sites by evaluating 15 check items on the existing information.

JICA and TANESCO joint study team has carried out the site reconnaissance for selected 4 candidate sites during 29 August ~ 2 September 2016. As the results, investigated candidate sites increase from 4 sites to 7 sites in the course of site investigation. Taking this opportunity, JICA and TANESCO joint study team has visited not only candidate sites but also pertinent authorities and facilities.

Members and schedule/Investigation items are shown in Table 1 and Table 2 respectively.

Table 1 Members of JICA Study Team

Name	Position	Company
Hiroshi Tadokoro	Senior Adviser	JICA
Abdallah Chikoyo	Planning Mechanical Engineer	TANESCO
Alex Gerald	Planning Electrical Engineer	TANESCO
Tetsuo Sada	Leader/Mechanical Engineer	NEWJEC
Junji Hirano	Mechanical Engineer	NEWJEC
Hidenobu Okuda	Ditto	Kansai Electric Power
Shingo Suzuki	Ditto	Kansai Electric Power

Table 2 Schedule/Investigation items

Date	Day	Investigation items
29 August	Mon	TANESCO Mtwara office Mtwara Local Government TANESCO Mtwara Power Plant (18MW Gas Engine) Mtwara Port Authority
30 August	Tue	Site reconnaissance of Mtwara Site 1 Site reconnaissance of Mtwara Site 2 Site reconnaissance of Mtwara New Site Site reconnaissance of TANESCO Site
31 August	Wed	Mtwara Water Supply Authority TPDC Gas Processing Terminal at Mtwara
1 September	Thu	Site reconnaissance of Lindi Site 1 Site reconnaissance of Lindi Site 2 Site reconnaissance of Lindi New Site Lindi Local Government Lindi Port Authority
2 September	Fri	Lindi Land Authority Lindi Water Supply Authority Detailed site reconnaissance of Mtwara New Site

After scrutinizing the investigation results on 7 candidate sites, JICA and TANESCO joint team can select the best feasible candidate site.

2. Site Investigation Results

The table 3 explains 7 candidate sites and Fig. 1 shows the location of each candidate site and Table 4 and Table 5 show the site investigation results respectively.

Table 3 Explanation of the candidate sites

	Name of Site	Explanation
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
	Mtwara New Site	The site that is found in the course of discussion with Mtwara Local Government
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

Figure 1 Location of the Candidate Site

Table 4 Screening of Sites (29/July/2016)

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 × 100 ton mobile crane, 1 × 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**

Table 5 Site Investigation Result on Candidate Sites of 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**

4. The Best Feasible Site

JICA and TANESCO joint study team selected Mtwara new site as the best feasible site for a 300 MW GTCC Power Plant. The major reasons are as follows;

(1) The site is ideal land height as power station. Any backfill or excavation seems not to be required

(2) The site is located at the edge of small peninsular and surrounded by deep sea. Therefore, sea water cooling (once-through type) system can be adopted (Fig.2 shows the comparison among steam turbine cooling system).

(3) Intake channel of the sea water cooling system can utilized as the unloading jetty, therefore the heavy equipment can be directly unloaded at the site without land transportation (Fig. 2 shows the conceptual idea of the unloading jetty).

(4) Environmental measures for nearby village is required during the construction stage and operation stage of the plant. However, the plant is gas-fired power station that is environmental friendly plant compared with the coal-fired plant. There are no environmental impact related to coal and ash. Only expected impact seems to be noise, but it can be solved to set the noise level at the plant boundary by the appropriate level during the plant design stage.

(5) The power plant will give good job opportunity for residents in nearby village during the construction stage and operation stage of the plant. This is one of positive impact.

Item	Sea water cooling	Cooling tower	Air-cooled condenser
Installation cost	High	Low	High
Efficiency of S/T	High	Medium	Low
Fresh water consumption	Almost 0	High	Almost 0
Space of land	Base	Almost same as sea water cooling	More vast
Land height above NSWL	4～5 m	No limitation	No limitation
Possibility of unloading Jetty	Yes	No	No
Notice 1	Hot water recirculation and heat accumulation have to be avoided	No notice	No notice
Notice 2	Mangrove forest area have to be avoided	No notice	No notice

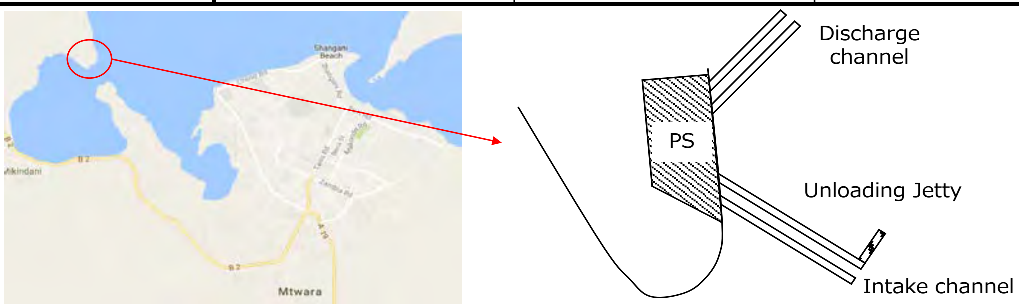


Figure 2 Comparison of S/T Cooling System and Conception of Unloading Jetty

5. Power Plant Area of the Best Feasible Site

Figure 3 shows the power plant area of the best feasible site. The hatched lines marked in red shows the plant area, and the hatched lines marked in green shows the reserved space if the plant area is short though several Baobab trees are required to be cut.

We will later confirm if the plant area is enough for a 300MW GTCC, and the result will be explained in the Draft Final Report.

Figure 3 Power Plant Area of the Best Feasible Site

6. Photos

Mtwara Site 1

Baobab

Sea Shore

Fishing Activities (Small)

Fishing Activities (Small)

Land View

Land View

Mtwara Site 2

 Sea Shore	 Mangrove (Small)
 Cattle Raiser	 Village
 Land View	 Land View

Mtwara TANESCO Site
(Land View)




Mtwara New Site


Deep Sea


Deep Sea


Sea Shore (P1)


Southern Edge Point (P2)


Baobab (P4)


Northern Edge Point (P6)

Lindi Site 1

Mangrove Forest

Sea Shore

Sea Shore

Sea Shore

Land View

Land View

Lindi Site 2

 Land View	 Land View
 Land View (Mangrove delta)	 Land View (Mangrove delta)
 Former / Old DG Plant	 Access Road

Lindi New Site


Land View


Eclipse of the Sun @1st September


Big Mangrove Forest


Big Mangrove Forest

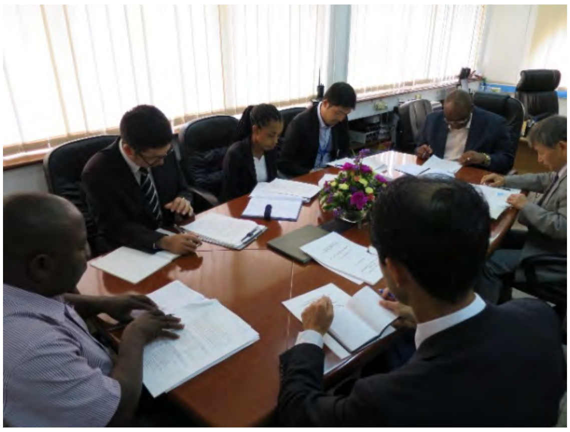

Outcrop of rock


Outcrop of rock

Meetings

<table>
<tr><td>
TANESCO Mtwara (29/August)</td><td>
Mtwara Local Government (29/August)</td></tr>
<tr><td>
Mtwara Port Authority (29/August)</td><td>
Mtwara Urban Water Supply (31/August)</td></tr>
<tr><td>
TPDC NG Terminal (31/August)</td><td>
TANESCO Lindi (1/Sept.)</td></tr>
</table>

Meetings

 Lindi Port Authority (1/Sept.)	 Lindi Land Authority (2/Sept.)
 Lindi Urban Water Supply (2/Sept.)	 TANESCO Planning Dept. (5/Sept.)
 Kinyerezi II Office (5/Sept.)	 TANESCO HQ (7/Sept.)

APPENDIX III

Site Earmarking Report for the Proposed Mkuranga 250MW CCGT Power Plant Project

TANZANIA ELECTRIC SUPPLY COMPANY LIMITED

"We light up your life"

Site Earmarking Report for the Proposed Mkuranga 250MW CCGT Power Plant Project

Abdallah Chikoyo
Dismas Mbote
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27th October – 6th November 2014

Prepared for the
Strategic Planning Department
TANESCO
Dar es Salaam

Table of Contents

1. StudyOverview

Tanzania Electric Supply Company Limited (TANESCO) and the United States Agency International (USAID) have contracted Consultants CDM Smith and Mott MacDonald to carry out three Pre-Feasibility Studies for a proposed 250 MW Combined Cycle Gas Turbine (CCGT) generation facility, 400 kV Transmission Line from Mtwara – SomangaFungu and 220 kV Transmission Line from Kakono to Nyakanazi.

The proposed pre-feasibility study will involve selection of site for generation facility and identification of the possible routes for mentioned transmission lines. This report dwells on the preliminary site selection for generation facility, the Mkuranga 250MW CCGT.

2. Mtwara – Dar es Salaam Gas Pipe line

The Mkuranga 250MW CCGT will be fuelled from Mtwara – Dar es Salaam main natural gas pipe line. The appended map (appendix 1) for gas pipeline show pipe meander and the positions of Block Valve Stations (BVS) which have gas taping-off provisions.

The main gas pipe line has a diameter of 36 inches and capacity of 784 mmscfd, of which the first year will supply 220 mmscfd and thereafter increase gradually to its full capacity within ten years. The pipeline line is expected to be operational from 2015. Tanzania Petroleum Development Corporation (TPDC) has already finalized Gas Sales Agreement (GSA) with TANESCO to supply new gas fired power plants (ie. Kinyerezi I) expected to be commissioned in first half of 2015.

3. Possible Gas Taping Points

TPDC provided coordinates for possible taping points (BVS) and thereafter verified by TANESCO team, the respective coordinates are shown in the table below.

Gas Take-off Point under Construction at BVS 03. Kilwa

Typical taping point at SomangaFungu. This point will supply natural gas to Kilwa Energy power plant and any other, BVS coordinates

BVS NAME	COORDINATE (Easting & Northing)	
	X	Y
BVS 13 (Mkuranga)	524844.581	9204551.15
BVS – Somanga Fungu	529275.89	9066470.43
BVS 03 (Lindi)	561382.97	8881061.913
BVS 01 (Mtwara)	612587.089	8863494.129

4. Earmarked Sites

There are nine(9) earmarked sites for generation facility, the sites were chosen with respect to the BVS position, sea water accessibility and with consideration of the consultant's site selection criteria. The following are coordinates of the earmarked sites.

District	Site Name	Coordinates (Easting & Northing)			Distance (to site - km)	
		Zone	X	Y	From BVS	From Sea
Mkuranga (BVS 13)	Site 1	-37	545072.04	9202457.05	18	4
	Site 2	-37	547567.85	9206259.91	23	4.6
	Site 3	-37	536504.23	9181334.59	25	1.7
Kilwa - Somanga (BVS Somanga)	Site 1	-37	529343.25	9066947.77	0.4	4
	Site 2	-37	530361.75	9066236.19	1.2	2.5
Lindi (BVS 03)	Site 1	-37	585970.59	8907107.29	35	0.6
	Site 2	-37	579510	8901078.7	27	0.37
Mtwara (BVS 01)	Site 1	-37	623142.7	8869147.26	13	0.8
	Site 2	-37	622974.56	8870502.97	20	4

Existing TANESCO 8MW gas fired generators at SomangaFungu Site.

5. Team Opinion on Site Selection and Evaluation

TANESCO understands that the consultant will evaluate the earmarked sites and recommend the best one.

Considering the estimated distances and site accessibility, Somanga Fungu sites seem to be more ideal compared to other visited sites, if at all there are no other outweighing technical factors. The Somanga fungu site is also planned to have a nearby Substation that will be serving Kilwa Energy 320MW CCGT power plant, the substation is now under feasibility study.

6. APPENDICES

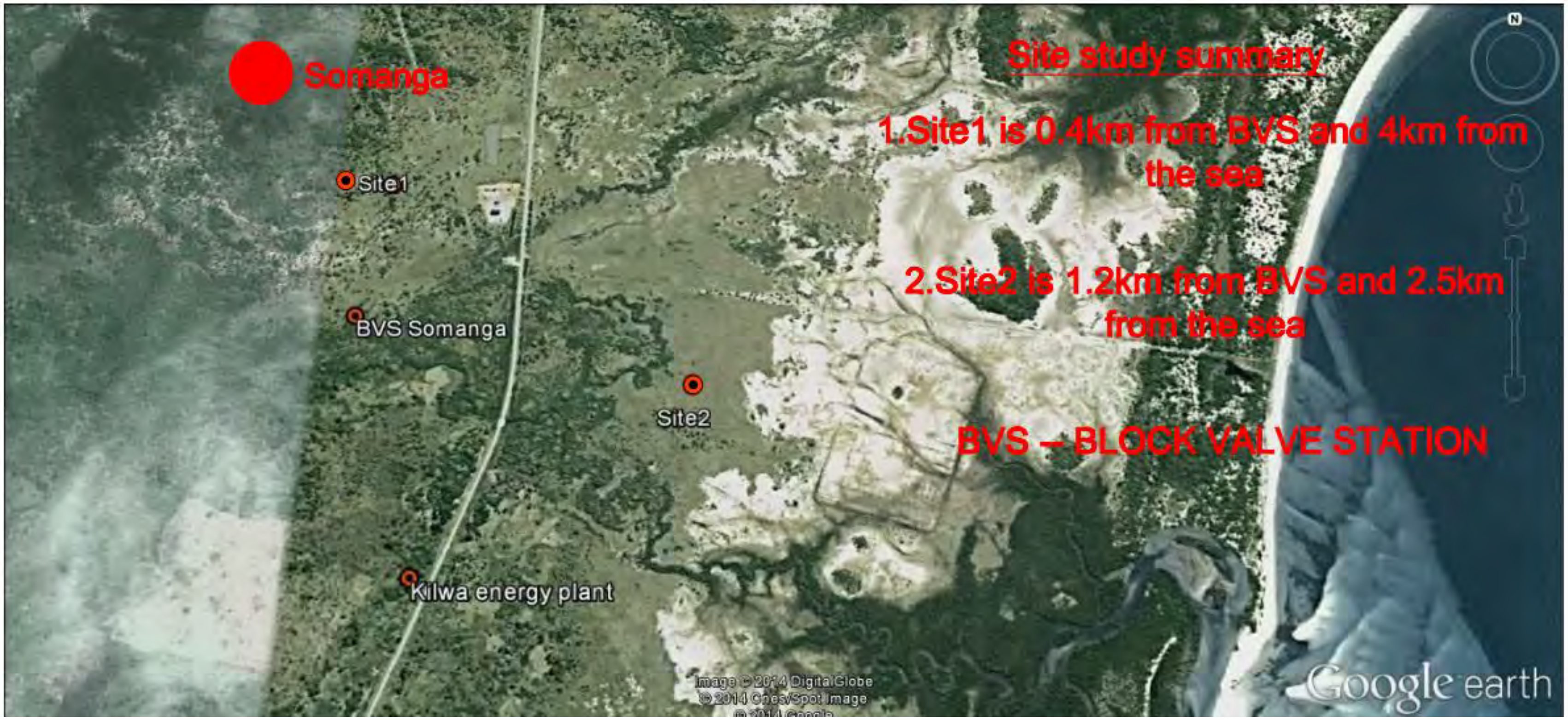
Appendix 1: Gas Pipeline

TPDC GAS PIPELINE ROUTE MAP

Appendix 2 : Mkuranga Sites - 1

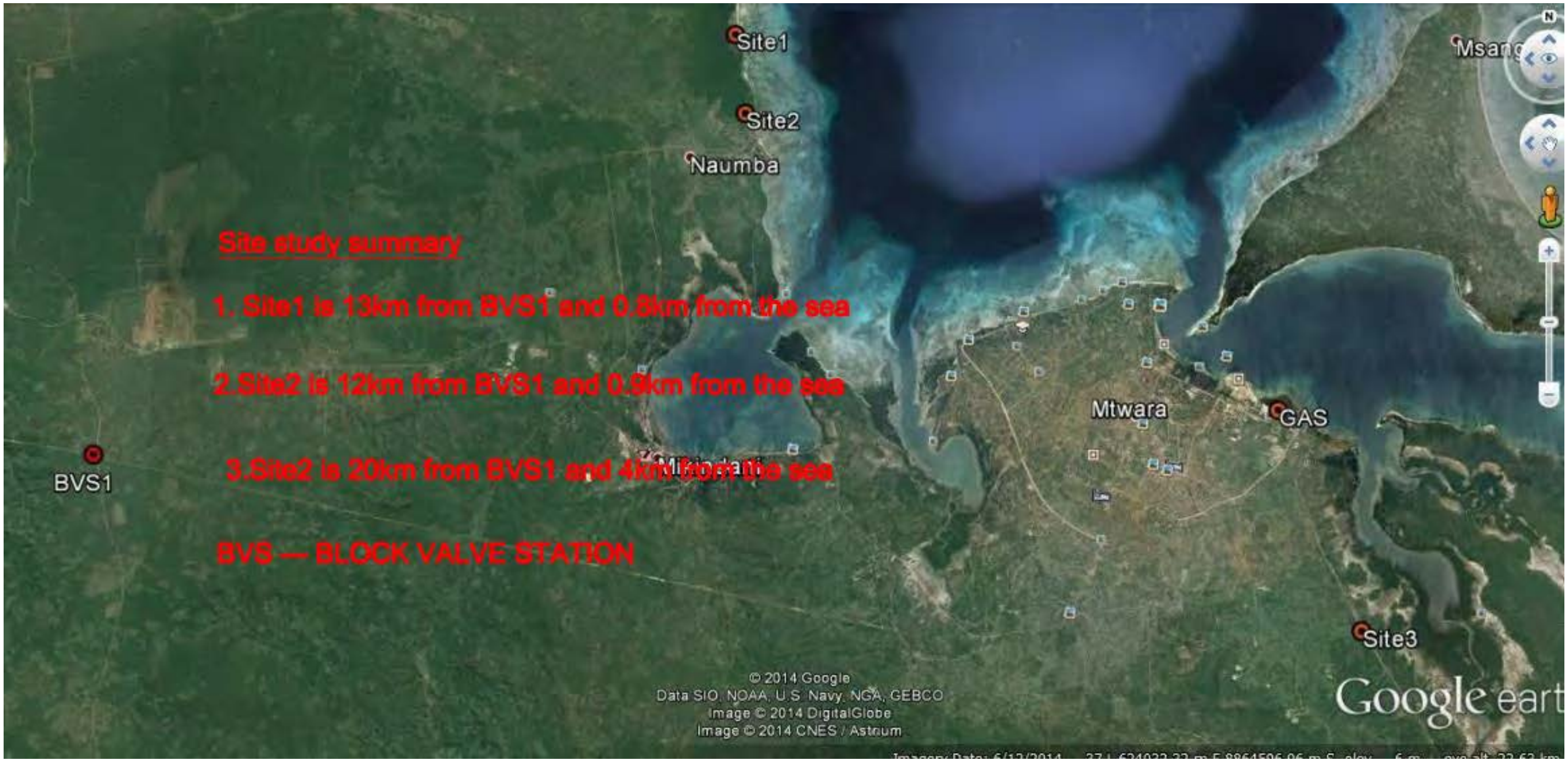
Appendix 3: Mkuranga Sites - 2

Appendix 4: SomangaFungu Site



Appendix 5: Lindi

Appendix 6: Mtwara



JICA