ELECTRIÇIDADE DE MOÇAMBIQUE (EDM)
THE REPUBLIC OF MOZAMBIQUE

PREPARATORY STUDY ON GAS-FIRED POWER PLANT DEVELOPMENT IN SOUTHERN MOZAMBIQUE

FINAL REPORT

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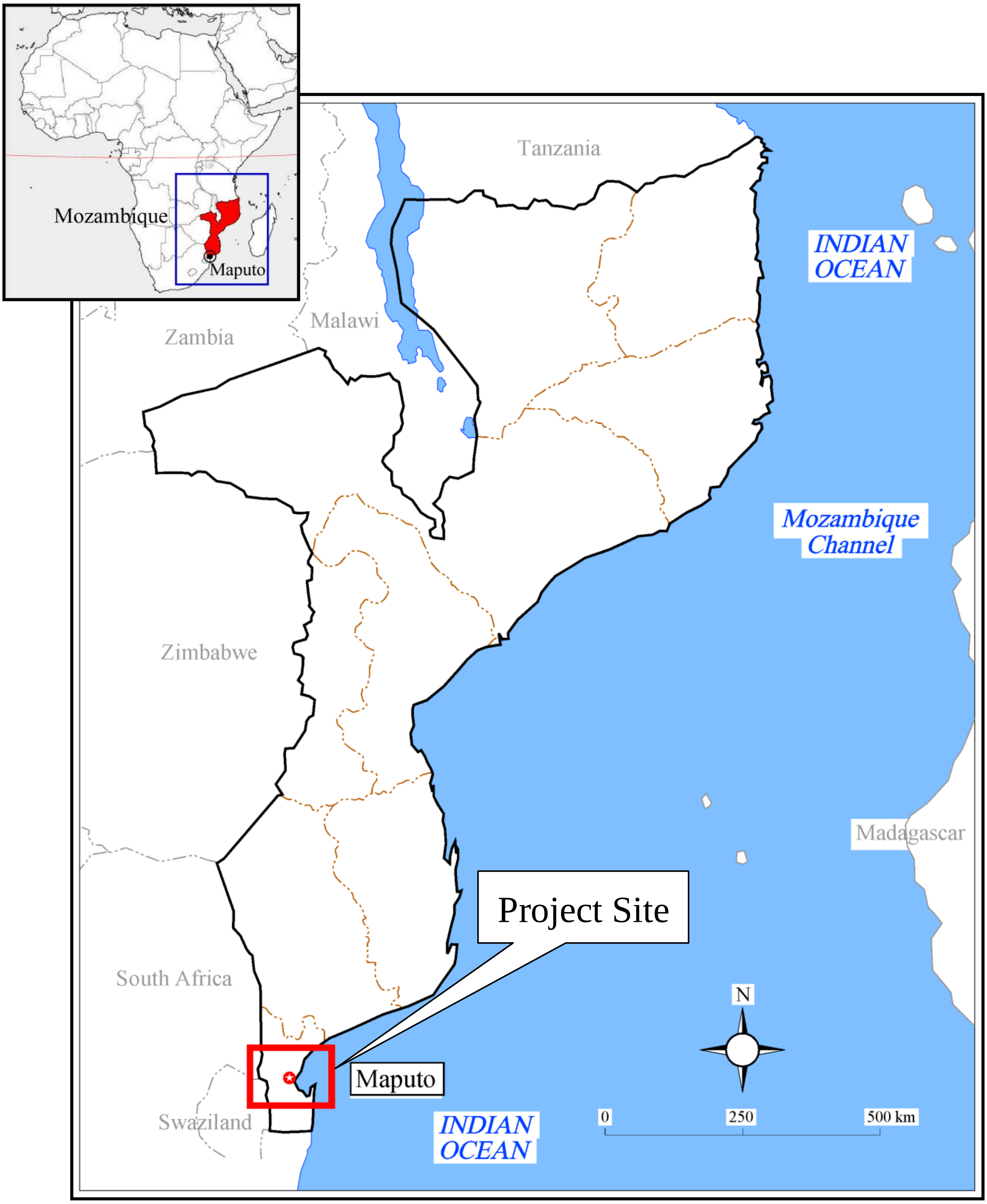

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Abbreviations

Abbreviation	English	Original Language (Portuguese language)
ACC	Air Cooled Condenser	
ADB	Asian Development Bank	
AdeM		Águas de Moçambique
AFD	French Development Agency	L'Agence Française de Développement
AGFUND	Arab Gulf Programme for Development	
ANE	National Roads Administration	Administração Nacional de Estradas
APFR	Automatic power factor regulator	
AQR	Automatic reactive power regulator	
ASME	American Society of Mechanical Engineers	
ASTM	American Society of Testing and Materials	
AVR	Automatic voltage regulator	
BCF	Billion cubic feet	
BCP	Boiler circulating pumps	
BDM	Break down maintenance	
BOP	Balance of Plant	
BS	British Standards	
C/P	Counterpart	
CBM	Condition based maintenance	
CCR	Central Control Room	
CCGT	Combined Cycle Gas Turbines	
CCTV	Closed-circuit television	
CEMS	Continuous Emission Monitoring System	
CF	Conversion Factor	-
CLDC	Central load dispatching center	
CMH	Mozambican Hydrocarbon Company (no official English name)	Companhia Moçambicana de Hidrocarbonetos
COD	Commercial operation date	
CPF	Central Processing Facility	
CPI	Investment Promotion Centre	Centro de Promocao de Investimentos
CPU	Central Processing Unit	
CTM	Maputo Thermal Power Station	Central Térmica de Maputo
DCS	Distribution control system	
DIN	German standards	Deutsches Institut fur Normung
DLP	Defect Liability Period	
DPCA	Provincial Directorate for Co-ordination of Environmental Affairs	Provinciais para Coordenação da Acção Ambiental
DSCR	Debt Service Coverage Ratio	-
DSR	Debt Service Ratio	
EDM	Mozambican Electricity Company (no official English name)	Electricidade de Moçambique
EIA	Environmental Impact Assessment	
EIRR	Economic Internal Rate of Return	
EIS	Environmental Impact Study	
EIB	European Investment Bank	
ENH	Mozambican National Hydrocarbon Company	Empresa Nacional de Hidrocarbonetos de Moçambique
EOH	Equivalent operation hours	
EPC	Engineering, Procurement and Construction (contract)	
EPDA	Environmental Pre-Feasibility Study and Scope Definition	Estudo de Pré-Viabilidade Ambiental e Definição do Âmb
EPRi	Electric Power Institute, Inc.	
ESIA	Environmental and Social Impact Assessment	
EU	European Union	
FCT	Fault clearing time	

Abbreviation	English	Original Language (Portuguese language)
FDI	Foreign Direct Investment	
FIDIC	International Federation of Consulting Engineers	Fédération Internationale Des Ingénieurs-Conseils
FIPAG	Water Supply Investment and Assets Fund	Fundo de Investimento e Património de Abastecimento de Água
FIRR	Financial Internal Rate of Return	
FOB	Free on board	
FS	Feasibility Study	
FUNAE	Mozambican National Rural Electrification Fund (no official English name)	Fundo de Energia
GDP	Gross Domestic Product	
GIZ	German Agency for International Cooperation	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMCB	Generator main circuit breakers	
GNI	Gross National Income	
GoM	Government of Mozambique	
GOV	Governor control unit	
GPS	Global positioning system	
GS	Gas Station	
GSA	Gas Sales Agreement	
GT	Gas Turbine	
HCB	Cahora Bassa Hydroelectric	Hidroeléctrica de Cahora Bassa
HHV	Higher Heating Value	-
HQ	Head office	
HRSG	Heat Recovery Steam Generator	
JIS	Japanese Industrial Standard	
I&C	Instrumentation and control	
I/O	Input/ output	
IDA	International Development Association	
IDC	Interest During Construction	
IFC	International Financial Corporation	
INAHINA	National Institute of Hydrography and Navigation	Instituto Nacional de Hidrografia e Navegação
INP	National Petroleum Institute	Institudo Nacional de Petróleos
IPP	Independent Power Producer	
JICA	Japan International Cooperation Agency	
JIS	Japanese Industrial Standards	
L1, L2, L3	Line bus	
LAN	Local area network	
LC	Local Currency	-
LCD	Liquid Crystal Display	
LHV	Lower Heating Value	
LCOE	Levelised Cost of Electricity	
LTPM	Long Term Parts Management	
LTSA	Long Term Service Agreement	
MCC	Motor control center	
MDF	Main distributing frame	
ME	Ministry of Energy	
MGC	Matola Gas Company	
MGJ	Million gigajoules	
MICOA	Ministry of Coordination of Environmental Affairs	Ministério para Coordenação de Acção Ambiental
MMR	Ministry of Mineral Resources	
MOH		
MPDC	Maputo Port Development Company	
MSL	Mean Sea Level	
MUSD	Millions of US Dollars	
MZN	Mozambique Metical	
N	Neutral bus	
NEDAP	National Energy Development and Access Program	

Abbreviation	English	Original Language (Portuguese language)
NGV	Natural Gas Vehicle	
NGO	Nongovernmental Organization	
NOK	Norwegian Krone	
NORAD	Government of Norway Agency for Development Cooperation	
NPFA	National Protection Fire Association	
O&M	Operation and Maintenance	
OC	Oriental Consultants Co., Ltd.	
ODA	Official Development Assistance	
OEL	Over excitation limiter	
OEM	Original equipment manufacturers	
OH	Overhaul	
OJT	On the job training	
ONAF	Oil natural air forced	
ONAN	Oil natural air natural	
PDCA	Plan-do-check-act	
PDCA	Provincial Directorate for Environmental Affairs	
PIP	Project implementation procedure	
PIU	Project Implementation Unit	
PM	Particulate matter	
PMU	Project Management Unit	
POED	Project for Entrepreneurial Development	
PPA	Petroleum Production Agreement	
PQ	Product quality	
PRS	Pressure Reduction Station	
PS	Power station	
PSA	Production Sharing Agreement	
PSS	Power system stabilizer	
PSS/E	Power System Simulator for Engineering	
PVB	Private branch exchange	
ROMPCO	Republic of Mozambique Pipeline Investments Company Ltd.	
RSA	Republic of South Africa	
SA	Surge arrestor	
SADC	Southern African Development Community	
SAPP	Southern African Power Pool	
SBU	Strategic Business Unit	
SCADA	Supervisory Control and Data Acquisition	
SEIA	Simplified Environmental ImpactAssessment	
SER	Simplified Environmental Report	
SIDA	Swedish International Development Cooperation Agency	
SOAPP	State of the Art Power Plant	
SPI	Sasol Petroleum International Ltd.	
SPT		Sasol Petroleum Temane Limitada
ST	Steam turbine	
STE	Mozambique Regional Transmission Backbone Project	Projecto Regional de Transporte de Energia, Centro-Sul
SUS	Steel Use Stainless	
TAC	Technical Assessment Commission	
TBM	Time-based maintenance	
TCF	Trillion cubic feet	
TEPSCO	Tokyo Electric Power Services Co., Ltd.	
TFD	Time of Flight Diffraction	
TOR	Terms of Reference	
TQM	Total quality management	
UAT	Unit auxiliary transformer	

Abbreviation	English	Original Language (Portuguese language)
UEL	Under excitation limiter	
UPS	Uninterrupted power supply	
USD	US dollars	
USGS	U.S. Geological Survey	
UT	Ultrasonic Testing	
VAC	Volts alternating current	
VAT	Value Added Tax	
VCB	Vacuum circuit breaker	
VDC	Volts direct current	
VT	Voltage transformer	
WACC	Weighted Average Cost of Capital	
WB	World Bank	
WHO	World Health Organisation	
WTP	Willingness-to-pay	
XLPE	Cross-linked polyethelene	

Appendices

Appendix1 : Drawings for Power Plant Layout
Appendix2 : Terms of Reference (TOR) of Engineering Consultancy Services
Appendix3 : Site Survey
Appendix4 : Geological & Geotechnical Survey
Appendix5 : Environmental and Social Study
Appendix6 : Records of Discussion during Stakeholders Meeting
Appendix7 : Environmental Checklist
Appendix8 : Itinerary for the First Site Survey
Appendix9 : Itinerary for the Second Site Survey
Appendix10 : List of Key Persons whom the Survey Team Met
Appendix11 : List of Collected Data and Information
Appendix12 : Minutes of Meeting of the 1st Mission
Appendix13 : Minutes of Meeting of the 2nd Mission

EXECUTIVE SUMMARY

1. Background and Purpose of the Study

The purpose of this "Preparatory Study on Gas-Fired Power Plant Development in Mozambique" is to prepare an approximate design and a Feasibility Study ("FS") for the gas-fired combined cycle power plant building project for which the Republic of Mozambique ("Mozambique") requests Japanese Official Development Assistance ("ODA") and to make the necessary investigations for the examination in order to execute it as a Japanese onerous fund cooperation project. The background of this study is as follows:

- In 2011, the nationwide power demand of Mozambique was only 616 MW of the maximum generating capacity of 4,068 GWh/year of gross power production, however there has been remarkable growth in the annual average increase power rates in the past 5 years, i.e., 14.1% in maximum generating capacity and 11.6% in gross power production. In particular, the maximum generating capacity in only Southern Mozambique is 369 MW which is 60% of the 616 MW nationwide power demand mentioned above noting that the annual average increase rate is showing steady growth.
- Although Electricidade de Mozambique ("EDM") is making efforts to ensure power supply capacity, e.g., rehabilitation of old small-scaled hydroelectric and thermal power plants, purchase of electric power from independent power producers ("IPP") of power supply being built in the Ressano Garcia area, and capital participation in IPP, the urgent issue to satisfy mid- and long-term power demand is to ensure a new power supply for Maputo, the capital of Mozambique.
- Based on such background, the Mozambique government requested Japanese ODA from the Japanese government in January, 2012, to support building a gas-fired combined cycle power plant in Southern Mozambique (50MW capacity).

2. Overview of Power Sector

An overview of the power sector of Mozambique is summarized as follows:

- The means of power supply is divided into three categories: the national grid, mini grids, and independent systems. For the national grid, EDM is responsible under the supervision of ME. And for mini grids, the Ministry of Energy ("ME") is responsible through relevant offices in provincial governments.
- Since Mozambique has a large geographical area extending 2,000 km from north to south, the network system is separated into two systems: one for the southern area and the other for the central and northern areas. These systems are independently operated, without being linked to each other.

- The Cahora Bassa Hydroelectric Power Plant ("HCB") with an output of 2,075 MW, the major power source in Mozambique, is linked to the network for the central and northern areas. A part of the generated power is transmitted to the central and northern areas by means of a 220 kV AC transmission line and the power supplied meets the load of these areas. Power is also sent to a neighboring country, Zimbabwe, by means of a 400 kV AC transmission line. However, the majority of the power generated by HCB is sent to the Apollo substation in South Africa by a 535 kV DC transmission line and it is then sent to the Southern African Power Pool ("SAPP").
- Since the system for the southern area, which covers Maputo, is located over 1,000 km from HCB, power is imported from SAPP via the networks of South Africa and Swaziland by means of a 400 kV AC transmission line. As a result, more than 80% of domestic demand is supplied by re-imported power.
- EDM has been conducting an update study to the existing study, "Mozambique Electricity Master Plan Study", which was completed in 2004. The update study, "Update of Master Plan 2010-2027", is scheduled to be completed by April 2013. Based on the update of the master plan, it is expected that the power supply plan for supply stable power will get off the drawing board.

3. Selection of the Site

Selection of the site is summarized as follows:

- Each candidate site has been carefully compared and assessed from technological and economical viewpoints, and the best-suited planned construction site was selected, estimating the approximate scale of the power plant facility. The selected candidate sites were the Beluluane industrial complex, which EDM had been studying, and a site on the CTM premises from which a coal-fired power plant had been removed.
- The following three points were considered, in respect of the views of EDM, as prerequisites for the comparison and study:
  - (i) Output of the CCGT power station should be maximized so that the contracted gas volume of 6 MGJ/ year can be fully used, considering that the gas contract is a take-or-pay contract.
  - (ii) The existing GT power station in CTM will perform base operations from 2013 to 2017 (when the CCGT power station is expected to start operation), using the contracted gas volume of 6 MGJ/ year.
  - (iii) From 2017, the CCGT power station will be in full operation and the GT power station of CTM will operate only in the case of an emergency, e.g., if the CCGT power station stops.
- In selecting a power plant construction site, the necessary layout of the site area, current situation, accessibility, topography, geology, and weather conditions of the site, constraints

of the system, fuel supply constraints, condenser cooling method, and selectivity of CCGT equipment were objectively and comprehensively compared and studied.

- As a result, the CTM site was selected as the project site for a power plant up to 100 MW. The major determining factor was transmission network capacity constraint.

4. Suitable Rated Power and General Specification

The suitable rated power and general specifications are summarized as follows:

- CCGT capacity is restricted by the amount of natural gas fuel that will be supplied. Since the gas supply amount to the new gas-fired power plant will be 6.0 MGJ/year, the power plant capacity is calculated at approximately 114 MW.
- For CCGT rated capacity, the CCGT range for selection can be expanded by making a setting with a margin of 70-110 MW and the promotion of proper and active competition bidding among EPC contractors.
- The related power generation plant will be built in southern Maputo city in Mozambique to cope with the tight power demand in Mozambique. For this plant, one unit operation is assumed for the present and continuous operation of the power plant with as high efficiency as possible is required. Globally, in the case of plants that require high efficiency operation and high capacity factor, multi-shaft 2 and more-on-1 CCGTs are installed. The JICA Study Team recommends a multi-shaft 2-on-1 CCGT since it is superior in the total efficiency of the power plant and it will allow partial load operation with high efficiency of about 50% even if a GT stops because of periodic maintenance, etc., and it has maintenance costs.
- As a result of comparing and studying the three types of cooling systems for an ST cooling system, i.e., once-through cooling system, wet type cooling tower system, and air-cooled condenser system, the conclusion was reached that the air-cooled condenser cooling system is the most suitable for this site, from the economic point of view.

5. Site Conditions

The meteorological, geological and topographical characteristics regarding the project site are summarized as follows:

- The ground level of the site was raised by 1.5 to 2.0 meters when the former coal-fired power plant was constructed in the 1950s, and the present ground level is approximately 3.3 m above mean sea level (“M.S.L.”) of Port Maputo.
- Since the embankment of the highway (EN2) located to the north acts as a topographic divide, rain that falls on the north side of the highway generally does not flow in the direction of the CTM site.
- As a result of field investigation by a standard penetration test (“SPT”) conducted at CTM

site, it was found that all boreholes feature a minimum of 4 consecutive SPT refusals (> 50 blows per 25 mm penetration), starting at depths ranging between 5 m and 15 m.

- Tropical storms hit Mozambique once a year on average and lesser-magnitude tropical depressions hit the country three to four times per year.
- In February 2000, two tropical cyclones landed in Mozambique and devastated the economic and social infrastructure across the country. The maximum total precipitation of 653 mm was a record for this month and accounted for approximately 80% of Maputo's normal annual precipitation of 800 mm.
- On February 6, 2000, the turbine buildings in CTM site suffered from flood damage. This damage was not caused by inundation from river water or storm surges, but was due to poor drainage within the CTM.

6. Basic Design

The basic design of the power plant is as follows:

- The proposed project at the CTM site has the following features:
    - (i) Major specifications
        - Rated generation capacity: 70 to 110 MW
        - Thermal efficiency (LHV): More than 50%
        - Capacity factor: More than 80% (for base power supply)
        - Fuel: Natural gas from Pande gas field
    - (ii) Major equipment
        - ✧ Combined Cycle Gas Turbine ("CCGT") plant
            - GT and generator: 2 sets
            - ST and generator: 1 set
            - Heat recovery steam generator: 2 sets
            - Air cooled condenser: 1 set
            - Auxiliary facilities such as 11 kV switch gear, step-up transformer, and fuel gas supply facility, water supply tank, etc.
        - ✧ Civil works such as foundation piling, buildings
        - ✧ Other facilities for water treatment, wastewater treatment, and fire fighting
- The control and monitoring system that will realize all-automatic operation of the generator facility will be configured as a DCS that takes technology and costs into consideration. The DCS facility will make it possible to control and monitor the whole generator facility, including control and monitoring of common facilities.

7. Natural Gas Supply Plan

The natural gas supply plan is as follows:

- EDM expects to receive not only 2.8 MGJ/ year for the Maputo site, but also 3.2 MGJ/ year for the Beluluane site, totaling 6.0 MGJ/ year for the project.
- According to the gas supply contract with MGC the available gas volume will be 4.5 MGJ/ year by July 2016, and it will increase to 5.8 MGJ/ year after July 2016.
- The gas price with MGC is assumed to be 5.6 USD/ MGJ (0.4 USD/ MGJ for transportation) for the Maputo site.

8. Project Implementation Plan

The project implementation plan is as follows:

- The project implementation schedule is estimated as below:
  - Selection of consultant: 8 months from the conclusion of loan agreement
  - Selection of EPC contractor: 15 months from the selection of consultant
  - Construction: 30 months from the notice to proceed
- No problems were found with the site preparation and the unloading & transportation of heavy equipment. However, the planning progress of a new trunk road construction adjacent to the construction site should be closely monitored.
- Consultant and EPC contractor shall be selected according to the JICA guidelines.

9. Project Cost

Project cost is as follows:

- Project cost was estimated based on the proposed project implementation schedule, price trends of combined cycle power facilities, construction prices in Mozambique, required manpower for consulting services, required activities and materials for operation and maintenance ("O&M") and other results of studies related to project cost estimates, and the results of the project cost estimate is summarized in the following table.

JICA Finance Portion	**Cost (Million USD)**
Power plant construction and associated works (EPC cost)	124,171
LTSA, training and spare parts	18,403
Consulting services	14,344
Contingencies and interest during construction	26,387
Total of JICA Finance Portion	183,305
Non Eligible Portion (site preparation, administration cost and tax)	11,487
Total	194,791

10. Financial and Economic Analysis

The financial and economic analyses are abstracted as follows:

- The financial soundness of EDM is analyzed on the basis of their financial statements. As for the debt service capacity, the quick ratio except for 2007 had basically surpassed 100%. Accordingly, the debt service capacity for the short-term of EDM is not significantly worrying. On the other hand, the ratios of return on assets and return on capital during the period from 2006 to 2010 were negative or close to zero in value. Hence, it can be said that the profitability of EMD is defective. The profitability is expected to improve through reviews and an increase in electricity sales price or the reduction in operation cost in the future.
- The FIRR of the Project is at 6.7%, which exceeds 6.47%, short-term national loan interest rates of the cutoff rate. Therefore the Project is regarded as financially viable. The debt service coverage ratio (DSCR), which shows the sovereign debt payment, is normally required to be 1.3 to 1.5 at minimum. If the DSCR of the project is over 2.2, it will meet this criterion. Hence, the Project is considered to be a sound investment.
- The EIRR of the Project is calculated at 17.1%. Since the EIRR exceeds the opportunity cost of capital in Mozambique (10%), the Project is judged to be economically feasible. Furthermore, through the implementation of the Project, direct and indirect job creation is expected. This job creation can contribute to the expansion of the economic scale of Mozambique and poverty reduction that the Government of Mozambique considers a top priority issue to be solved.

11. Environmental and Social Considerations

Environmental and social considerations are abstracted as follows:

- The following baseline information was collected and analyzed:
  - Outline of the project components
  - Natural environment conditions in and around the Project site (meteorology, air quality, noise level, water quality, etc.)
  - Socio-economic conditions in and around the Project site (administration, demography, education & hygiene, industries, etc.)
  - Environmental laws/regulations/standards, systems and related authorities in Mozambique
- Based on the above baseline information, scoping and evaluation for the environmental and social impacts were conducted. The results are summarized as follows:
  - During construction

Although there would be some impacts on air quality, noise & vibration and wastes arising from construction works, these impacts are minor and temporary, and can be readily reduced to a permissible level by application of appropriate mitigation measures.

- During operation

  Since the power plant shall be designed and built to meet applicable environmental regulations and standards in Mozambique, there is no significant environmental issues expected.

- Land acquisition and resettlement are not necessary for the Project because the proposed site is within the vicinity of the existing power plant owned and operated by EDM, and there are no resettlements involved in the Project because there are no legal and/or illegal settlers that will be displaced.

Chapter 1

Introduction

Chapter 1 Introduction

1.1 Background of the study

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- Although Electricidade de Mozambique ("EDM") is making efforts to ensure power supply capacity, e.g., rehabilitation of old small-scaled hydroelectric and thermal power plants, purchase of electric power from independent power producers ("IPP") power supply being built in the Ressano Garcia area, and capital participation in IPP, the urgent issue to satisfy mid- and long-term power demand is to ensure a new power supply for Maputo.
- Based on such background, the Mozambique government requested Japanese ODA from the Japanese government in January, 2012, to support building a gas-fired combined cycle power plant in Southern Mozambique (50 MW capacity).

1.2 Purpose of the study

The purpose of this study is to evaluate the approximate design and FS for the gas-fired combined cycle power plant building project requested by the Mozambique government and to make investigations necessary for the examination to execute it as Japanese ODA loan, i.e., the necessity of this project, overview, project cost, implementation schedule, implementation method (procurement and execution), business implementation system, operation and maintenance management, environmental and social considerations.

1.3 Scope of works

Maputo and Matola in Mozambique (Figure 1.3-1)

(Source: JICA Study Team)

Figure 1.3-1 Target area

This study shall be organized and implemented based on the study items in Table 1.3-1 consistent with the Japan International Cooperation Agency's ("JICA's") operational guidance.

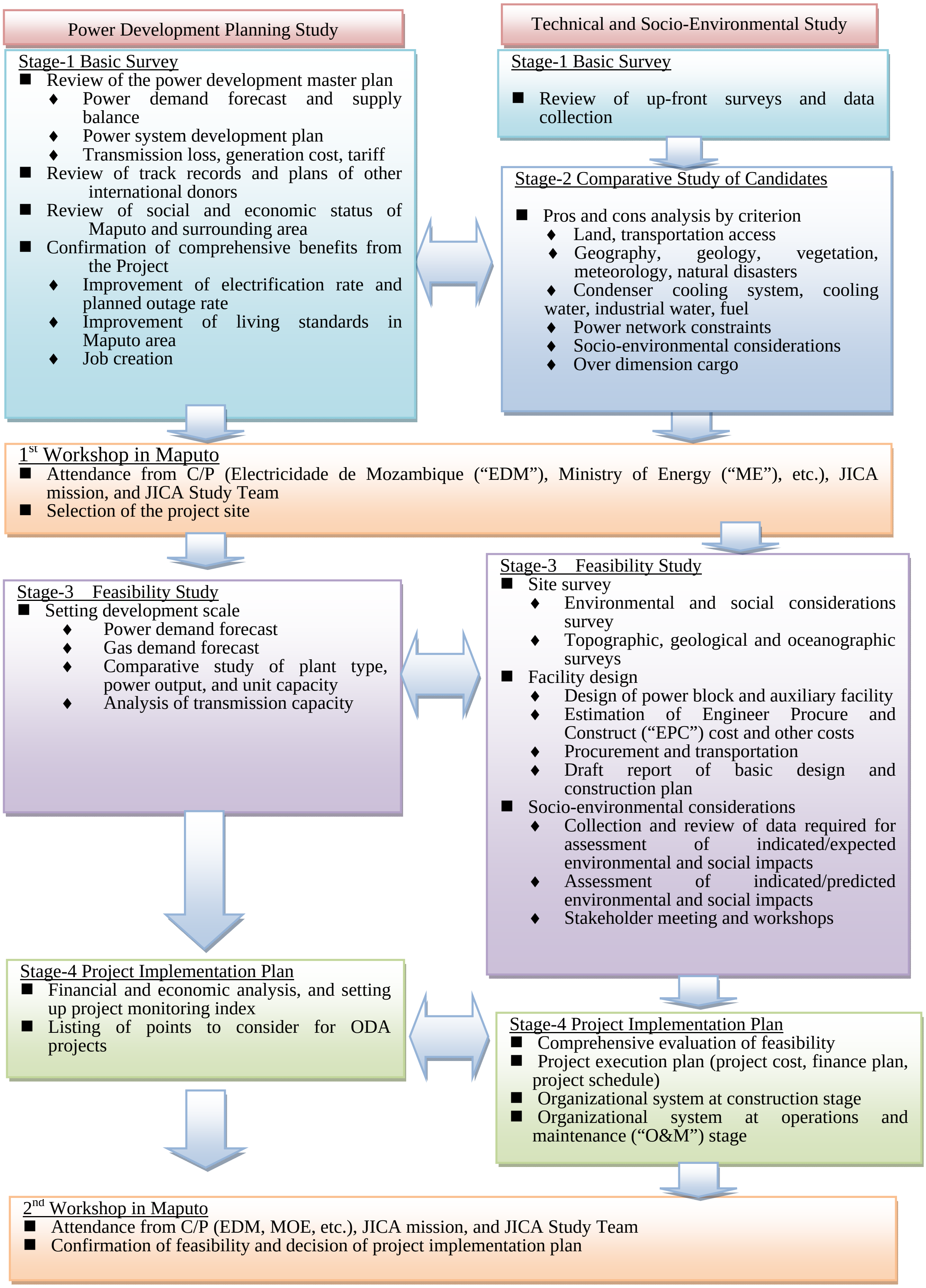
Table 1.3-1 Study items

Stage-1 Basic Survey: Background and consistency with key national plans	
4.1.1	Submission and discussion of Inception Report
(1)	Analysis of relative documents and planning of surveys
(2)	Draft of Inception Report
(3)	Discussion of Inception Report with JICA and counterpart ("C/P")
4.1.2	Review of background and consistency with key national plans
(1)	Review of the power development master plan of Mozambique
(2)	Review of track records and plans of other international donors for the power sector
(3)	Review of social and economic status of Maputo and surrounding area
(4)	Review of power demand forecasts, operational records and development plan of Mozambique's power system
(5)	Confirmation of comprehensive benefits from the Project
Stage-2 Selection of the project site	
4.1.3	Selection of the project site
(1)	Comparative study
(2)	Draft and discussion of Progress Report for decision making
Stage-3 Feasibility study	
4.2.1	Survey of relevant information for basic design
(1)	Site conditions
(2)	Socio-economic conditions
(3)	Fuel gas supply plan
(4)	Power transmission and power system stability
4.2.2	Planning of project outline
(1)	Purpose of the Project
(2)	General overview of Combined Cycle Power Plant ("CCPP")
(3)	Terms of Reference ("TOR") and scope of works for the consulting service to the project
4.2.3	Basic design
(1)	Plot plan
(2)	Type of power plants and unit capacity
(3)	Fuel gas supply plan
(4)	Condenser cooling system
(5)	Civil work
(6)	Mechanical work
(7)	Electrical work
(8)	Common facility
(9)	Substation and transmission facility
(10)	Other auxiliary equipment
(11)	Transportation route for major parts of equipment
4.2.4	Planning of procurement and construction
4.2.5	Project implementation plan
4.2.8	Socio-environmental consideration
(1)	Legal regulation of socio-environmental consideration

(2)	Socio-environmental conditions of the Project site
(3)	Scoping
(4)	Baseline data correction
(5)	Analysis of environmental impact
(6)	Mitigation plan
(7)	Monitoring plan
(8)	Checklists of JICA Guidelines for Environmental and Social Considerations
(9)	Stakeholders' meetings
(10)	Support to making Environmental Impact Assessment ("EIA") report
4.2.9	Compensation plan for land acquisition and inhabitant resettlement
Stage-4 Project implementation plan	
4.2.6	Organizational system at construction stage
(1)	Establishment of Project Management Unit ("PMU")
(2)	Organizational structure and manpower allocation of PMU
(3)	Finance and budget of PMU
(4)	Technical capacity of PMU
(5)	Experience of PMU for similar projects
4.2.7	Organizational system at the operation and maintenance stage (organizational structure, manpower allocation, finance and budget, technical capacity, and experience)
4.2.10	Project cost
4.2.11	Listing of points to consider for ODA projects
4.2.12	Monitoring index for project effectiveness
4.2.13	Draft and discussion of Draft Final Report
4.2.14	Organizing a workshop in Japan
4.2.15	Draft and submission of Final Report

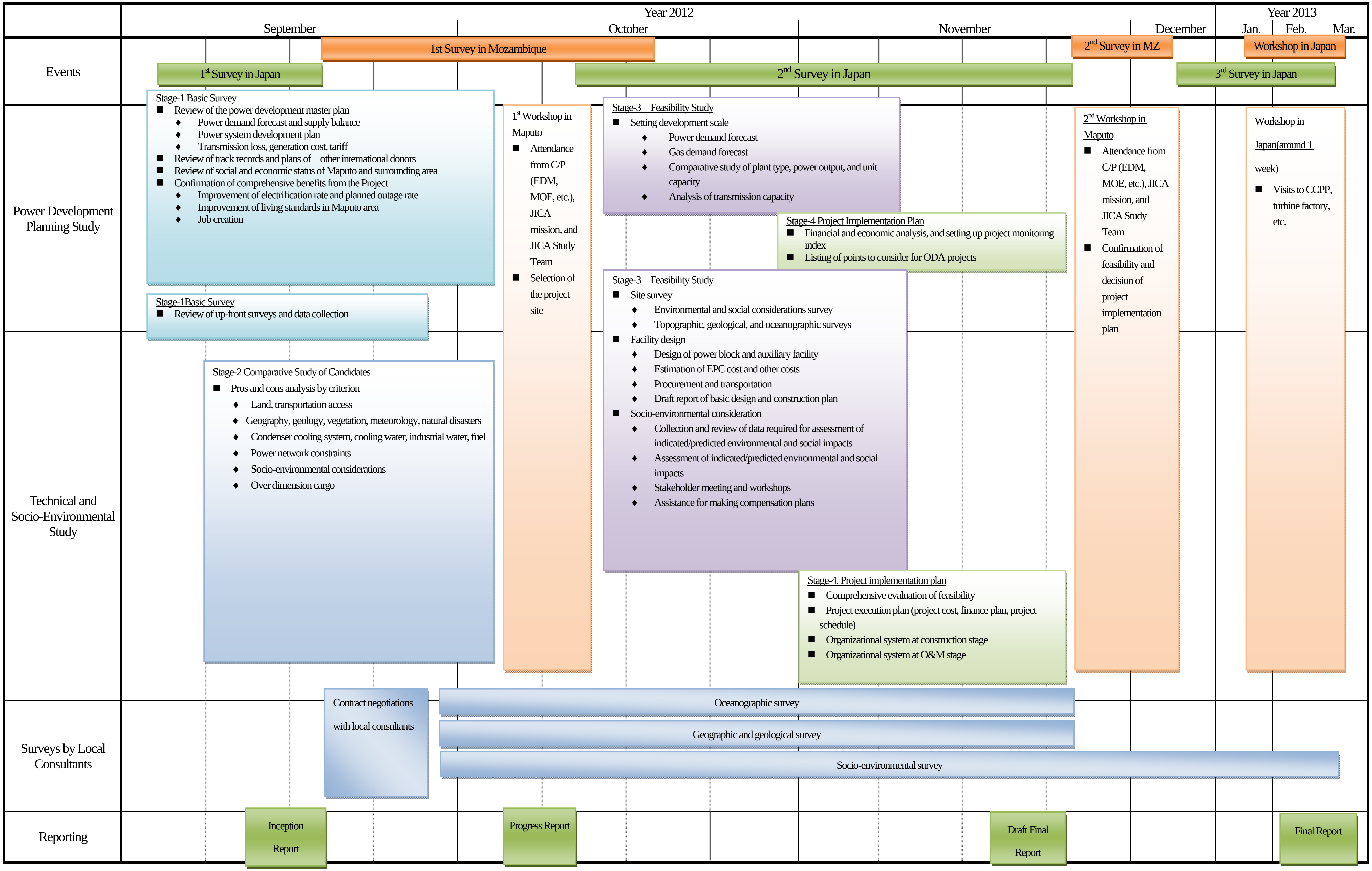
(Source: JICA Study Team)

Figure 1.3-2 shows every component of the Study and the linking structure. The implementation schedule of the Study is shown in Figure 1.3-2.



(Source: JICA Study Team)

Figure 1.3-2 Overall study flow

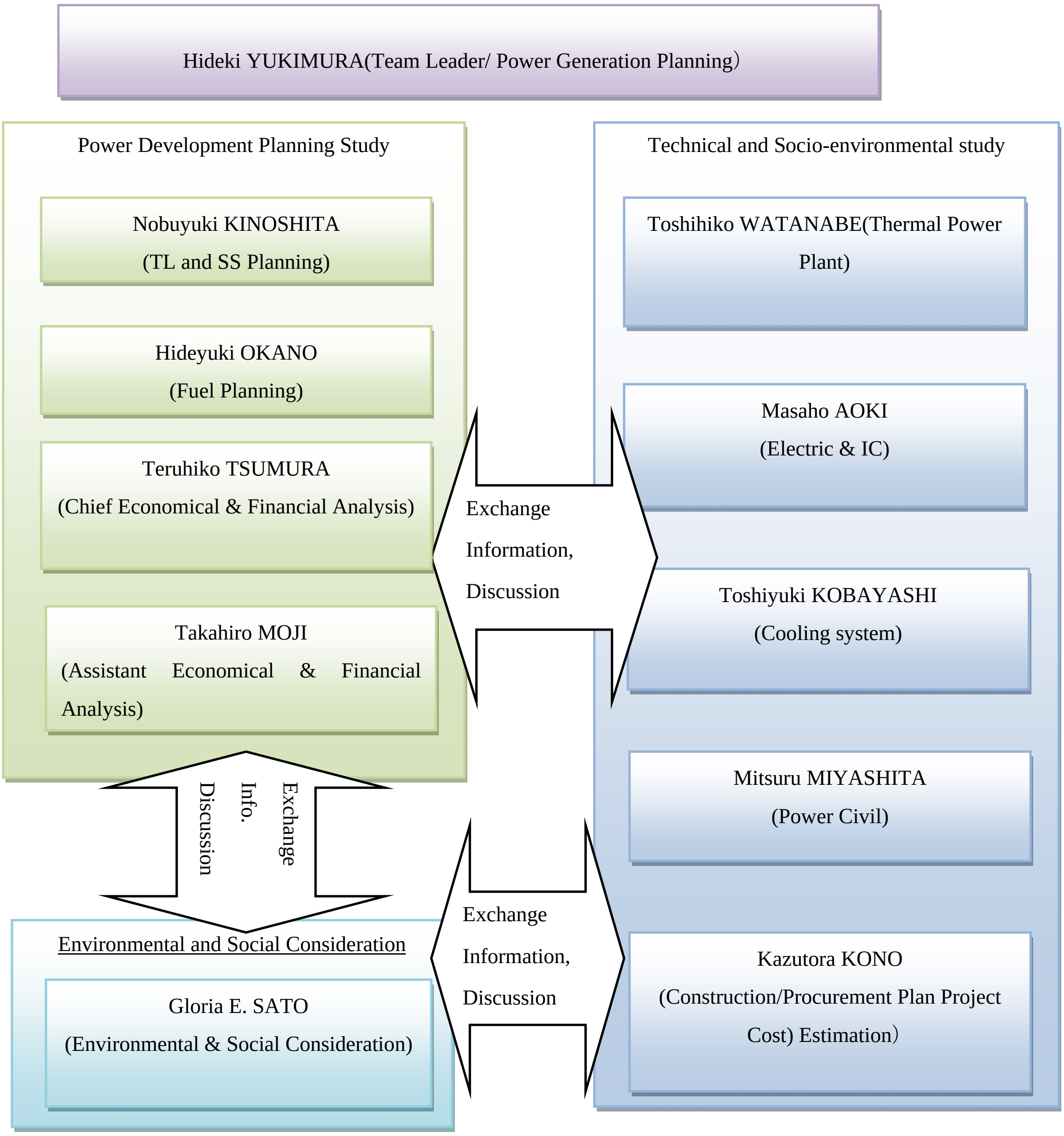


(Source: JICA Study Team)

Figure 1.3-3 Study schedule

1.4 Organizational framework for the Study

The team for the Survey is a joint venture of consultants consisting of Tokyo Electric Power Service Co., Ltd ("TEPSCO") and Oriental Consultants Co., Ltd. ("OC"), who have been entrusted with the consulting services for the Survey by JICA. The composition and designation of the JICA Study Team is shown in Figure 1.4-1.



(Source: JICA Study Team)

Figure 1.4-1 JICA Study Team

When the need arises for smooth operation of the Survey in any part thereof, MOE and/or EDM are kindly requested to assign counterpart personnel, who will work closely with the members of the JICA Study Team, on a full time or a part time basis depending on the requirements, to the greatest extent as is practically possible. The expected roles of the counterpart personnel are, for instance, as follows:

- To make appointments and to set up meetings with authorities, departments and other organizations and firms the JICA Study Team intends to visit for the purpose of this Survey.
- To attend field surveys and other locations with the JICA Study Team and to provide any assistance in relation to accommodation, work rooms, adequate transportation, obtaining permissions if required, etc.
- To assist and to advise the JICA Study Team as much as possible on their collection of data and information.

Chapter 2

Overview of Power Sector

Chapter 2 Overview of Power Sector

2.1 Social and Economic Conditions

2.1.1 Land Area and Population

Mozambique has a total land area of 799,380 km2 politically divided into 10 provinces and 1 city namely, Niassa, Cabo Delgado, Nampula, Zambezia, Tete, Manica, Sofala, Inhambane, Gaza, Maputo province and Maputo city. It has a total population of 23 million according to the latest statistics from the National Statistics Institute (see Table 2.1-1). There are more than 70 percent of this population are living in rural areas concentrating along the coast (more than 50%), mostly young (45.9% is less than 15 years old).

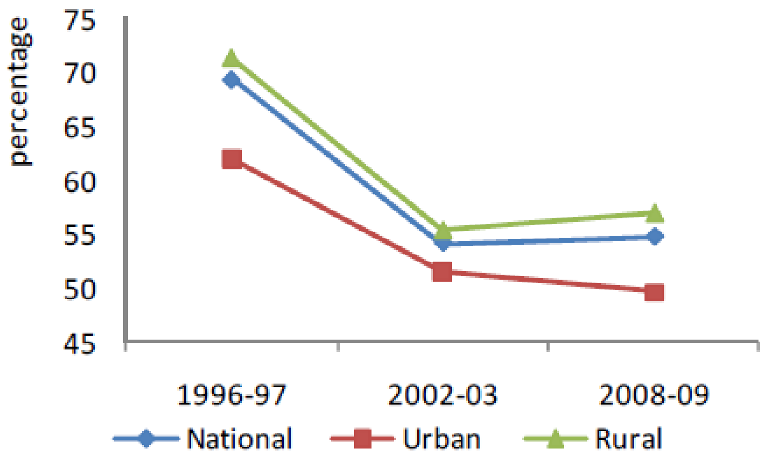
Table 2.1-1 Total Population, Area and Population Density by Province, 2011

Provinces	Population	Percent Struct.	Area km_2	Inhab/km_2
Total	**23,049,621**	**100**	**799,380**	**29**
Niassa	1,415,157	6	129,056	11
Cabo Delgado	1,764,194	7.6	82,625	21
Nampula	4,529,803	19.2	81,606	56
Zambezia	4,327,163	18.7	105,008	41
Tete	2,137,700	9.2	100,724	21
Manica	1,672,038	7.3	61,661	27
Sofala	1,857,611	8	68,018	27
Inhambane	1,402,245	6.5	68,615	20
Gaza	1,320,970	6.1	75,709	17
Maputo Province	1,444,624	6.3	26,058	55
Maputo City	1,178,116	5.1	300	3,927

(Source: Statistical Yearbook 2011 of National Institute of Statistics)

2.1.2 Poverty Incidence

Mozambique has continued the fastest growing non-oil economy in Sub-Sharan Africa with an average growth of 7.5% per year (1993-2009). Despite this progress, the country lacks economic diversification, weak institutions, lacks infrastructure development, among others that hinders the country to move forward. According to the Report from the Ministry of Planning and Development, there was a decrease in poverty incidence from around 70 percent in 1996 to around 55 percent in 2003 as shown in Fig. 2.1-1. In 2008/09, the poverty condition has stagnated at around 55 percent due to the slow growth of agricultural productivity, recurrent weather shocks that reduced the yields, decline trade due to increase in international food and fuel, among others.



(Source: Ministry of Planning and Development, 2010)

Figure 2.1-1 Poverty Headcount (%)

In recent years, the country has undertaken a series of economic reforms. Almost all aspects of the economy have been liberalized to some extent. Mozambique has considerable mineral resources although exploitation has been limited by its recently ended civil war. But the large reserves of natural gas in the Pande and Temane of Inhambane province have exploited, which is set to become a major source of foreign exchange.

Agriculture is the most important sector and is mostly carried out by peasant farmers who cultivate 92% of the total cropland. Commercial farming occupies only 250,000 hectares, or 8% of the total land cultivated. Though the contribution of agriculture to the Gross Domestic Product (GDP) is between 25% and 30%, an estimated 80% of the country's population gains its livelihood from this sector emphasizing the importance of agriculture to the nation. Most of the agricultural activities rely on rain that falls from November to December and are limited to one season.

2.1.3 Mozambique's Rich Resource

Mozambique is one of the largest power producers in the SADC region. Hydropower is Mozambique's most important commercial energy resource, with the potential estimated at about 14,000 MW, of which about 2,300 MW has so far been developed, 2,075 MW at Cahora Bassa Dam located at the Zambezi River and the remaining is distributed among a number of sites throughout the country. The capacity at Cahora Bassa is committed to the supply electricity to Mozambique, Zimbabwe, and Malawi. However, the majority of the power generated by

Cahora Bassa is sent to the Apollo substation in South Africa and is then sent to the Southern African Power Pool.

Apart from hydro resources, Mozambique has not yet to exploit its oil reserves. Presently, accumulation of natural gas deposits have been discovered on-shore in the provinces of the aforesaid Inhambane and Cabo Delgado. According to statistical estimate, the total natural gas reserves in Mozambique are 4.8 to 8.8 TCF in the Mozambique Basin and 52.5 to 110 TCF in the Rovuma Basin. The majority of production of gas is now being exported to South Africa through a pipeline.

Moreover, Mozambique has three relatively large known deposits of coal located in the Province of Tete. Total coal reserves are estimated at about three billion tonnes. Coal has been produced since 1940, from Moatize mines, both for in country use and export. Although the operations had to be suspended due to civil war, it restarted the activities.

2.1.4 Economic Condition

(1) Macroeconomic

The Gross Domestic Production (GDP) per capita of the country was estimated at around USD 635 in 2012 and had steadily increased during the period of 2005 to 2012 (refer to Table 2.1-2). The GDP between 2005 and 2012 had also increased. Fiscal performance remained strong until 2012, with government revenue rising from 20.12% of GDP in 2005 to 28.74% of GDP in 2012. Government Gross Debt had decreased from 131.87% of GDP in 2000 to 39.98% in 2012. Receipts of Official Development Assistance (ODA), which has increased year by year, amounted to USD 2,013 million in 2009 and ODA will be continuously carried out, while the amount of the Foreign Direct Investment (FDI) recorded at USD 881 million in the same year. The detailed condition of FDI will be described afterward.

Table 2.1-2 Selected Macroeconomic Indicators

Indicators	Unit	2000	2005	2006	2007	2008	2009	2010	2011	2012
National Accounts										
GDP at Current Prices	Billion US $	4.138	6.579	7.215	8.121	9.943	9.967	9.481	12.830	14.27 (f)
GDP per Capit at Current Prices	US$	236.46	336.49	361.80	399.26	479.23	471.00	439.25	582.61 (f)	635.44 (f)
Real GDP Growth Rate	%	14.7	8.4	8.7	7.3	6.8	6.4	8.1	…	…
Government Finance										
Government Revenue	% GDP	21.93	20.12	22.93	25.2	25.34	27.06	29.68	29.44 (f)	28.74 (f)
Total Expenditure and Net Lending	% GDP	23.66	22.90	26.99	28.15	27.81	32.57	33.64	34.38 (f)	35.06 (f)
Overall Deficit (-) / Surplus (+)	% GDP	-5.3	-3.5	-0.5	-2.4	-2.7	-5.1	-5.4	…	…
External Sector										
Exports Volume Growth (Goods)	%	19.95	16.78	10.45	-3.499	8.713	-1.195	-9.380	4.278 (f)	1.459 (f)
Imports Volume Growth (Goods)	%	-13.68	-0.0990	5.561	1.495	19.67	13.90	-2.061	22.83 (f)	9.504 (f)
Current Account Balance	Billion US $	-0.697	-0.7610	-0.7730	-0.7850	-1.179	-1.220	-1.113	-1.667 (f)	-1.818 (f)
Current Account Balance	% GDP	-16.66	-11.56	-10.72	-9.670	-11.86	-12.24	-11.74	-12.99 (f)	-12.74 (f)
Debt and Financial Flows										
Government Gross Debt	% GDP	131.87	80.96	53.61	41.92	42.14	40.13	39.51	33.20 (f)	39.98 (f)
Net Official Development Assistance	Million US $	906.2	1,297.00	1,605.70	1,778.10	1,996.10	2,013.30	…	…	…
Net Foreign Direct Investment	Million US $	139.2	107.9	153.7	427.4	591.6	881.2	…	…	…

(Source: ADB Statistics Department; IMF: World Economic Outlook, October 2010 and International Financial Statistics, April 2011; ADB Statistics Department: Development Data Platform Database, April 2011. United Nations: OECD, Reporting),
Notes… Data Not Available; (f) Forecast

As the GDP by sector is shown in Table 2.1-3, the agriculture, livestock, hunting and forestry sector has a 24% share of GDP and is the largest sector in the country, followed by manufacturing sector, transport, storage and communication sector, trade sector, real estate activities, rentals and services sector, financial activities sector, water and electricity sector and education sector, public administration, defense and social security sector and construction sector and so forth. Those shares have hardly changed for the last ten years. The proportion of the sector of electricity, gas and water had been almost stable 4.4% to 4.8% during the period of 2001 to 2010 in the above table.

Table 2.1-3 Share of Gross Domestic Product by Sector (2001 to 2011)

Unit:%

No.	Description	2001	2002	2003	2004	2005	2,006	2007	2008	2009	2010	2011
1	Agriculture, livestock, hunting and forestry	23.1	23.7	23.4	22.8	22.5	22.9	23.1	23.6	23.8	23.6	23.7
2	Fishing, aquaculture, and related services activities	2.0	1.9	1.9	1.8	1.7	1.6	1.7	1.7	1.4	1.4	1.4
3	Extrative industries	0.5	0.5	0.6	0.9	0.9	1.0	1.1	1.1	1.1	1.2	1.3
4	Manufacturing	13.7	13.6	15.0	15.7	14.8	14.0	13.5	13.2	12.7	12.4	12.3
5	Water and electricity	4.4	4.4	4.6	4.9	5.3	5.5	5.6	4.6	4.9	4.8	4.8
6	Construction	3.3	3.3	3.4	3.0	3.1	3.2	3.3	3.5	3.4	3.4	3.3
7	Trade	9.9	9.5	9.5	9.5	9.8	11.0	11.2	11.2	11.2	10.8	10.2
8	Vehicle repairs, motocycles and good	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4
9	Acomodation, restaurants and similar	1.5	1.5	1.5	1.4	1.5	1.5	1.6	1.7	1.6	1.6	1.6
10	Transport, storage and comunication	9.8	9.7	9.4	9.5	9.5	9.7	9.9	10.4	10.8	11.6	12.0
11	Financial activities	3.0	3.2	3.3	3.9	5.3	5.1	5.2	5.0	5.2	5.4	5.4
12	Real estate activities, Rentals and services	10.9	10.1	9.6	9.4	8.8	8.1	7.6	7.2	6.9	6.5	6.2
13	Public administration, defense and social security	3.9	3.8	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.7	3.7
14	Education	3.4	3.2	3.3	3.4	3.5	3.5	3.7	3.7	3.9	4.0	4.0
15	Health and social action	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.4	1.4	1.4	1.4
16	Other collective services activities	2.4	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.6	1.5	1.5
17	SIFIM	-1.5	-1.7	-2.6	-2.8	-2.7	-3.2	-3.1	-3.0	-3.1	-3.2	-3.1
18	Tax on products	8.0	9.2	9.6	9.3	8.9	8.9	8.7	9.2	9.3	9.4	10.0
	Gross Domestic Product	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(Source: Central Bank of Mozambique)

(2) Foreign direct investment (FDI)

It can be said that Mozambique's economy has been driven by foreign direct investment (FDI). Private sector investment was over USD 1.9 billion in 2011 as a result of large FDI in coal mega-projects. A total of 30,000 new jobs were created by the 285 new projects, of which 13 were in the Nacala Exclusive Economic Zone, representing a USD 400 million investment from export companies.

The Maputo area has traditionally had an overwhelming concentration of growth and jobs but this has started to change. In 1990–2003, 75 percent of FDI in Mozambique was concentrated in Maputo City and Maputo Province. Its share of new investments has steadily declined, from nearly 75 percent in 2006 to less than 20 percent in 2009. This shows a more even distribution of new investments to other regions of the country, especially in the mineral resources, energy, agriculture processing, and more recently, tourism and construction sectors.

The data of Centro de Promocao de Investimentos (CPI) for authorized investments by sector from 2005 to 2009 shows that Maputo Province has a fairly well-diversified economic base, with investments in transport, telecommunications, the financial sector, industry, and tourism (Refer to Table 2.1-4).

Table 2.1-4 CPI-Authorized Investments in Maputo Province by Sector, 2005-2009

	2005		2006		2007		2008		2009		2005-2009		2005 - 2009 Mozambique Total	
Sector	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)
Transport & communication	209	5,852,549	1,388	158,026,142.00	515	57,681,514	356	83,813,954	365	17,794,625	2,833	323,168,785	4,134	439,361,325
Agriculture and fishiries					25	10,500,000			147	3,203,875	172	13,703,875	816	53,397,122
Agriculture and fishiries	3,511	112,771,297	1,232	23,073,927	2,401	57,314,514	1,698	31,147,316	1,100	37,834,066	9,942	262,141,121	49,545	6,303,139,512
Construction	50	1,150,000	83	1,983,036	933	7,529,977	298	13,426,833	206	3,975,800	1,570	28,065,646	4,375	149,649,500
Industrial	708	28,592,271	959	21,777,570	5,079	325,242,053	2,065	137,485,597	858	21,291,616	9,669	534,389,108	18,705	892,668,673
Mineral resources and energy	154	15,638,650.00	292	23,000,000							446	38,638,650	1,903	6,627,891,567
Services									1,445	43,877,978	1,445	43,877,978	3,545	167,730,328
Tourism & hotels	2228	47,511,506	1,709	368,823,696	605	28,044,286	1,615	68,165,022	73	8,002,172	6,230	520,546,682	17,139	1,310,411,321
Banking, insurance, and leasing	84	1,900,000	62	2,933,500	20	1,532,857	29	12,833,333			195	19,199,690	394	39,883,750
Others	540	14,545,747	6,378	48,766,443	314	51,957,706	562	32,382,301			7,794	147,652,197	8,651	239,389,817
TOTAL	**7,484**	**227,962,021**	**12,103**	**648,384,314**	**9,892**	**539,802,908**	**6,623**	**379,254,357**	**4,194**	**135,980,132**	**40,296**	**1,931,383,732**	**109,207**	**16,223,522,916**

(Source: Mozambican Authorities (CPI 2005-2009))

Table 2.1-5 CPI-Authorized Investments in Maputo Province by District, 2005-2009

	2005		2006		2007		2008		2009		2005-2009	
District	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)	No. of Employment	Committed investment (MZN)
City of Maputo	1,322	46,336,999	9,910	558,554,512	2,438	140,704,758	1,022	129,724,692			14,692	875,320,961
Matola	301	9,978,178	844	29,333,173	3,692	52,720,855	2,470	90,051,628	1,361	64,810,142	8,668	246,893,976
Boane	323	14,894,037	25	5,435,000	718	174,885,695	398	41,167,965	158	4,503,000	1,622	240,885,697
Inhaca					15	320,800					15	320,800
Machava	18	187,217							1,152	14,050,606	1,170	14,237,823
Magude	25	2,857,143	10	160,000							35	3,017,143
Manhiça	10	325,000			514	4,280,000	265	9,001,200	460	2,570,100	1,249	16,176,300
Marracuene	5,000	50,000,000	30	450,000	660	114,714,286	366	4,915,652	214	6,549,119	6,270	176,629,057
Matutuine	335	3,883,447	149	44,609,432	1,738	51,655,714	805	82,301,903	687	41,534,199	3,714	223,984,696
Moamba	150	99,500,000	534	4,297,680			1,141	18,969,300	112	1,462,966	1,937	124,229,946
Namaacha			601	5,544,517	117	520,800	61	1,732,731	50	500,000	829	8,298,048
Xinavane							95	1,389,285			95	1,389,285
TOTAL	**7,484**	**227,962,021**	**12,103**	**648,384,314**	**9,892**	**539,802,908**	**6,623**	**379,254,357**	**4,194**	**135,980,132**	**40,296**	**1,931,383,732**
Total Mozambique	***15,113***	***482,186,373***	***19,372***	***850,209,001***	***27,469***	***8,062,268,793***	***20,495***	***1,080,254,032***	***26,758***	***5,748,620,716***	***109,207***	***16,223,538,916.00***

(Source: Mozambican Authorities (CPI 2005-2009))

Still, Maputo province remains the predominant business and financial center of the country, and within the province, the bulk of new investments continue to take place in Maputo City, with Matola District being a distant second (refer to Table 2.1-5). FDI has given rise to employment promotion, capital such as machinery and infrastructure, creation of added value products, and economic development.

(3) Industry in Maputo Area

The country's largest industrial park, Beluluane, and the Mozal aluminum smelter are both located in Maputo, as are other large beer, soft drink, cement, and cereal milling industries (e.g., Cimentos de Mozambique, Cervejas de Moçambique, Coca-Cola). There are also a number of large and promising agribusiness investments such as the Maragara sugar mill and Bananalandia, which supplies bananas to both the domestic and South Africa markets. The province also benefits from a number of universities and technical schools. Further, much of the country‘s tourism growth has taken place in the Maputo area, which includes the Maputo Elephant Reserve and the Kruger Transfrontier Park, which Mozambique shares with South Africa and Swaziland.

As for the Mozal aluminum smelter, since 1998, Mozambique has been engaged in an intensive effort to attract megaprojects in order to establish itself as a favorable environment for FDI. The US$2.8 billion aluminum smelter projects Mozal I and II, which had been constructed in the Matola district in the late 1990s and in the early 2000s, are the largest aluminum smelter projects in this country. Non mega-projects FDI rose in importance during the period of 2006 to 2010 and the inflows have become increasingly diversified, which accounted for close to 44 percent of total FDI inflows.

The smelters produce about 506, 000 tons of aluminum ingots per year. Alumina is sourced in Australia and aluminum ingots are exported mainly to the EU. The firm is a joint venture of the Australian-British BHP Billiton mining company (47%), the Japanese Mitsubishi Corporation (25%), the Industrial Development Corporation of South Africa (24%), and the Government of Mozambique (4%).

With regards to Beluluane Industrial Park, as noted above, Maputo Province hosts Beluluane Industrial Park, located in the Matola Industrial Zone. The World Bank‘s Private Sector Development Project financed establishment of the park in 2007. The park spans 24 hectares and has attracted 22 businesses employing some 1,000 workers and has generated US$20 million in investment. The park is located across from Mozal.

(4) The Industrial Customers for the Power Demand in Maputo Area

In and around Maputo area there are substantial business enterprises that demand the new power in order to operate their business. Such enterprises require new electricity of 527MW as a whole by 2015/16 (Table 2.1-6). There is a growing likely that the economic situation in Maputo area is and will be quite active due to being the increasing energy demand for the industrial customers in Maputo.

Table 2.1-6 Current and Future Industrial Customers for Power Demand in Maputo

No.	CUSTOMER NAME	LOCATION	INITIAL LOAD (MW)	STATUS
1	Incomati Sugar	Xinavane/Maputo	15	Operational
2	Maragra Sugar	Manhiça/Maputo	10	Operational
3	Steel Tube Factory	Beluluane/Maputo	10	Operational
4	Exports to SEC	Swaziland	100	Operational
5	Exports to LEC	Lesotho	20	Operational
6	CIF MOZ	Salamanga	20	Construction
7	Facim-Sogex Multipurpose	Maputo	15	Construction
8	Intaka 5000 Houses	Maputo	20	Construction
9	Catembe Bridge + Residential Expansion Zone	Maputo	30	Construction to start 2013
10	GS Cimentos	Beluluane/Maputo	20	Committed 2014
11	Cim Magude/Africa Great Wall	Magude/Maputo	22	Committed 2014
12	New Sommershield	Maputo	15	Committed 2014
13	Matola Mall	Matola Maputo	15	Committed 2014
14	ADIL Cimentos	Maputo	10	Potential 2014
15	Techobanine Port	Salamanga/Maputo	18	Potential 2015-16
16	FerroxChang	Belluluane/Maputo	7	Potential 2015-16
17	Cim Moç-Matola/CIMPOR	Matola/Maputo	15	Operational/Expansion
18	Matola Coal Terminal – Fase IV	Matola/Maputo	10	Expansion
19	Chibuto Heavy Sands	Chibuto/Gaza	45	Potential
20	Chibuto Heavy Sands Smelting	Chibuto/Gaza	88	Potential
21	Arcellor Mittal	Beluluane/Maputo	22	Potential
TOTAL			**527**	

(Source: EDM)

2.2 Overview of Network System

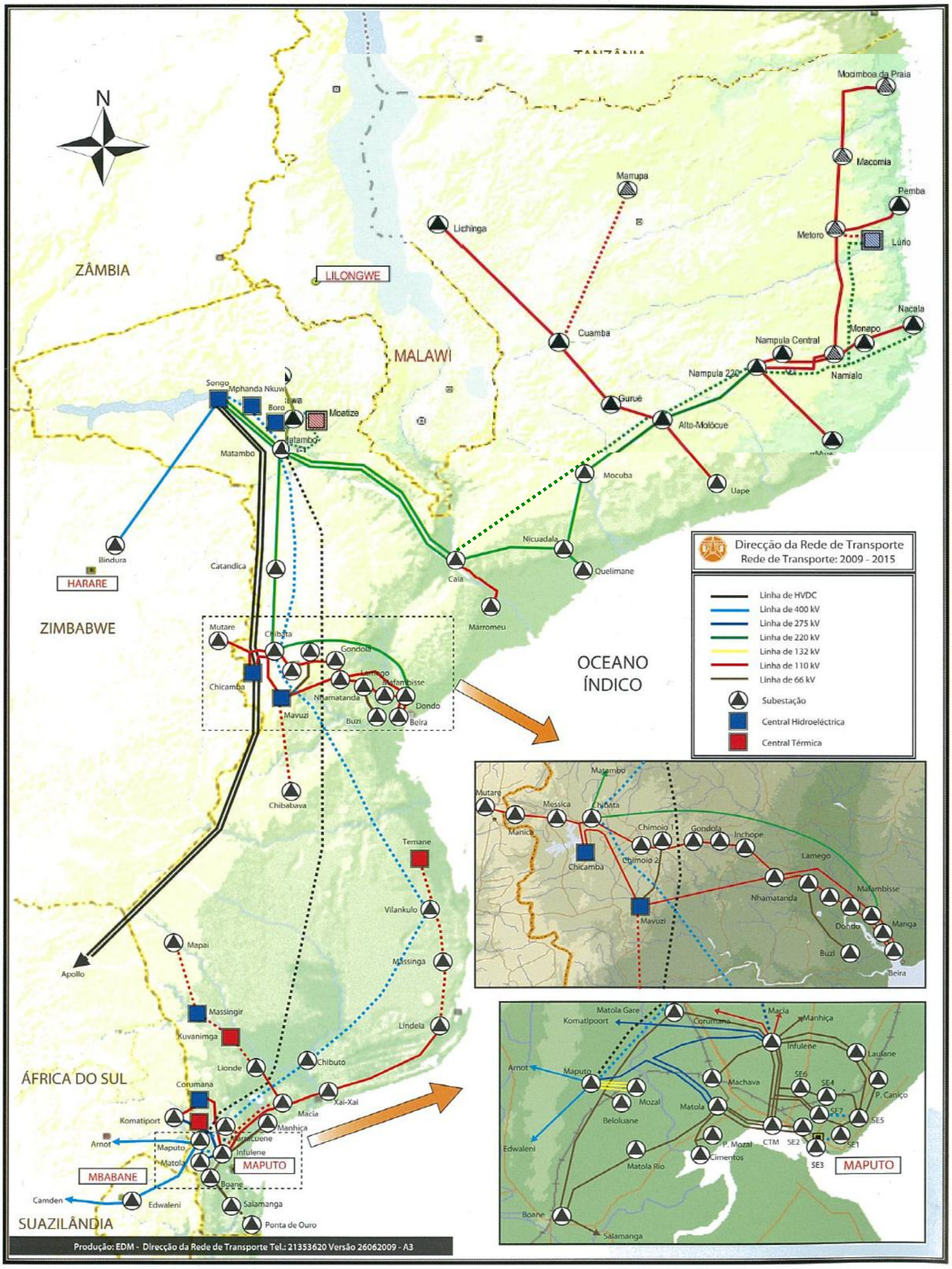
2.2.1 Network System

Figure 2.2-1 is a diagram of the network system in Mozambique. Since Mozambique has a large geographical area extending 2,000 km from north to south, the network system is separated into two systems: one for the southern area and the other for the central and northern areas. These systems are independently operated, without being linked to each other.

The Cahora Bassa Hydroelectric Power Plant ("HCB") with an output of 2,075 MW, the major power source in Mozambique, is linked to the network for the central and northern areas. A part of the generated power is transmitted to the central and northern areas by means of a 220 kV AC transmission line and the power supplied meets the load of these areas. Power is also sent to a neighboring country, Zimbabwe, by means of a 400 kV AC transmission line. However, the majority of the power generated by HCB is sent to the Apollo substation in South Africa by a

535 kV DC transmission line and is then sent to the Southern African Power Pool ("SAPP").

Since the system for the southern area, which covers Maputo, the capital of Mozambique, is located over 1,000 km from HCB, power is imported from SAPP via the networks of South Africa and Swaziland by means of a 400 kV AC transmission line. As a result, more than 80% of domestic demand is supplied by re-imported power.



(Source: Characterization of the transmission network 2010 (EDM))

Figure 2.2-1 Network System Diagram

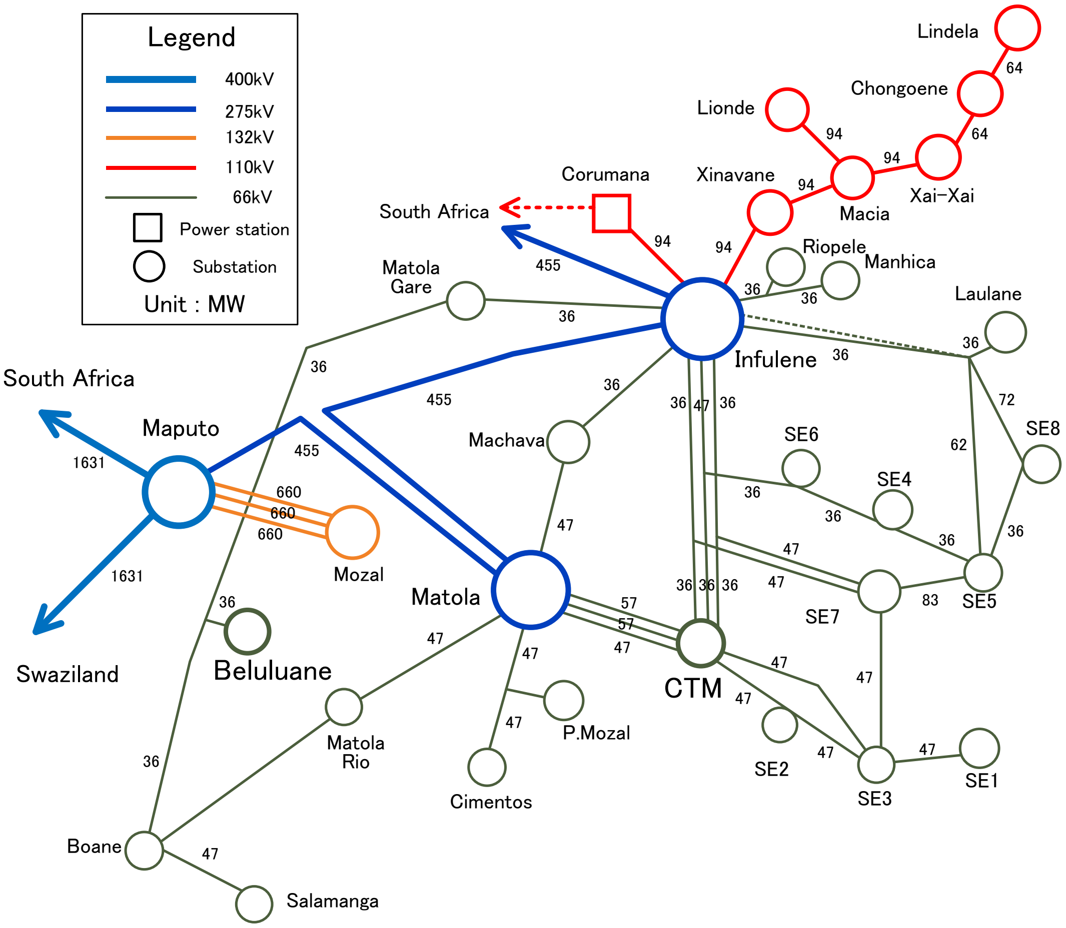
2.2.2 Southern System

Since the southern gas-fired thermal power plant will be situated in Maputo City and its vicinity, it will be connected to the southern system. Figure 2.2-2 shows the southern system and transmitting capacity of the transmission lines.

Power is currently transmitted from the power pool of South Africa to Mozambique via a 400 kV transmission line stepped down from 400 kV to 275 kV and 132 kV at the Maputo substation. Power is transmitted to the Mozal aluminum refinery plant, the biggest user of Mozambique located in the neighborhood of the Maputo substation and accounting for about 70% of the total power demand of the southern system, via three dedicated transmission lines of 132 kV (275 kV designed).

Power to general consumers is further stepped down to 110 kV or 66 kV at the Infulene and Matola substations. The 110 kV voltage is used only in the northern region of the southern system, while the 66 kV system plays a role of power transmission in the other regions. The transmitting capacity of the 66 kV transmission lines is relatively small, standing at 36 MW to 57 MW (with the power factor assumed to be 95%). There are concerns that overloading may occur in the near feature as demands grow.

Turning attention to the two candidate sites for the southern gas-fired thermal power plant, the Beluluane site is located close to the existing Beluluane substation which is connected with the main system through T-shape branching from the 66 kV Matola Gare-Boane line with a transmission capacity of 36 MW. On the other hand, the CTM site is situated adjacent to the existing CTM substation and is connected to eight 66 kV lines with a transmission capacity of 36 to 57 MW.



(Source: Created with reference to PSSE network analysis data provided by EDM) (Unit: MW)

Figure 2.2-2 The Southern System and Transmitting Capacity of Transmission Lines

2.2.3 Facilities in the Southern System

Table 2.2-1 shows the details of the transmission facilities in the southern system. The 400 kV transmission lines are employed as international interconnection lines to South Africa and Swaziland. The 110 kV transmission lines are used as supply lines from the base substations of the system. Furthermore, the 66 kV transmission lines are utilized as local supply lines to meet local demand.

Table 2.2-2 shows the details of the substation facilities. A 400 kV transformer is employed in the Maputo substation to transform the receiving voltage from international interconnection lines into 275 kV or 132 kV for domestic use. There are 275 kV transformers located at the Infulene and Matola substations that are the supply bases of the southern system, and these transformers are used for connection with the 110 kV or 66 kV system, aiming at local supply. In addition, there are transformers with a primary voltage of 110 kV or 66 kV located at substations for distribution to serve general loads.

Table 2.2-1 Details of Transmission Facilities in the Southern System

From	To	Voltage (kV)	Length (km)	Completion Year	Capacity (MVA)
Arnout	Maputo	400	49.9	2000	1293
Edwalene	Maputo	400	58.1	2000	1293
SE Matola	Infulene	275	16	2000	479
Komatipoort	Infulene	275	85	1972	479
SE Maputo	Matola	275	16	2004	479
Motraco (Maputo)	Mozal	275 (132)	3.5	2000	1293
Motraco (Maputo)	Mozal	275 (132)	3.5	2000	1293
Motraco (Maputo)	Mozal	275 (132)	3.5	2000	1293
Infulene	Macia	110	125.0	1983	99
Macia	Chicumbane	110	49.0	1983	99
Macia	Lionde	110	53.0	1983	99
Infulene	Corumana	110	92.0	1984	99
Komatipoort	Corumana	110	40.0	1990	99
Chicumbane	Lindela	110	233.8	2002	68
Infulene	Boane	66	30.0	1982	38
Infulene	2M	66	4.5	2003	50
Infulene	CTM	66	7.5	2004	38
Infulene	CTM	66	7.5	2004	38
Infulene	Manhica	66	62.0	1975,1988, 2004	38
Infulene	Machava	66	7.5	1991	38
Infulene	SE5(Compone)	66	15.1	1990	38
CTM	Matola	66	4.9	1998	60
CTM	SE6	66	3.8	1992	38
CTM	Matola	66	4.9	1998	60
CTM	Matola	66	4.9	1998	60
Matola	Machava	66	2.5	1998	50
Matola	Boane	66	21.9	1998	50
Matola	Cimentos	66	2.7	1998	50
SE6	SE4	66	2.4	1998	38
SE4	SE5	66	4.8	1996	38
CTM	SE3	66	5.4	2001	50
CTM	SE2/3	66	5.4	2001	50
Boane	Salamanga	66	76.7	2002	50
2M	SE7	66	7.9	2004	50
2M	SE7	66	7.9	2004	50
SE7	SE5	66	4.0	2004	88
SE3	SE1	66	2.1	2004	55
SE3	SE7	66	2.2	2005	77
Infulene	CTM	66	7.5	1972	38

(Source: Characterization of the transmission network 2010 (EDM))

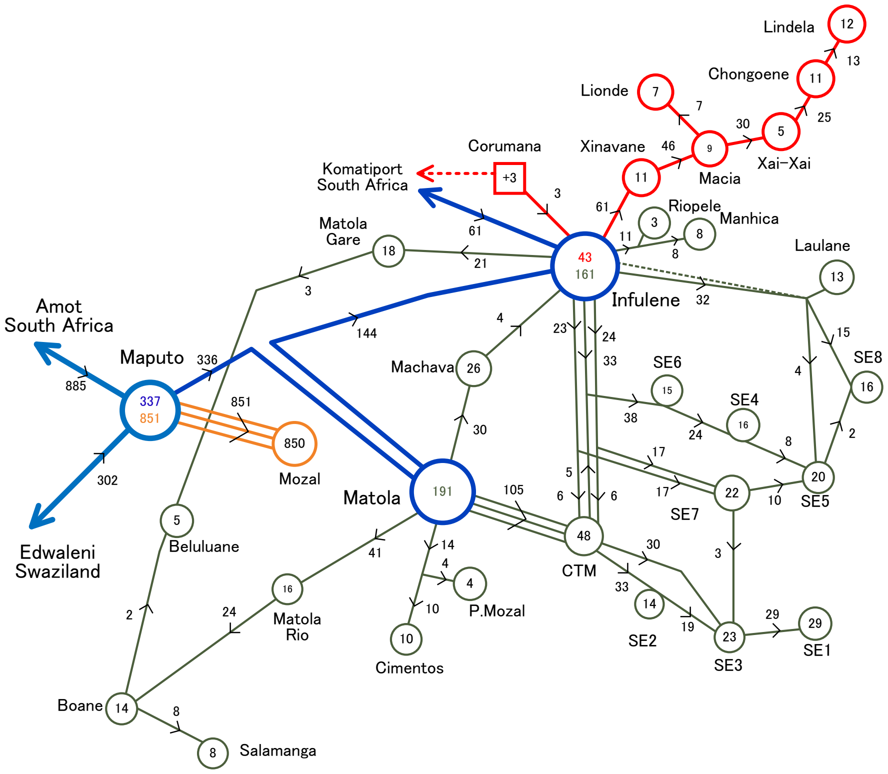
Table 2.2-2 Details of Substation Facilities in the Southern System

Name	Year	Voltage	kV							Total Capacity
			400	330	275	220	132	110	66	
Beluluane	1998	66/11	-	-	-	-	-	-	1	20
Boane	1980	66/33	-	-	-	-	-	-	3	30
Central Termica	1972	66/33	-	-	-	-	-	-	14	60
Infulene	1972	275/110/66	-	-	6	-	-	5	7	372
Lindela	2002	110/33	-	-	-	-	-	1	-	10
Lionde	1985	110/33	-	-	-	-	-	5	-	16
Machava	2004	66/33	-	-	-	-	-	-	3	30
Macia	2002	110/33	-	-	-	-	-	4	-	10
Manhica	2000	66/33	-	-	-	-	-	-	1	30
Manica	1972	110/33	-	-	-	-	-	1		6.3
Maputo (Matraco)	2000	400/275/132	3	-	1	-	3	-	-	1500
Maputo (EDM)	2000	400/275	1	-	1	-	-	-	-	400
Matola 275	2006	275/66	-	-	1	-	-	-	7	320
Matola Rio	2003	66/33	-	-	-	-	-	-	1	10
Matola Gare	2004	66/33	-	-	-	-	-	-	3	30
Salamanga	2002	66/33	-	-	-	-		-	1	10
SE Movel 0 (Xinavane)	1997	110/33/22						1		10
SE Movel 2	2004	110/33	-	-	-	-		1	-	10
SE Movel 3 (SE5)	2004	66/33	-	-	-	-		-	1	20
SE1	2003	66/11	-	-	-	-		-	1	30
SE2	2003	66/11	-	-	-	-		-	1	30
SE3	2001	66/11	-	-	-	-		-	4	60
SE4	1994	66/11	-	-	-	-		-	1	30
SE5	1990	66/11	-	-	-	-		-	5	20
SE6	1994	66/33/11	-	-	-	-		-	1	20
SE7	2004	66/11	-	-	-	-		-	4	30
SE8	2005	66/11	-	-	-	-		-	2	30
SE9	2005	66/11	-	-	-	-		-	2	60

(Source: Characterization of the transmission network 2010 (EDM))

2.2.4 Power Flow

The power flow has been analyzed using the 2011 network data provided by EDM. The analysis results are shown in Figure 2.2-3. The maximum power flow by voltage class is provided in Table 2.2-3. The maximum power flow of the 400 kV transmission line is 885 MW on the Maputo-Amot line of the interconnection line with South Africa. This allows a sufficient margin to meet the transmitting capacity of 1,631 MW. Similarly, both the 132 kV and 110 kV transmission lines have a wide margin of transmitting capacity and have not lead to any problems such as power overloads. In the 66 kV transmission lines, on the other hand, the utilization rate of the facilities tends to be higher on the transmission lines where the power transmitting capacity is as small as 36 MW (power factor assumed at 0.95). Above all, the power flow of the transmission line branching off at the Infulene-CTM line and leading to the SE6 substation is 38 MW, which is slightly higher than the transmitting capacity. However, power flow exceeding the capacity is found only in this transmission line.



(Source: Analysis results using PSSE network data provided by EDM)

Figure 2.2-3 Power Flow in 2011 (Unit: MW)

Table 2.2-3 Maximum Power Flow by Voltage Class

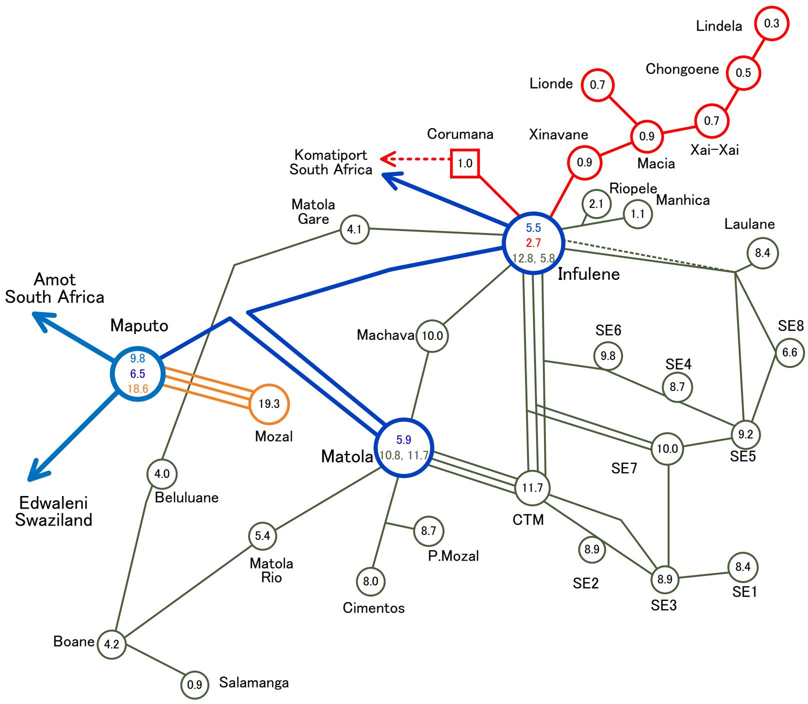
Voltage (kV)	Line Section	A. Power Flow (MW)	B. Capacity (MW)	Utilization Rate (%) (= A/B)
400	Maputo-Amot	885	1631	54
275	Maputo-Matola	336	455	74
132	Maputo-Mozal	284	660	43
110	Infulene-Xinavane	61	94	65
66	Branching point-SE6	38	36	106

(Source: Analysis results using PSSE network data provided by EDM)

2.2.5 Fault Current

Fault current analysis has been done using the 2011 network data provided by EDM. The results of the analysis are provided in Figure 2.2-4 and the maximum fault current by voltage class is illustrated in Table 2.2-4.

The power system of the country is small-scaled and the southern system does not have a main power supply. For these reasons, the fault current is as small as about 10 kA for each voltage class, except on the Mozal 132 kV bus. Mozal is located close to the 400 kV Maputo substation and is connected with three separate transmission lines. For this reason, Mozal is expected to produce a fault current as large as 19.3 kA when faults occur.



(Source: Analysis results using PSSE network data provided by EDM)

Figure 2.2-4 Fault Current in 2011 (Unit: kA)

Table 2.2-4 Maximum Fault Current by Voltage Class

Voltage (kV)	Station	Fault current (kA)
400	Maputo	9.8
275	Maputo	6.5
132	Mozal	19.3
110	Corumana	1.0
66	Infulene	12.8

(Source: Analysis results using PSSE network data provided by EDM)

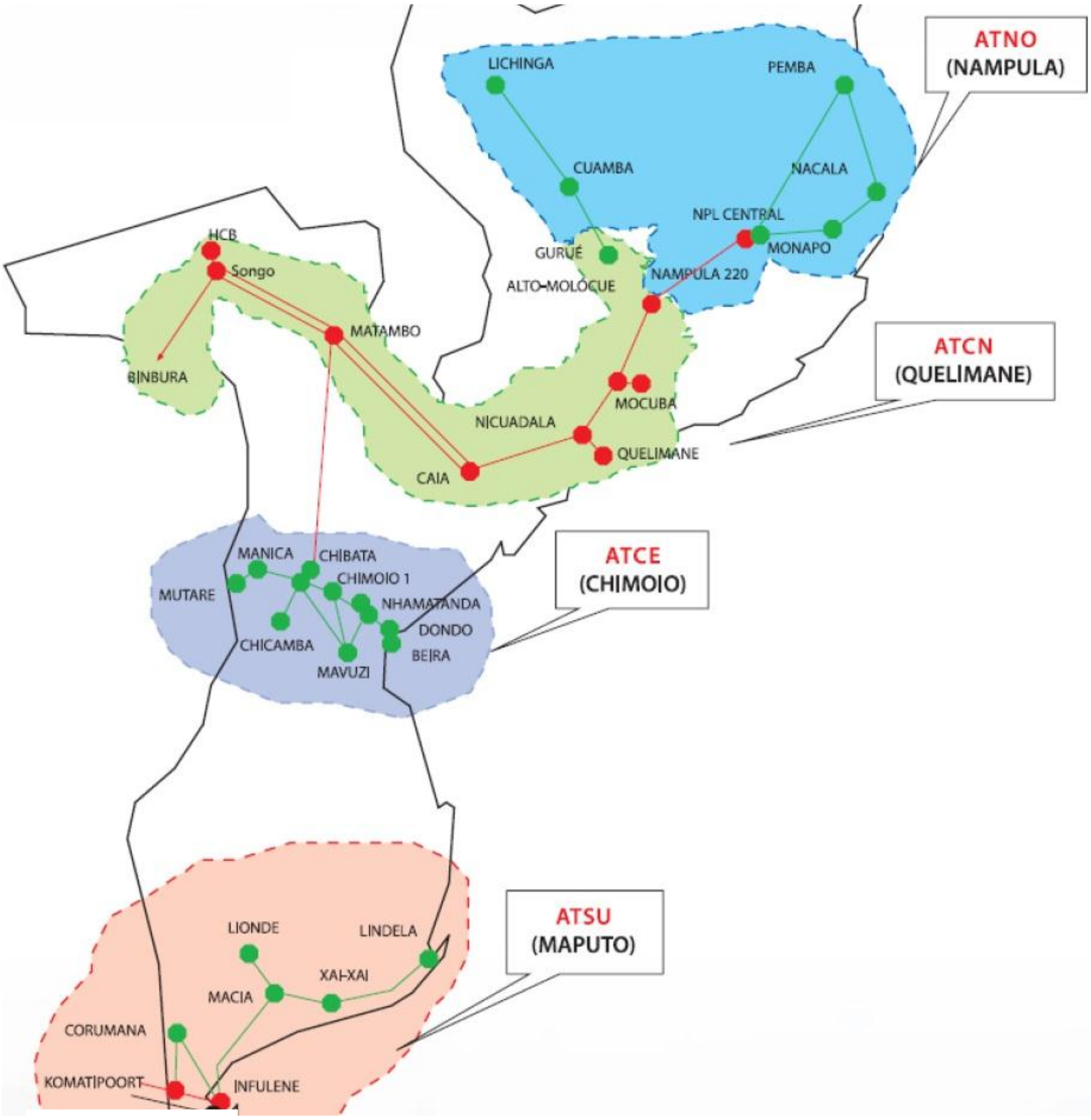
2.3 Power Demand Forecast and Development Plan

2.3.1 Geographical Scope

The national power system in Mozambique is geographically separated into three regional systems of the Northern, Central, and Southern regional systems respectively. There is a 220kV interchange transmission line between the Northern and Central regional systems while the Southern regional system is independently operated without any interchange power from the others, but it is interconnected with the South African grid with the supplied power originally generated at Cahora Bassa HPP (2,075 MW).

The Northern regional system is operated by ATNO (Nampula) while the Central regional system is operated by the two operators of ATCN (Quelimane) and ATCE (Chimoio) whose supply areas are geographically defined. In the Southern regional system, ATSU (Maputo) is the only system operator (refer to Figure 2.3-1). In making power demand forecasts, therefore, power consumption is estimated by each regional system and summed up as the national power demand for the whole country.

The Backbone Transmission Project is planned to come into operation in the early 2020s, although starting operation had originally been expected in 2017. Thereby, the desired power transmission line between the Central and Southern regional systems is no longer expected to start during this decade to enable central-to-south power transmission by using some large hydro and/ or coal-fired power sources to be developed in Tete province. The synchronization and implementation of a variety of billion-dollar projects (like long-distance-and-multi-circuit transmission projects and large scale hydro/thermal power projects) is quite difficult particularly from a financial viewpoint, and EDM has expressed its opinion that many projects could be increasingly delayed. In this context, it is recommended that power development planning in the Southern regional system be considered independently from other regional systems with the pursuit of supply/demand balance within the Southern system only.



(Source: EDM)

Figure 2.3-1 Regional Power Systems in Mozambique

2.3.2 Current Supply/demand Status

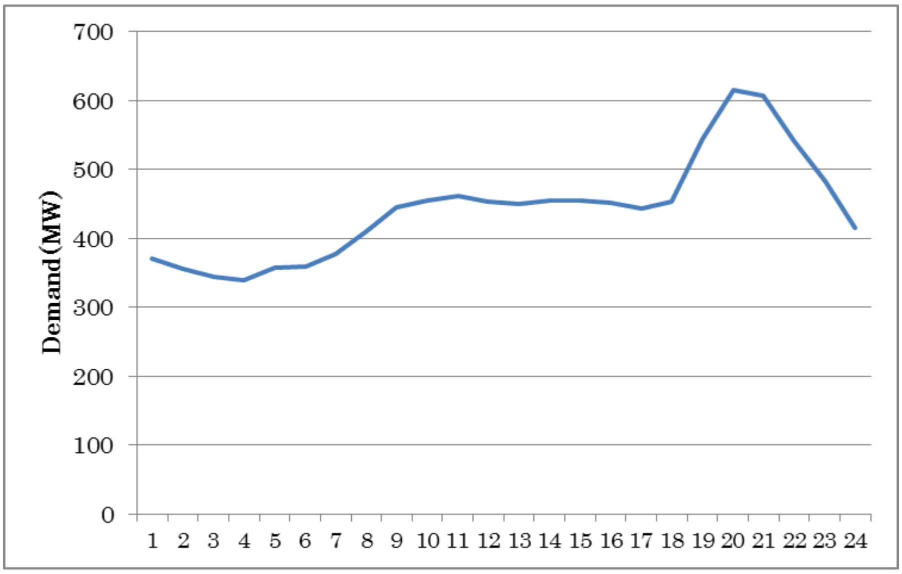
Table 2.3-1 shows the data of power supply/demand balance across the country from 2007 to 2011. According to the statistics, the growth rate of power consumption over that period was 11.6% per annum while that of maximum demand was 14.1% per annum. Load factor tended to decrease and reached by 75% in 2011. This implies that power consumption during peak time was relatively increased and consequently load factor went down. However, 75% is still a large number compared to other developing countries. It is, therefore, considered that load shedding has frequently taken place during peak time in summer particularly and consequently the number of load factor remains high.

Maximum demand occurs every November in the summer. It also tends to peak at around 8 pm. Mozambique has a similar lighting-demand structure as other developing countries (refer to Figure 2.3-2).

Table 2.3-1 Power Supply/Demand Balance in Mozambique (2007 to 2011)

	2007	2008	2009	2010	2011
Peak Demand (MW)	364	416	481	534	616
Load Factor	82%	83%	76%	76%	75%
Electricity Energy (GWh)	2,622	3,032	3,193	3,553	4,068
Generation	*224*	*352*	*386*	*368*	*389*
Purchase (mainly from HCB)	*2,381*	*2,653*	*2,775*	*3,118*	*3,588*
Imports (Mainly from SA)	*17*	*27*	*39*	*67*	*91*
Loses (T/D lins) ※	-20	-23	-26	-27	-31
Saleable Energy (GWh)	2,099	2,362	2,679	2,973	3,358
Distribution	*1,561*	*1.632*	*2,077*	*2,297*	*2,547*
Large Customers	*15*	*60*	*88*	*96*	*101*
Exports	*523*	*670*	*514*	*580*	*710*

(Source: EDM Demand Forecast Report, partially modified by the JICA Study Team)



(Source: EDM)

Figure 2.3-2 Load Profile for Maximum Daily Demand (November 16, 2011)

Regional power demand is shown in Table 2.3-2, however the figures of total demand are different from those in "Saleable Energy" in Table 2.3-1. One possible reason for this difference is that Table 2.3-1 has counted power consumption by Large Customers whereas Table 2.3-2 has not. Meanwhile, the Southern region, including the capital city Maputo, consumes approximately 2/3 of the electric energy of the entire country. This means that ensuring a stable supply of power to the Maputo area is essential for the further development of the country.

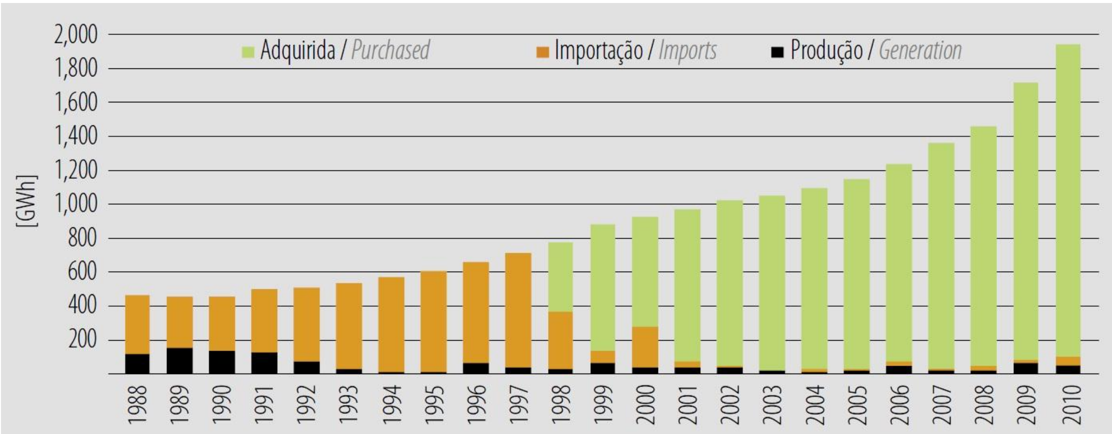
Table 2.3-2 Regional Power Demand (GWh)

	2005	2006	2007	2008	2009	2010	2011	AGR*
South	1,153	1,239	1,373	1,550	1,731	1,910	2,095	10.5%
Center	393	427	467	497	558	603	739	11.1%
North	190	218	244	255	302	363	428	14.5%
Total	1,736	1,884	2,084	2,302	2,591	2,876	3,262	11.1%

(Source: EDM)

Note: * Annual Growth Rate

Taking the Southern region's power supply/demand balance into account as shown in Figure 2.3-3, power purchases from Cahora Bassa HPP (2,075 MW) have been ramped up since 1988 when EDM started buying electricity from the said HPP. In 2011, EDM bought 1,800 GWh of electricity energy from Cahora Bassa HPP, accounting for more than 90% of the Southern region's power demand.



(Source: EDM Statistic Report 2011)

Figure 2.3-3 Power Supply Structure in the Southern Regional System

Under the power purchase agreement between EDM and Cahora Bassa HPP, EDM has the right to increase the amount of "Additional Power" on a mutual agreement basis while 300 MW of firm power is securely fixed. Table 2.3-3 shows both the actual data and projection of purchased power from Cahora Bassa HPP, illustrating that the amount of purchased power has increased from year to year. Moreover, EDM plans to increase purchased power by 600 MW in 2015 and subsequently by 700 MW in 2015 or later. However, there appears to be a low likelihood of buying additional electricity after 2015 because of insufficient surplus hydro energy.

Table 2.3-3 Power Purchased from Cahora Bassa HPP

Year	Firm Power (MW)	Additional Power (MW)	Energy (GWh)
2008	300	90	2,635
2009	300	100	2,775
2010	300	100	3,022
2011	300	200	3,549
2012 (planned)	300	200	4,205
2013 (planned)	300	200	4,205
2014 (planned)	300	300	4,993
2015 - (planned)	300	400	5,782

(Source: EDM)

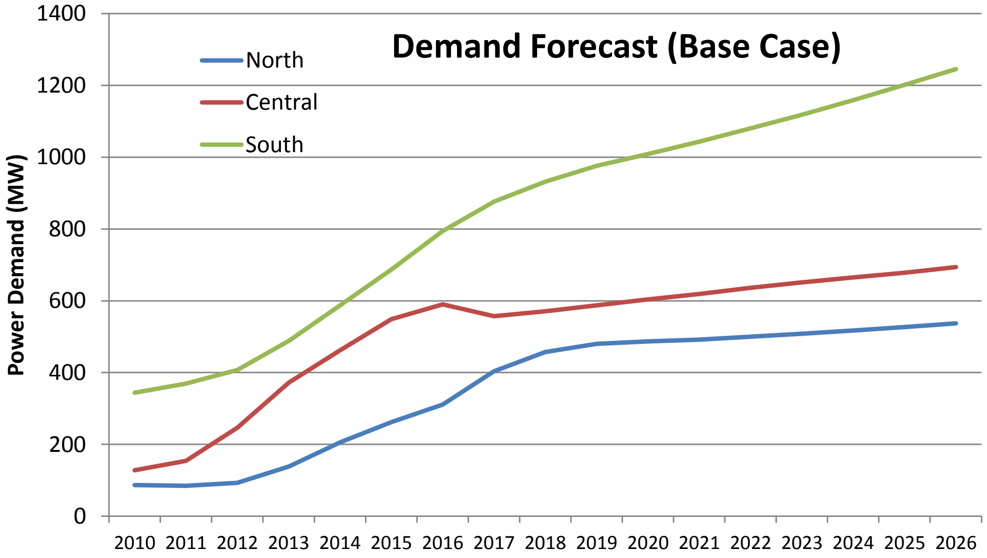
2.3.3 Power Demand Forecast

Power demand forecasts are referred to in the report of Technical Assistance to Strengthen EDM's Capacity for Investment and Network Development Planning – Master Plan Update Project, Load Forecast Report, August 7, 2012, funded by IDA, AFD, EIB, and AGFUND in the course of the Mozambique National Energy Development and Access Program ("NEDAP", 5 years, US$215 million). The report foresees power demands for general customers and large customers respectively, and shows the total expected power demand from 2012 to 2026. Power demand for general customers is calculated with a statistical formula using several economic parameters like GDP growth rate, GDP elasticity, and electricity price elasticity. The figures of GDP growth rate are derived from official announcements of the Ministry of Planning and Investment assuming that it remains 6%/year on average across the country, and partly 7%/year in the higher developing areas and 5%/year in other slower growing areas.

In respect to power demand forecasts for large consumers, each and every potential key project consuming power at more than 2 MW has been listed and summarized. The key projects are aluminum smelters, natural gas/ coal/ other natural resource developers, large agro-industries and relevant infrastructure industries.

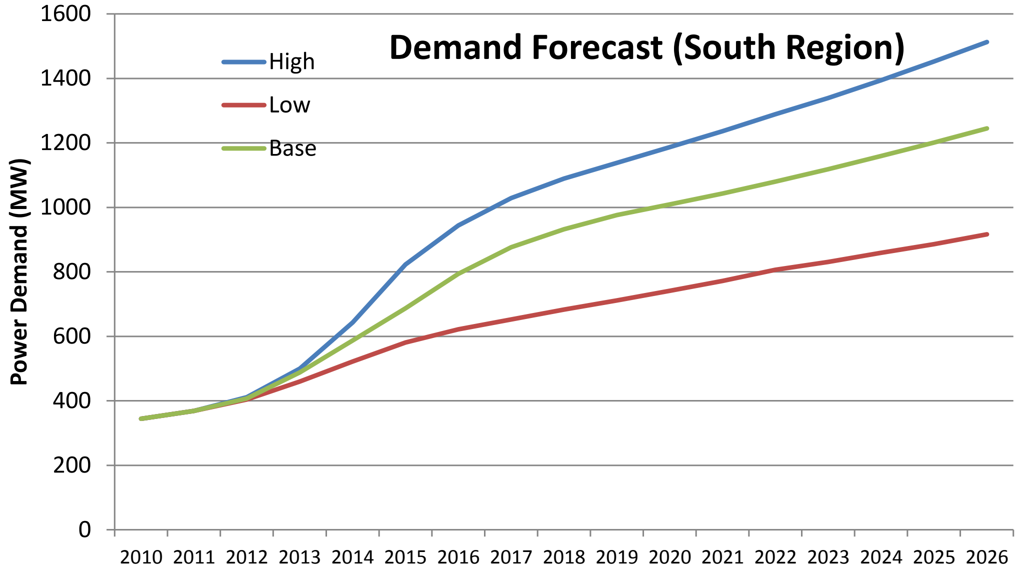
The report also refers to three cases of demand forecast such as Base case, High case, and Low case in consideration of any deviation of power demand for key projects and regional economic growth.

Figure 2.3-4 shows three regional demand forecasts. The Southern region, including Maputo city, is one of the fastest growing areas in Mozambique where power demand is expected to increase by 2.2 times in 5 years and 2.7 times in 10 years. Figure 2.3-5 shows the Southern region's demand forecast by each economic development case.



(Source: Master Plan Update Project, Load Forecast Report, August 7, 2012)

Figure 2.3-4 Regional Demand Forecast by Base Case



(Source: Master Plan Update Project, Load Forecast Report, August 7, 2012)

Figure 2.3-5 Southern Region's Demand Forecast by Development Case

2.3.4 Power Development Plan

(1) Outline of EDM's Power Development Plan

EDM and Norconsult have jointly prepared the "Generation Master Plan for the Mozambican Power Sector" of which the first draft was issued in July 2009. The Master Plan reflects large-scale hydropower projects in the Zambezi river system and coal-fired power projects adjacent to the planned coal mining projects in Tete province, synchronizing the construction of the DC/AC transmission line projects with a total capacity of 6,000 MW. This is the so-called Backbone Transmission Project which would substantially have a strong impact on EDM's power development plan. With huge financial costs of approximately US$2.8 billion, the Backbone Project is a massive multi stakeholders' project. Therefore, EDM is of the opinion that some relevant institutions have not anticipated the timely implementation of the project. It is, for example, assumed that the coal-fired power projects in Tete province are vulnerable in their timely operation as the project owner, Vale, one of the world's biggest mining companies, may be significantly affected by the status of their core mining business and may potentially make the decision to delay the project if global coal markets fall. In this regard, the Backbone Project is NOT a reliable project for the purpose of stable power supply at this point in time.
Assuming all the power generation projects along with the Backbone Project are successfully put into operation, the power output from the projects will largely exceed the power demand in Mozambique. This requires careful preparation and arrangements between EDM and the owners/operators of the Backbone Project in terms of sale of surplus energy to other countries, long-term shutdown of aged power plants, and particularly power system operation including interconnections with neighboring countries. However, such preparation work has not progressed yet because the projects have low likelihood of implementation so far.

In this regard, EDM is still seeking a practical power development plan[1] with no uncertainty of the above-mentioned issues. At the working level, Figure 2.3-4 and Figure 2.3-5 are considered as a likely power development scenario of power supply/demand balance in kW and kWh. In this plan, part of the generation capacity of Mpanda Nkuwa HPP (1,500 MW) is expected to be put into operation in 2019 while other large projects are still under consideration on whether or not to reflect to EDM's power development plan.

In addition, some medium-scaled hydropower projects across the countries are planned to start operation during the next few decades. As to thermal power projects, two IPPs such as Benga

[1]The CTM is to be commissioned in 2016 under the EDM's practical power development plan. It is emphasized that even if EDM is successfully able to start commissioning the CTM project in 2016, the power shortage will not be solved. This report, however, indicates that the commissioning year of the CTM project will be 2018 based on a realistic schedule.

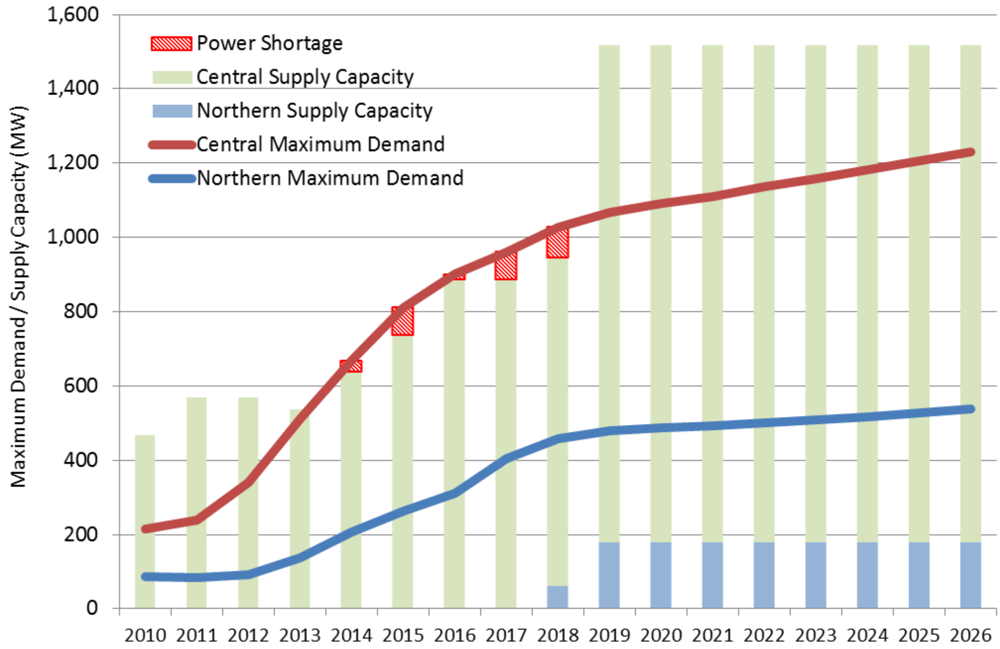
(coal, 250 MW) and Moatize (coal, 300 MW) are to start operations in 2016 with only 50 MW respectively. In this power development plan, it is worth mentioning that the assumption was made that the Backbone Transmission Project was not expected to start operation. It was assumed that only the interconnected transmission line would be in operation, by which electricity from Cahora Bassa HPP is transferred to the Southern regional system via the South African Power Grid. Therefore, electricity generated by the power projects planned in the Northern/Central areas is to be transferred and then distributed to the Central and Northern regional systems first through the existing interchange transmission line. Subsequently, remaining electricity, that may be limited, could be transferred to the Southern regional system via the South African Power Grid.

(2) Supply/Demand Balance in kW (Capacity Balance)

Since there is no interchange transmission line between the Southern regional system and the Central/Northern regional systems, each regional power supply/demand balance was examined independently.

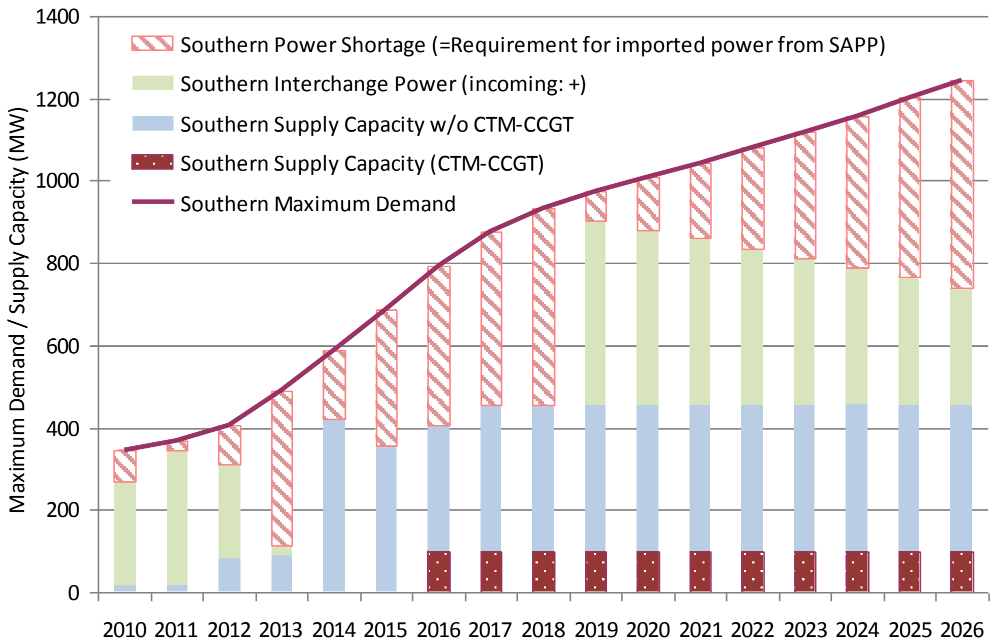
Figure 2.3-6 is a cumulative graph showing maximum power demand forecast and supply capacity planned (with some actual figures partially recorded) from 2010 to 2026 in the Northern/Central areas. In 2014 to 2018, minor power shortage is expected, however power generation capacity appears to be strong after 2019 when Mpanda Nkuwa HPP and other projects start commercial operation. However, the question remains about the reserve margin of the Northern/Central systems to ensure stable power supply. Since these supply/demand balances have been examined on installed capacity basis, it would be better to consider a proper number of reserve margin. Because the data of planned/forced outages and transmission/distribution losses are not available in the Mozambican power sector, the JICA Study Team has assumed that the desirable number of reserve margin is 1.2 from its technical experience in power system planning. In consideration of the reserve margin of 1.2, in the period of 2014 to 2018 there would be severe power shortages during the peak time/season and moreover in the period after 2019 there would no longer be any electric power transferred to the Southern regional system.

In the Southern regional system, power supply/demand in kW will not be in equilibrium without importing peak power from the South African Power Grid at the peak time over all periods of the analysis. The capacity of CTM-CCGT can make a great contribution to relieve the dependency of Mozambique from importing costly peak power (refer to Figure 2.3-7). Meanwhile, the amount of imported peak power from the South African Power Grid will be 400MW at most, and that is quite small compared to the power demands of South Africa.



(Source: JICA Study Team)

Figure 2.3-6 Northern/Central Regions' Supply/Demand Balance in kW (Demand: Base)

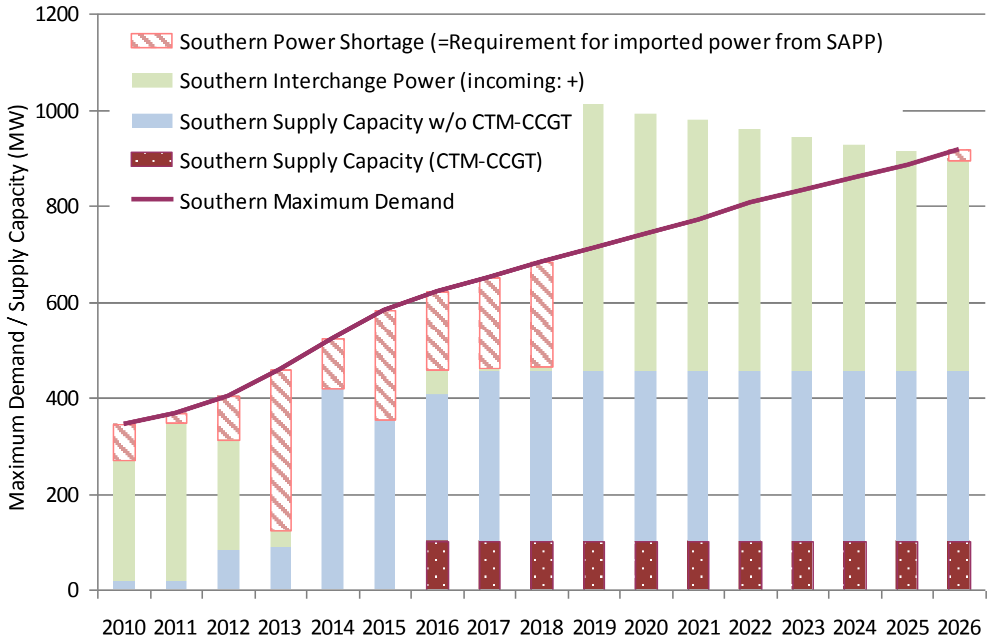


(Source: JICA Study Team)

Figure 2.3-7 Southern Regions' Supply/Demand Balance in kW (Demand: Base)

In the low demand case, power supply/demand can be equalized with less imported peak power compared to the base demand case. However, the chance remains of peak power shortage potentially after 2019 even if CTM-CCGT starts operation in 2016.

In summary, CTM-CCGT is essential to secure the capacity balance in the Southern regional system until 2026 at the least. This project can contribute to reduce the likelihood of any power shortages during peak time/season and the amount of importing costly peak power from the South African Power Grid.



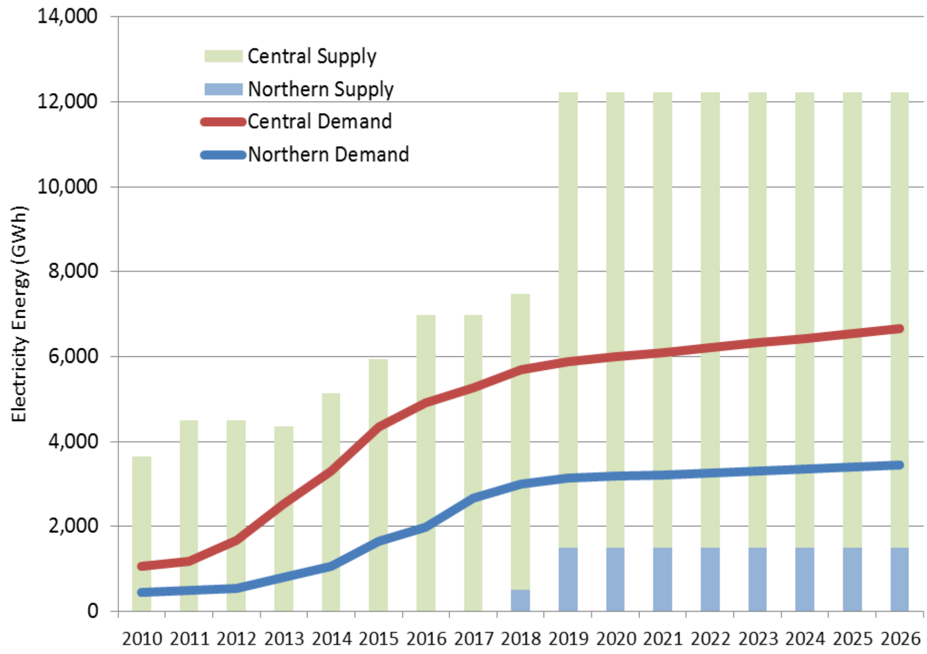
(Source: JICA Study Team)

Figure 2.3-8 Southern Region's Supply/Demand Balance in kW (Demand: Low)

(3) Supply/Demand Balance in kWh (Energy Balance)

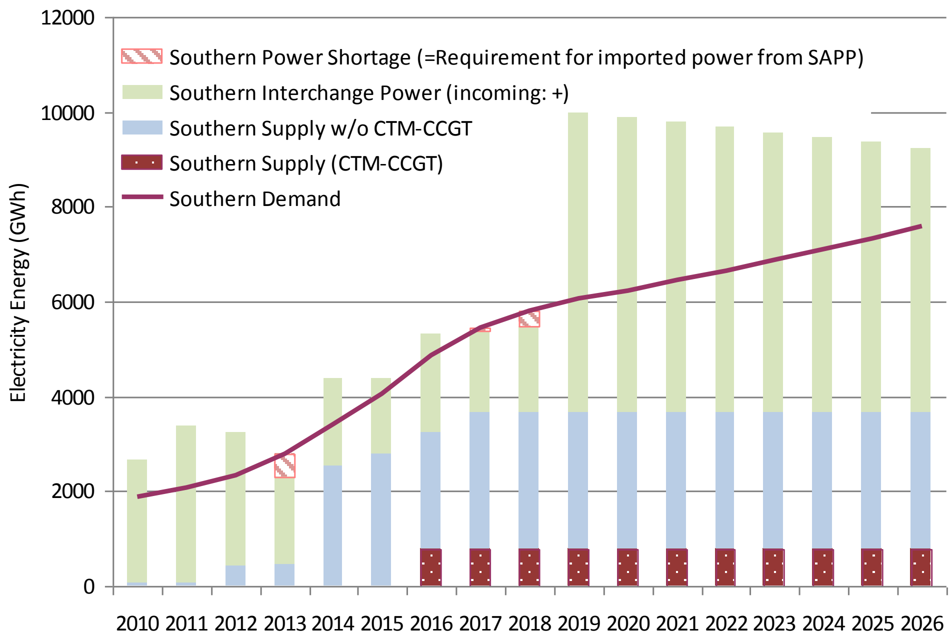
Figures 2.3-9 and 2.3-10 are cumulative graphs showing power consumption forecast and power supply planned (with some actual figures partially recorded) from 2010 to 2026 in the Northern/Central areas. Cahora Bassa HPP (in operation) and Mpanda Nkuwa HPP (expected operation start in 2019) are to contribute sufficient power supply to the Northern/Central areas. However, one point to be considered is that this estimate was made based on installed capacity and higher plant factor (=0.95) according to EDM's plan.

Figure 2.3-11 illustrates the energy demand/ supply balance in the Southern region. Even if the power plants were operating at their full capacity, the Southern regional system would face a critical power shortage situation in the period until 2018 just before Mpanda Nkuwa HPP starts operation. After 2019, it is assumed that there is still the potential of a lack of power supply in the South, provided that the power plants are operated in an ordinary manner with time for regular maintenance and monitoring the actual conditions of river water flow to the dams. In any case, the electricity energy generated at CTM-CCGT (assumed at 100 MW) is essential for securing stable energy supply.



(Source: JICA Study Team)

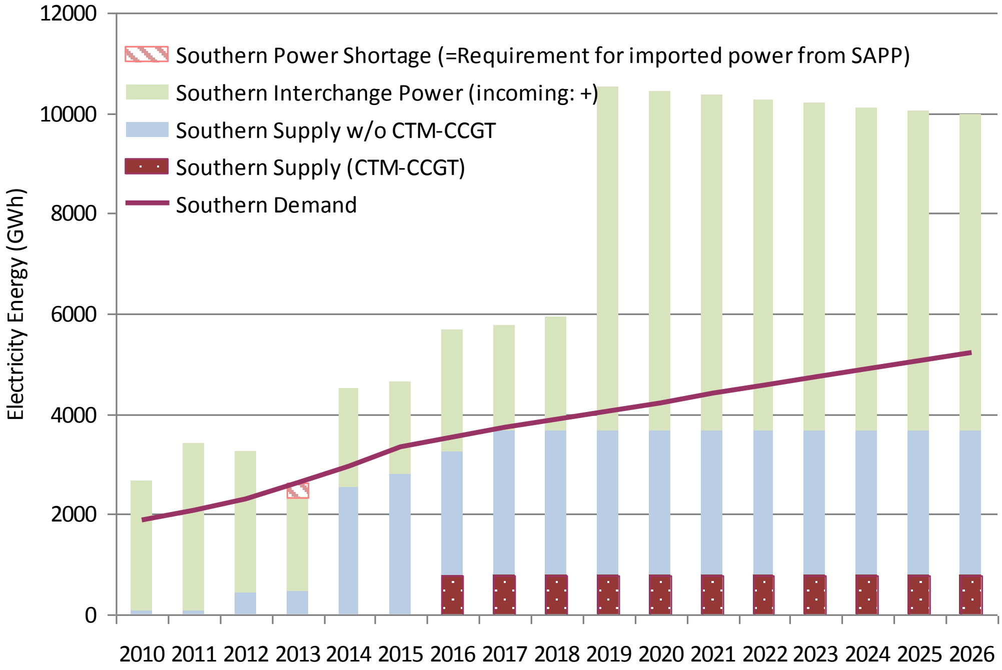
Figure 2.3-9 Northern/Central Regions' Supply/Demand Balance in kWh (Demand: Base)



(Source: JICA Study Team)

Figure 2.3-10 Southern Region's Supply/Demand Balance in kWh (Demand: Base)

For the case of low demand, Figure 2.3-11 presents the supply/demand balance in kWh in the Southern regional system. It is clearly shown that over the period of 2010 to 2026 the amount of power shortage can be decreased. After 2019, it is expected that lower efficient thermal power projects need to be in standby mode and generate electricity during peak time/season. The CTM-CCGT project, with its much higher thermal efficiency, would need to continue operation as a base power supply source even in the case of low demand.



(Source: JICA Study Team)

Figure 2.3-11 Southern Region's Supply/Demand Balance in kWh (Demand: Low)

Table 2.3-4 Supply/Demand Balance in kW (Demand: Base Case)

	(Unit: MW)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Northern	Maximum Demand (Base)	87	85	93	138	206	262	311	404	457	480	487	492	500	508	517	527	537
	Supply Capacity	0	0	0	0	0	0	0	0	60	180	180	180	180	180	180	180	180
	-Alto Malema HPP (60 MW)									60	60	60	60	60	60	60	60	60
	-Lurio HPP (120 MW)										120	120	120	120	120	120	120	120
	Interchange Power (incoming: +)	87	85	93	138	175	188	296	329	315	300	307	312	320	328	337	347	357
	Balance (shortage: -)	0	0	0	0	-31	-74	-15	-75	-82	0	0	0	0	0	0	0	0
Central	Maximum Demand (Base)	128	154	246	372	462	549	590	557	571	587	604	619	636	651	665	678	694
	Supply Capacity	468	568	568	537	637	737	886	886	886	1,336	1,336	1,336	1,336	1,336	1,336	1,336	1,336
	-Chicamba HPP (38 MW)	*38*	*38*	*38*	*12*	*12*	*12*	*44*	*44*	*44*	*44*	*44*	*44*	*44*	*44*	*44*	*44*	*44*
	-Mavuzi HPP (42 MW)	*30*	*30*	*30*	*25*	*25*	*25*	*42*	*42*	*42*	*42*	*42*	*42*	*42*	*42*	*42*	*42*	*42*
	-Cahora Bassa HPP (2,075 MW)	*400*	*500*	*500*	*500*	*600*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
	-Cahora Bassa North HPP (1,245 MW)																	
	-Mpanda Nkuwa HPP (1,500 MW)										*150*	*150*	*150*	*150*	*150*	*150*	*150*	*150*
	-Benga Coal TPP (250 MW)							*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*
	-Moatize Coal TPP (300 MW)							*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*
	-Mavuzi HPP (60 MW)																	
	-Lupanta HPP (600 MW)										*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*
	-Boroma HPP (200 MW)										*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
	Interchange Power (incoming: +)	-340	-414	-322	-165	-175	-188	-296	-329	-315	-749	-732	-717	-700	-685	-671	-658	-642
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern	Maximum Demand (Base)	344	369	407	488	587	687	794	876	932	976	1,009	1,043	1,080	1,118	1,159	1,201	1,245
	Supply Capacity	16	16	81	88	421	356	406	456	456	456	456	456	456	456	456	456	456
	-Corumana HPP (14 MW)	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*
	-CTM Existing GTPP (52 MW)					*50*	*50*											
	-Temane GTPP (7-62 MW)				*7*	*12*	*12*	*12*	*62*	*62*	*62*	*62*	*62*	*62*	*62*	*62*	*62*	*62*
	-Aggreko GTPP (65 MW)			*65*	*65*	*65*												
	-Ressano Sasol-EDM (140 MW)					*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*
	-Ressano Gigawatt-Mozambique (100 MW)					*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
	-Kuvaninga GTPP (38 MW)					*38*	*38*	*38*	*38*	*38*	*38*	*38*	*38*	*38*	*38*	*38*	*38*	*38*
	-Massingir HPP (30 MW)																	
	-CTM CCGT (100 MW)							*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
	Interchange Power (incoming: +)	253	329	229	27	0	0	0	0	0	449	425	405	380	357	334	311	285
	Power Shortage (= Requirement for imported power from SAPP)	75	24	97	373	166	331	388	420	476	71	128	182	244	305	369	434	504
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (Country)	Maximum Demand	559	608	746	998	1,255	1,498	1,695	1,837	1,960	2,043	2,100	2,154	2,216	2,277	2,341	2,406	2,476
	Supply Capacity	484	584	649	625	1,058	1,093	1,292	1,342	1,402	1,972	1,972	1,972	1,972	1,972	1,972	1,972	1,972
	Power Shortage (= Requirement for imported power from SAPP)	75	24	97	373	166	331	388	420	476	71	128	182	244	305	369	434	504
	Balance	0	0	0	0	-31	-74	-15	-75	-82	0	0	0	0	0	0	0	0

(Source: EDM and some estimations by the JICA Study Team)

Table 2.3-5 Supply/Demand Balance in kWh (Demand: Base Case)

	(Unit: GWh)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Northern	Demand (Base)	447	494	531	808	1,066	1,655	1,991	2,661	3,003	3,147	3,186	3,208	3,252	3,297	3,346	3,397	3,450
	Supply	0	0	0	0	0	0	0	0	499	1,498	1,498	1,498	1,498	1,498	1,498	1,498	1,498
	-Alto Malema HPP (60 MW)									*499*	*499*	*499*	*499*	*499*	*499*	*499*	*499*	*499*
	-Lurio HPP (120 MW)										*999*	*999*	*999*	*999*	*999*	*999*	*999*	*999*
	Interchange Power (incoming: +)	447	494	531	808	1,066	1,655	1,991	2,661	2,504	1,649	1,688	1,710	1,754	1,799	1,848	1,899	1,952
Central	Demand (Base)	617	678	1,143	1,714	2,229	2,699	2,918	2,614	2,675	2,742	2,818	2,877	2,952	3,020	3,083	3,134	3,204
	Supply	3,644	4,485	4,485	4,357	5,145	5,934	6,968	6,968	6,968	10,712	10,712	10,712	10,712	10,712	10,712	10,712	10,712
	-Chicamba HPP (38 MW)	*156*	*156*	*156*	*49*	*49*	*49*	*181*	*181*	*181*	*181*	*181*	*181*	*181*	*181*	*181*	*181*	*181*
	-Mavuzi HPP (42 MW)	*124*	*124*	*124*	*103*	*103*	*103*	*173*	*173*	*173*	*173*	*173*	*173*	*173*	*173*	*173*	*173*	*173*
	-Cahora Bassa HPP (2,075 MW)	*3,364*	*4,205*	*4,205*	*4,205*	*4,993*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*	*5,782*
	-Cahora Bassa North HPP (1,245 MW)																	
	-Mpanda Nkuwa HPP (1,500 MW)										*1,248*	*1,248*	*1,248*	*1,248*	*1,248*	*1,248*	*1,248*	*1,248*
	-Benga Coal TPP (250 MW)							*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*
	-Moatize Coal TPP (300 MW)							*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*	*416*
	-Mavuzi HPP (60 MW)																	
	-Lupanta HPP (600 MW)										*1,664*	*1,664*	*1,664*	*1,664*	*1,664*	*1,664*	*1,664*	*1,664*
	-Boroma HPP (200 MW)										*832*	*832*	*832*	*832*	*832*	*832*	*832*	*832*
	Interchange Power (incoming: +)	-3,027	-3,807	-3,342	-2,643	-2,916	-3,235	-4,050	-4,354	-4,293	-7,970	-7,894	-7,835	-7,760	-7,692	-7,629	-7,578	-7,508
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern	Demand (Base)	1,897	2,085	2,324	2,784	3,402	4,070	4,855	5,460	5,799	6,055	6,242	6,438	6,646	6,864	7,095	7,337	7,591
	Supply	66	66	66	95	2,188	2,805	3,254	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680
	-Corumana HPP (14 MW)	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*	*66*
	-CTM Existing GTPP (52 MW)					*146*	*350*											
	-Temane GTPP (7-62 MW)				*29*	*51*	*76*	*87*	*513*	*513*	*513*	*513*	*513*	*513*	*513*	*513*	*513*	*513*
	-Aggreko GTPP (65 MW)																	
	-Ressano Sasol-EDM (140 MW)					*777*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*	*1,165*
	-Ressano Gigawatt-Mozambique (100 MW)					*832*	*832*	*832*	*832*	*832*	*832*	*832*	*832*	*832*	*832*	*832*	*832*	*832*
	-Kuvaninga GTPP (38 MW)					*316*	*316*	*316*	*316*	*316*	*316*	*316*	*316*	*316*	*316*	*316*	*316*	*316*
	-Massingir HPP (30 MW)																	
	-CTM TPP (100 MW)							*788*	*788*	*788*	*788*	*788*	*788*	*788*	*788*	*788*	*788*	*788*
	Interchange Power (incoming: +)	2,580	3,313	2,811	1,835	1,850	1,580	2,059	1,693	1,789	6,321	6,206	6,125	6,006	5,893	5,781	5,679	5,556
	Power Shortage (= Requirement for imported power from SAPP)	0	0	0	854	0	0	0	87	330	0	0	0	0	0	0	0	0
	Balance	749	1,294	553	0	636	315	458	0	0	3,946	3,644	3,367	3,040	2,709	2,366	2,022	1,645
Total (Country)	Maximum Demand	2,961	3,257	3,998	5,306	6,697	8,424	9,764	10,735	11,477	11,944	12,246	12,523	12,850	13,181	13,524	13,868	14,245
	Supply Capacity	3,710	4,551	4,551	4,452	7,333	8,739	10,222	10,648	11,147	15,890	15,890	15,890	15,890	15,890	15,890	15,890	15,890
	Power Shortage (= Requirement for imported power from SAPP)	0	0	0	854	0	0	0	87	330	0	0	0	0	0	0	0	0
	Balance	749	1,294	553	0	636	315	458	0	0	3,946	3,644	3,367	3,040	2,709	2,366	2,022	1,645

(Source: EDM and some estimations by the JICA Study Team)

2.4 Outline of Cooperation Projects Implemented by Other Donor Agencies

The Ministry of Energy (“ME”), which holds jurisdiction over the power sector in Mozambique, and EDM, which is the publicly-owned electricity company under the jurisdiction of the ME, with the support from foreign countries, have engaged in human capacity building, the establishment of policy and regulatory framework of the Mozambican power sector, and the development and operation of power equipment and facilities. This chapter provides an outline of power projects implemented (or to be implemented) in cooperation with other donor agencies.

2.4.1 On-going Power Projects

Table 2.4-1 shows the on-going power projects in Mozambique, classified into three categories: technical cooperation projects, transmission projects, and rural electrification projects, with total project costs amounting to USD 669.19 million.

The technical cooperation projects are supported by aid agencies such as the World Bank (“WB”), International Development Association (“IDA”), L'Agence Française de Développement (“AFD”), the Government of Norway (through the Agency for Development Cooperation, “NORAD”) and the Government of Sweden (through the Swedish International Development Cooperation Agency, “SIDA”). The technical cooperation projects for the power sector are characterized by the wide range of aid agencies and countries involved.

The Mozambique Electricity Master Plan was prepared with the assistance of NORAD in 2004. In 2008, however, the need to upgrade the Master Plan was recognized so terms of reference (“TOR”) for an update of the previous Master Plan were prepared. Currently, the Master Plan is being updated to be completed by April 2013. Sub-Item 1.1.3: "Update of Master Plan 2010 - 2027" in Table 2.4-1 corresponds to this project.

Table 2.4-1 On-going Power Projects

Item	Name of the Project	Cost [MUSD]	Funder
1. Ongoing projects			
1.1 Feasibility Study and Technical Assistance			
1	Feasibility Study of Second Line Caia - Nampula	1.80	IDA
2	Integrated Management System (Sigem)	6.74	IDA
3	Update of Master Plan 2010-2027	1.30	AFD
4	Capacity Building	4.00	Swedish
5	Feasibility Study for Electrification of Vilanculos (OHL 110 kV Chibabava - Vilankulos)	0.05	Swedish
	Sub Total - Item 1.1	**13.84**	
1.2 Transmission Projects			
1	Rehabilitation and Reinforcement of Distribution network. Maputo City (Lot 1)	33.35	Portugal
2	Rehabilitation and Reinforcement of distribution network. Maputo City (Lot 2)	31.90	Portugal
3	Mobil Substation	6.09	Reino Belga
4	66kV Lines in Maputo	6.65	EDM
5	Mixed credit	150.00	Danida
6	Assembly of the Second Transformer in Matambo SS	13.00	World Bank
7	110kV Transmission Line Mavuzi - Chibabava	19.50	EU
8	SVC in Mocuba	10.03	GdM
9	Rehabilitation Chimoio SS and Acquisition of Mobile SS 110/33/22 kV 10 MVA	6.30	Kingdom of Belgium
10	Electricity II (Line DL8)	0.40	EDM
11	Electricity IV (Chibata - Dondo 220kV)	55.00	ADB/OPEC
12	Rural Electrification of North area of Gaza Province (110kV Lionde - Mapai)	54.00	Korean Exim Bamk
13	Transmission line 275 KV Corumana - Lionde	25.30	Danida
	Sub Total - Item 1.2	**386.22**	
1.3 Rural Electrification Projects			
1	LCREP of Niassa	11.40	IDB
2	EDAP (Expansion MV Network in Maputo, Manica, Tete, Nampula and Cabo Delgado)	147.70	BM/Afund/OFID/AFD/EIB
3	Rural Electrification Sofala, Manica and Tete Provinces (Lot B)	15.80	Suecia/Noroega
4	Rehabilitation of Bilene SS	1.90	EDM
5	Rural Electrification of Inhambane, Zambezia and Nampula Provinces	30.00	EXIM BANK/INDIA
6	Rural Electrification of Niassa, Cabo Delgado and Manica Provinces	25.00	EXIM BANK/INDIA
7	Electricity III	19.33	ADB/OPEC
8	Rural Electrification of Cabo Delgado Phase III - Addendum (Ibo)	13.00	NORWAY
9	Rural Electrification of Pande	3.00	GoM
10	Rural Electrification of Chimbonila	2.00	Norway
	Sub Total - Item 1.3	**269.13**	
	TOTAL - Item 1	**669.19**	

(Source: EDM, 2012)

2.4.2 Priority Projects without Funding

Table 2.4-2 shows the priority power projects to be implemented in accordance with the power development plan for which a funding source has not been determined. This table shows only the projects to be implemented over the period 2010 - 2015. The projects are divided into four categories: transmission projects, rural electrification projects, distribution and rehabilitation projects, and generation projects with a total project cost expected to amount to USD 2,906.07 million. Although some transmission projects have already gained financial commitment, most of the projects still require a large amount of funds for implementation, thus requiring financial support from developed countries.

The Beluluane Gas-Fired Power Plant Project requested by the Government of Mozambique through ME and EDM corresponds to Sub-Item 2.10.2: “1. Beluluane 50 MW Gas Fired Power Plant: 75 MUSD.” In addition, the Project for Rehabilitation of the existing Maputo Thermal Power Plant corresponds to Sub-Item 2.10.2 “10. Expansion of Gas Turbine HRSG Coupled to Existing Plant: 70 MUSD.” Both are designated as priority projects to be implemented.

Table 2.4-2 Priority Projects Without Any Funding

Item	Name of the Project	Cost [MUSD]	Remarks
2. . Priority Projects Without Funding			
2.1 Transmission Projects (2010 - 2015)			
1	Rehabilitation and Reinforcement of Infulene SS	32.00	
2	Rehabilitation and Reinforcement of Transmission Net grid in Maputo	4.70	
3	Transmission line 275 kV Infulene - Maputo	50.80	
4	Rehabilitation and Reinforcement of Maputo SS and Power Transfer to South Area	96.68	
5	Transmission line 275 kV Maputo - Salamanga and Salamanga 66/33 kV SS Extension	48.59	committed
6	Transmission Line 66kV Salamanga - Catembe	24.12	
7	Reinforcement of Maputo Transmission Capacity (SS Costa do Sol)	47.70	
8	Interconnection of Moamba Gas Plant (750 MW) to 275 kV Network	750.00	
9	Reinforcement of Chicumbane SS and Interconnection of 275 KV Lionde SS	35.40	
10	Reinforcement the Network of Major Corridors 66 kV of Maputo	30.00	
11	Interconnection SE1, 3, 5 and Facim - to 66 kV SE5	9.55	
12	Construction of FACIM SE and interconnection CTM, SE and SE1	20.00	
13	Rural Electrification of Vilanculos (OHL 110 kV Chibabava - Vilankulos)	42.10	committed
14	110 kV Transmission Line Vilankulos - Massinga	32.80	
15	Manga Substation	21.17	
16	Reinforcement of Chimoio substation	20.17	
17	Reinforcement the Network of Tete	38.40	
18	SVC North System	19.00	committed
19	Reinforcement of Caia - Nampula - Nacala 220 kV	312.20	
20	Reinforcement of Nampula Transmission System (Namialo SS)	12.05	
21	Reinforcement of 220/110 kV Substation (System Center - North)	21.00	committed
22	Central Dispatch Center / North	30.09	committed
	Sub Total - Item 2.1	**1,698.52**	
2.2 Rural Electrification Projects (2010-2015)			
1	Rural Electrification of Niassa province - Phase III (Mecula and Nipepe)	36.90	
2	Electrification of Border Villages of Niassa, Zambezia, Tete, Manica and Maputo Provinces	49.30	
3	Rural Electrification and Urban Maputo Province	63.04	
4	Rural Electrification of Vilanculos	39.34	
5	Rural Electrification of Sofala North Administrative Posts	11.03	
6	Rural Electrification of Balama, Namuno and Machaze	25.00	
7	Agricultural Areas Electrification in Mozambique	128.30	
	Sub Total - Item 2.2	**352.91**	
2.3 Distribution & Rehabilitation Projects (2010-2015)			
1	Rehabilitation of Lichinga Distribution Network - Niassa Province	14.60	
2	Rehabilitation of Nampula Distribution Network - Nampula	16.34	
3	Reinforcement and Expansion of Nacala Distribution Grid	20.02	
4	Rehabilitation of Beira Electrical Network	8.08	
5	Rehabilitation of Xai-Xai Distribution Networks - Gaza Province	11.97	
6	Reinforcement of Matola Network	31.44	
7	Rehabilitation and Reinforcement of Maputo Distribution Network	30.00	
8	Reinforcement the surrounding Maputo Network Package 2	39.72	
9	Reinforcement end Extension of Maputo Netgrid Phase I 2011	17.51	
10	Reinforcement end Extension of Maputo Netgrid Phase II 2011	21.67	
11	Loss Reduction Project in Maputo Distribution Area (Guava)	21.77	
12	Ring Fance Project in Matola Area	10.02	
	Sub Total - Item 2.3	**243.14**	
2.4 Generation Projects			
1	Beluluane 50MW Gas Fired Power Plant	75.0	
2	Moamba 120MW Gas Fired Power Plant	150.0	
3	Mocimboa da Praia 50 MW Gas fired power plant	90.0	
4	Kuvaninga 50MW Gas Fired Power Plant	75.0	
5	Temane 10MW Gas Fired Power Plant	15.0	
6	Feasibility Study for Revue Basin (Tsate, Mueneze, Mavuzi II & III)	1.5	
7	Feasibility Study of Pavue at Pungue River	1.5	
8	Feasibility Study Mutelele at Ligonha River	0.7	
9	Conversion of Diesel Generator to Gas Turbine	12.0	
10	Expansion of Gas Turbine HRSG Coupled to Existing Plant	70.0	
11	Feasibility Study for Buzi Gas usage for Electricity Generation	0.2	
12	Feasibility Study for *Condensates* Usage from Natural Gas for Electricity Generation	0.2	
13	Feasibility Study for Corrumana Hydropower Rehabilitation	0.2	
14	Feasibility Study for Expansion of Temane Gas Power Plant	0.2	
15	Alto Malema Basin	120.0	
	Sub Total - Item 2.4	**611.50**	
	Total - Item 2	**2,906.07**	

(Source: EDM, 2012)

2.4.3 Recently Completed Projects

Table 2.4-3 shows recently completed power projects, which are separated into two categories:

transmission projects and rural electrification and distribution projects. Total project costs amount to USD 385.51 million.

Similar to the case for on-going transmission projects and rural electrification projects described in Subsection 2.10.1, the projects have been implemented with the support from a wide range of foreign countries and aid agencies.

Table 2.4-3 Recently Completed Projects

Item	Name of the Project	Cost [MUSD]	Funder
3. Recently Concluded Projects			
3.1 Transmission Projects Recently Completed			
1	Feasibility Study of the Central - South Line (CESUL)	6.00	IDA/Noroega
2	Paiol Explosion – Supply Transformer For Chicumbane	0.78	Dinamarca
3	Matola Substation 275/66kV	18.50	KUWAIT/OPEC
4	National Dispatch Center	5.10	DANIDA
5	Commissioning of 2º Transformer at Machava Substation	0.38	BDSA
6	Creation of the Environmental Unit	0.54	DANIDA
7	Rural Electrification of Marromeu	9.60	KfW/EdM
8	Project of the 110kV Transmission Line Nampula - Pemba	6.80	BADEA/ IDB/ EDM
9	Rural Electrification of Cabo Delgado Phase II	10.25	BADEA/BID
10	Gurue - Cuamba - Lichinga - 110kV Transmission Line	46.43	Suecia/Noroega
11	Feasibility Study for Electrification of Niassa (Cuamba - Marrupa 110kV Line)	0.40	BADEA
12	Rural Electrification of Cabo Delgado Phase III	53.00	NORWAY/BADEA/BID/EU
13	Alto Molocue - Uape - 110kV Transmission Line	9.96	EXIM BANK - India
	Sub Total - Item 3.1	**167.74**	
3.2 Rural Electrification & Distribution Projects Recently Completed			
1	ERAP Package I, II and III, Extension of Distribution Networks	14.91	BAD
2	Rehabilitation of Maputo and Matola	7.77	ICO/SPAIN
3	Service connection in Matola City	3.00	GTZ
4	Connection of 12,000 consumers in the area of Maputo and Matola	3.00	GTZ
5	Increasing Number of Consumers in Matola Area	10.50	Elswedy-Egipto
6	Rehabilitation and Reinforcement of Infra infrastructures Damaged by Paiol Explosion	4.30	DANIDA
7	Rehabilitation and Reinforcement of Maputo Distribution Net Work	23.50	DANIDA
8	Rural Electrification of Gaza Province	19.95	EXIM BANK - India
9	Rural Electrification of Morrumbene and Massinga	1.60	Dinamarca
10	LCREP of Inhambane (Massinga - Morrungulo)	11.40	Dinamarca
11	Rural Electrification of Gorongosa	4.34	KFW
12	Rural Electrification of Sofala, Manica and Tete Provinces	15.80	Suecia/Noroega
13	Rural Electrification of Chibabava and Buzi Districts, Sofala Province	9.67	Suecia / Dinamarca
14	Rural Electrification of Tete Districts	32.00	GoM
15	Rural Electrification of Tete Districts - Addenda 1 & 2	10.56	EU
16	Rural Electrification of Namacurra	8.76	NORAD
17	Rural Electrification of Namacurra Pebane Extension	6.00	NORAD
18	Rehabilitation and Reiforcement of Distribution Network of Beira City	15.50	DSBA
19	Rural Electrification of Mecanhelas, Maua, Metarica and Marrupa, Niassa Province	14.00	Suecia/Noroega
20	Rural Electrification of Sanga - Niassa Province	1.21	GoM
	Sub Total - Item 3.2	**217.77**	
	Total - Item 3	**385.51**	

(Source: EDM, 2012)

2.4.4 Scale of Project Costs

A simple sum of all project costs listed in Subsections 2.10.1, 2.20.2 and 2.10.3 adds up to USD 3,800 million as shown in Table 2.4-4. The sum of the costs of the on-going projects and the recently completed projects accounts for only 27.8% of the total project costs. The projects to be implemented by 2015 (listed in Section 4.2) still require a large amount of investment. For the recently completed projects, the project costs incurred by ME and EDM account for 10.1% of the total amount with the rest dependent on foreign aid. As this trend continues, both government-based support from other countries and private investment are considered essential for the future of the power sector of Mozambique.

Table 2.4-4 Total Investment Amount in Power Sector

Category	Amount (MUSD)	%
On-going projects	669.2	17.6%
Priority projects without funding	2,745.3	72.2%
Recently completed projects	385.5	10.1%
Total	3,800.0	100.0%

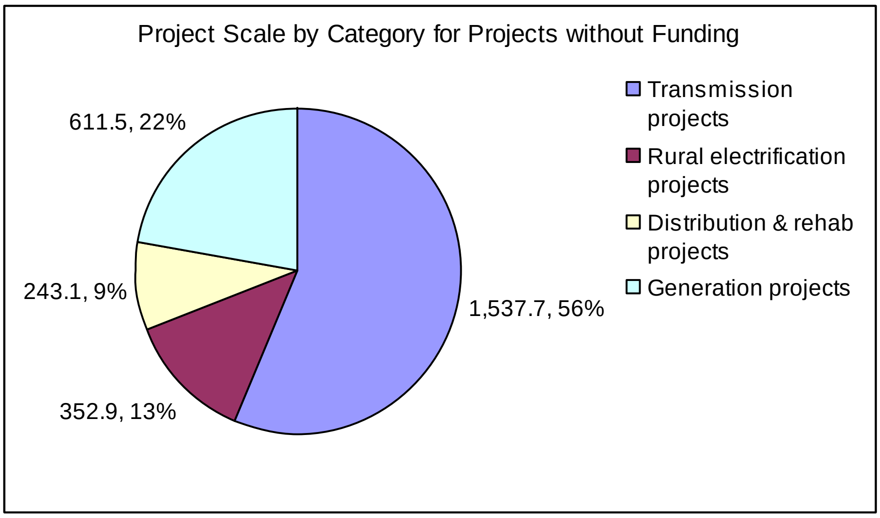
(Source: EDM, 2012)

As mentioned in Subsection 2.10.2, the total project costs for priority power projects without funding amounts to USD 2,745.3 million with the breakdown shown in Table 2.4-5 and Figure 2.4-1. The cost of transmission projects accounts for the largest share (56.0%), followed by generation projects (22.3%). However, the sources of funding necessary to implement these projects have still not been identified.

Table 2.4-5 Priority Power Projects without Funds

Category	Amount (MUSD)	%
Transmission projects	1,537.7	56.0%
Rural electrification projects	352.9	12.9%
Distribution & rehab projects	243.1	8.9%
Generation projects	611.5	22.3%
Total	2,745.3	100.0%

(Source: EDM, 2012)



(Source: EDM, 2012)

Figure 2.4-1 Breakdown of Priority Power Projects without Funding

2.4.5 Assistance to the Mozambican Power Sector by International Aid Agencies

WB, in cooperation with IDA, has provided assistance to the Mozambican power sector. The most recent case is the "Energy Development and Access Project (EDAP APL-2)", which primarily aims at improving the access rate to electricity and the quality of power supply in rural and peri-urban areas. The project extends for five years from 2010 to 2015 and the total project cost is expected to reach USD 80 million. The project has the following three components:

- Reinforcement of the Primary Networks and Grid Extension Component (USD 50.0 million)
- Investments in Rural and Renewable Energy Component (USD 18.0 million)
- Energy Sector Planning, Policy and Institutional Development Component (USD 10.2 million)

WB is also providing support for the "Mozambique Regional Transmission Backbone Project (CESUL)" in collaboration with NORAD. Figure 2.4-1 shows the locations of the above-mentioned WB assisted projects as well as other major power projects. The project information on the above-mentioned "EDAP APL-2" and information on WB's assistance program for the Mozambican power sector are detailed in the following document:

- Project Appraisal Document on a Proposed Credit in the Amount Of SDR 49.7 Million (US $80 Million Equivalent) to the Republic of Mozambique for an Energy Development and Access Project (APL-2) (January 6, 2010)

2.4.6 Assistance to the Mozambican Power Sector by Norway

Norway is one of the developed countries that is most actively involved in assistance to the Mozambican power sector, and it currently provides support to the following six projects:

- Institutional Capacity Building in the Ministry of Energy, 2007–2010, Norwegian Krone (“NOK) 41 million
- Technical Assistance to Electricidade de Moçambique, 2008–2010, NOK 13 million
- Cabo Delgado Electrification Project, 2006–2013, NOK 342 million
- Marrupa-Cuamba-Mecanhelas Electrification Project, 2007–2012, NOK 41 million
- Chimbonila Electrification Project, 2011–2012, NOK 11 million
- Support to the National Energy Fund (“FUNAE”), 2010–2011, NOK 3 million

As a member of the International Cooperation Partner (“ICP”) countries, Norway has taken a leading role in dealing with common issues shared by the Southern African Development Community (“SADC”), which Mozambique is affiliated with. Projects that Norway is currently involved in are as follows:

- Support to the SADC Secretariat on Energy Related Issues
- Mozambican Regional Transmission Backbone Project (CESUL)
- Electricity Regulators’ Peer Review Network
- The Southern African Power Pool – Regional Electricity Market

2.4.7 Assistance to the Mozambican Power Sector by Germany

Germany has often provided both grant and loan assistance to the Mozambican power sector. Among the most significant projects is the project for construction of a database regarding the energy sector. This database is intended to capture, store and sort all the literature on the energy sector published in the past 15 years, and the results are expected to be incorporated into this survey. The project is being implemented by the German Agency for International Cooperation (“GIZ”) in collaboration with Universidad Pedagogica (Pedagogica University) and it is currently underway. It is necessary to maintain contact with GIZ, in order to obtain this database upon its completion.

Chapter 3

Selection of the Site

Chapter 3 Selection of the Site

This chapter describes how the approximate scale of the power plant facility was estimated, how each candidate site was compared and assessed from technological and economical viewpoints, and how the best-suited planned construction site was selected. The selected candidate sites were Beluluane industrial complex, which EDM had been studying, and a site on the CTM premises from which a coal-fired power plant had been removed. The Ressano Garcia region near PRS-1 gas decompression station was excluded as a candidate site for this survey because the construction of a power generation facility using a gas engine had already been planned at this site.

In addition, the following three points were considered, in respect of the views of EDM, as prerequisites for the comparison and study:

1. Output of the CCGT power station should be maximized so that the contracted gas volume of 6 MGJ/ year can be fully used, considering that the gas contract is a take-or-pay contract.
2. The existing GT power station in CTM will perform base operations from 2013 to 2017 (when the CCGT power station is expected to start operation), using the contracted gas volume of 6 MGJ/ year.
3. From 2017, the CCGT power station will fully operate and the GT power station of CTM will operate only in the case of an emergency, e.g., if the CCGT power station stops.

3.1 Evaluation Criteria

To select one of the two prospective candidate sites above, a survey was conducted of the evaluation items shown in Table 3.1-1 below Survey Items. These evaluation items for site selection are generally used in order to select a thermal power station construction site and include a comprehensive survey from the viewpoints of technology and economy.

Table 3.1-1 Survey Items for Selection of Sites for a Power Plant

Study Items	Survey Items
Site area	• Site area drawing (available site area (ha), shape of site area, positional relationship with the existing facilities) • Surplus site area for extension plans
Access	• Distance from major highways, railways and water channels • Means of transportation • Current status of the access route

Study Items	Survey Items
Topographic/geo-graphical features	• Topographic map (1/25,000 or 1/50,000) • Geographical documentation on peripheral area, and geographical data on existing thermal power plants • Degree of difficulty in land preparation, and need of implementing special ground improvement works
Vegetation	• Survey of documentation (presence or absence of rare species) • Handling of mangroves
Meteorology	• Basic data on the natural environment around the site, e.g., atmospheric temperature, humidity, precipitation, wind direction/velocity, and atmospheric pressure
Natural disasters	• Records of floods, high tides, and earthquakes in the power plant site area
Cooling water and condenser cooling system	• Distance from the water source • Topographic features of rivers and ocean bottoms (plan view and cross sectional view) • Long-term hydrological data (river flow, etc.) • Annual flow rate/flow rate for allowing water intake (at the time of low water level), and fluctuation in water levels and water temperatures • Data on floods and high tides • Water quality data (when river water is used as service water)
Service water	• Distance to the industrial water supply source • Water supply capacity and water quality data • Usage charges
Fuel	• Position and route of gas pipes • Gas properties • Pressure and temperature at interface point • Fuel supply capacity and price
Transmission network	• Trunk network configuration • Distance to the substation of the trunk system or the switching station • Restrictions on system (current flow, short-circuit capacity and stability)
Environmental and social considerations (planned site for power plant)	• Presence or absence of protected areas such as National Parks and historic sites • Presence or absence of precious animals and plants • Relocation of inhabitants, agricultural land or cemetery in the site area • Adaptability as an industrial area
Evaluation of environment impact (cooling water route)	• Presence or absence of protected areas such as National Parks and historic sites • Presence or absence of rare animals and plants • Relocation of inhabitants, agricultural land or cemeteries in the site area • Circulation of thermal effluents
Transportation of heavy objects	• Means of transportation (river, overland route, railroad) • Load limits (status and load capacity of bridges and roads, and water depth in normal and dry season) • Dimensional limits (bridges, roads, tunnels, river widths (in dry season))

(Source: JICA Study Team)

3.2 Required Area for Power Plant

The JICA Study Team estimated the required area for the new power plant at each candidate site based on a typical CCGT layout consisting of main equipment such as GTs, HRSGs and STs, and related equipment such as gas supply equipment, water treat equipment, waste water equipment, etc. To estimate the required area for the power plant, the following conditions were set.

3.2.1 Setting Conditions for the Layout of the Power Plant for the Candidate Sites

(1) Maximum Power Plant Capacity

The planned new CCGT is expected to have continuous full load operation as base load operation, and to supply electric power to meet Mozambique’s tight power demand. Based on previous experience with CCGTs, it is assumed that the CCGT will operate continuously, except for outages for periodic inspections (e.g., combustion inspections, hot gas pass inspections and major inspections) and maintenance, and regular work (washing GT compressors with water, changing generators’ brushes, etc.). The plant capacity factor is assumed to be 83%. This CCGT plant efficiency (lower heating value, “LHV”) is estimated to be 50%.

Power generation capacity is restricted by the volume of natural gas. The volume of gas to be supplied to the new gas-fired power plant is 6.0 MGJ/ year at both candidate sites. Calculating from this gas supply volume, the new power plant capacity will be approximately 114 MW.

Available generation capacity $= 6.0 \times 10^{6} \times 10^{9} \times (50/100) / (24 \times 365 \times (83/100) \times 3.6 \times 10^{9})$

Table 3.2-1 Available Plant Capacity for Fuel

Site	Beluluane	CTM
Gas volume	6.0 MGJ/year	6.0 MGJ/year
Capacity	114 MW	114 MW

(Source: JICA Study Team)

(2) Required Area for Power Plant

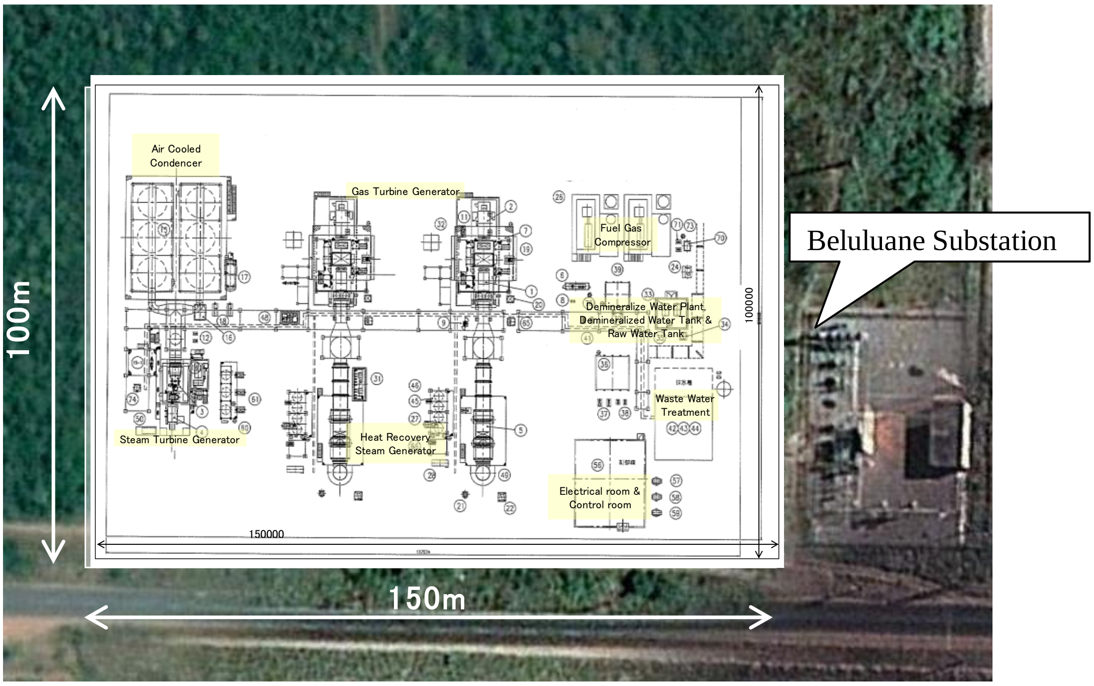
EDM had two prospective areas for the planned CCGT. The first area was the Beluluane site, neighboring the Beluluane transformer station, is 1.5 ha (100 m x 150 m). The second area was the CTM site of approximately 3.7 ha consisting of a former coal-fired power plant area and an area of diesel oil tanks for existing GTs. One typical 110 MW class multi-shaft 2-on-1 CCGT could be located on the Beluluane site, and two units of CCGT could be located on the CTM site.

The results of the study are shown in Table 3.2-2 below.

Table 3.2-2 Available Power Output for Land

Site	Beluluane	CPM
Available site area	1.5 ha (100 m × 150 m)	3.7 ha
Maximum plant capacity	110 MW	110 MW x 2

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 3.2-1 Beluluane Site

(Source: JICA Study Team)

Figure 3.2-2 CTM Site

(3) Conclusion

From (1) and (2) above, it is possible to install one block of multi-shaft 110MW class CCGT, consisting of two 30 MW to 40 MW class GT generators, two HRSGs, one ST generator, and related equipment, at both the Beluluane and CTM sites..

3.3 Land Preparation and Accessibility

The necessity for land preparation and the accessibility at CTM Maputo and Beluluane sites are evaluated in this chapter.

(Source: JICA Study Team)

Figure 3.3-1 Location of CTM Maputo & Beluluane Sites and Access Route from Port Maputo

3.3.1 Beluluane Site

(1) Necessity of Land Preparation

The site area is approximately 15,000 m^2 (150 m x 100 m). The site is flat and there are no obstacles to overcome to prepare the land for new power plant construction. Also, there are no inhabitants or cultivation activities within the site.

Therefore, large-scale land preparation or resettlement is not required.

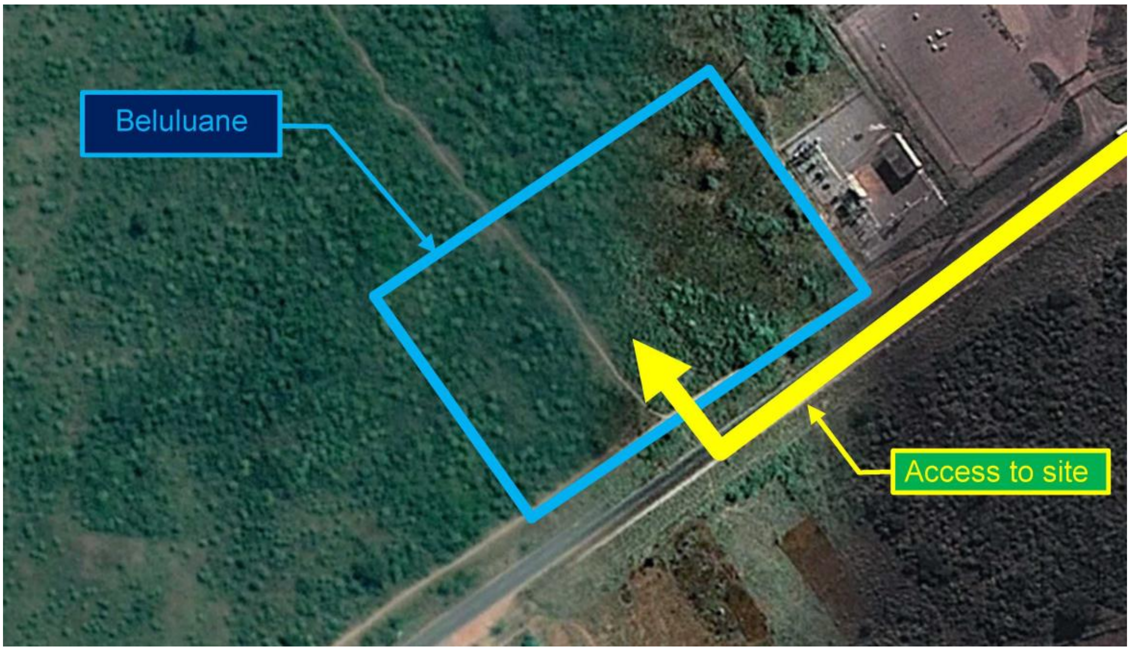
(2) Accessibility

(a) Accessibility from Port Maputo

The site is located about 20 km from Port Maputo and is adjacent to the existing Mozal aluminum refinery. As shown in Figure 3.3-1, major trunk roads (EN1, 2 & 4) can be used for the transportation of heavy equipment from Port Maputo to the site.

(b) Accessibility from the front road

As shown in Figure 3.3-2, the site faces the trunk road leading to the Mozal aluminum refinery. Therefore, the construction of new access road to the site is not required.



(Source: JICA Study Team)

Figure 3.3-2 Access from the Front Road at Beluluane Site

3.3.2 CTM Site

(1) Necessity of Land Preparation

The site is within EDM's existing power plant site, and the total site area reserved for the new power plant is approximately 27,000 m^2. The site is flat and there are no obstacles to overcome to prepare the land for construction. Also, there are no inhabitants or cultivation activities within the site.

Therefore, large-scale land preparation or resettlement is not required. However, the following issues should be given attention prior to the construction of new power plant.

(a) Existing fuel tanks

There are three existing fuel tanks that are no longer used at site, and these tanks should be removed prior to the construction of the power plant if any equipment is to be located over the area of these tanks.

(b) Inhabitants between railway and EN2

There are some illegal inhabitants living between the railway adjacent to the site and EN2. According to interviews with these inhabitants, they have been notified that they will be relocated due to the construction of Maputo Ring Road, of which details are mentioned in Chapter 8.2.3.

(2) Accessibility

(a) Accessibility from Port Maputo

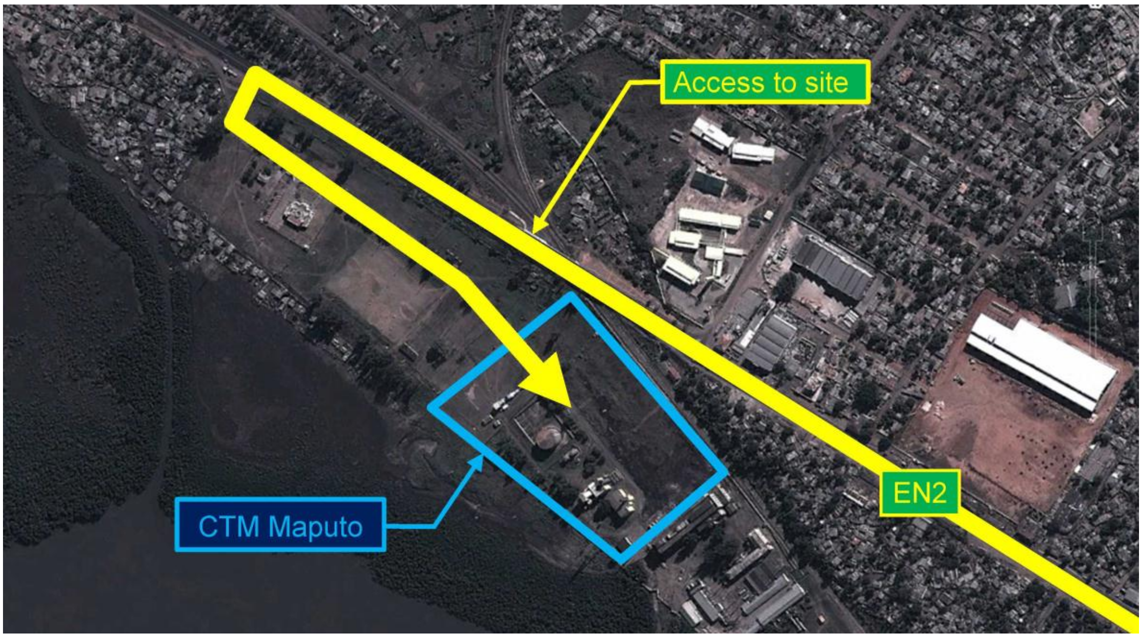
The site is located about 3 km from Port Maputo. As shown in Figure 3.3-1, major trunk roads (EN1 & 2) can be used for the transportation of heavy equipment from Port Maputo to the site.

(b) Accessibility from the front road

As shown in Figure 3.3-3, there is an existing access road from EN2 leading to the site. Therefore, the construction of new access road to the site is not required.

(c) Maputo Ring Road

If Maputo Ring Road is constructed prior to the construction of the new power plant, the conditions of access to the site mentioned above will change. Therefore, the progress of the planning and construction of Maputo Ring Road should be carefully monitored.



(Source: JICA Study Team)

Figure 3.3-3 Access from the Front Road at CTM Site

3.4 Topography, Geology and Meteorology

An outline of the topographical, geological and meteorological conditions of both the Beluluane and CTM sites are summarized in Table 3.4-1. As described in the table, both sites have no significant issues from the viewpoint of topography, geology and meteorology. For details of meteorological conditions of the CTM site, please refer to Chapter 5.

Table 3.4-1 Topographical, Geological and Meteorological Conditions of the Two Candidate Sites

Item	CTM Site	Beluluane Site
Topography and geology	The site is situated on alluvial soil deposited at the river mouth. Hard clay (N-value >50) is approximately 10 meters below the ground level. Accordingly, it is recommended to adopt the pile foundation for heavy machinery and structures.	The site is situated on diluvial upland at approximately 30 m above M.S.L. Since the site is located on flat land, large-scale grading work is not required. Although information about geological conditions of the site is not available, it can be inferred that there are no significant problems in foundation design. In fact, an aluminum smelter and cement factories, which use heavy machinery supported by strong foundations, are located in the Beluluane Industrial Park.
Meteorology	There is no risk of flood or storm surge damage. However, a proper drainage system would be newly established within the CTM in order to avoid water inundation.	There is no risk of flood damage.

(Source: JICA Study Team)

3.5 Constraints of a Power System

3.5.1 Three Elements of Constraints

Three technical constraints, i.e., power flows, fault currents, and stability, must be satisfied for the stable operation of a power system and the system must be analyzed in order to make this judgment. Power flow analysis has been conducted to ascertain whether the facilities, such as the transmission line and transformer, would not be overloaded and whether the proper value of voltage could be maintained.

The power system facility cannot avoid faults such as short-circuiting. Should a fault occur, the facility must be isolated from the system by a breaker. Fault current analysis must be carried out to check if the fault current is lower than the rated breaking current of the breaker and thus the breaker could break the fault current without any problems.

If a fault has occurred in the system and after the faulty facility has been isolated from the system, the system must be able to continue the stable operation as prior to the occurrence of the fault. Stability analysis must be performed to confirm whether any disturbances after the occurrence of the fault have settled down as time passes and whether the system can return to stable status.

3.5.2 Target System

The current published future demand for power is forecast in the CESUL project, however EDM is currently executing a Master Plan study to be completed at the end of 2012. EDM provided the JICA Study Team with the network analysis data that it is using to develop the plan. The JICA Study Team has also conducted network analysis of the power system in EDM's current network expansion plan.

Concretely, the following two cases of demand and system configuration, which are prerequisites for analyzing the power system, are assumed:

- Base case: Demand is assumed as the forecast value of the CESUL project, and the existing system will not be reinforced and will remains as it is in 2011 until the new southern gas-fired power station is completed
- Reference case: Work data of demand and network configuration as of October 2012 from EDM's current network expansion plan are used

3.5.3 Base Case

(1) Forecast Demand

Values forecast in the CESUL project, which are the newest published data, are used.

Table 3.5-1 shows the expected growth of demand for the Southern system in the case where demand grows moderately. Since the Southern gas-fired power station is expected to start operation in 2017, that year is used as the subject of network analysis, and the expected demand in that year is 653 MW as the average growth rate from 2015 to 2020 is expected to be 7.9%.

Table 3.5-1 Forecast Demand of the CESUL Project

Year	Demand (MW)	Growth rate (%)
2010	344	
2015	575	10.8
2020	791	6.6
2025	995	4.7
2030	1213	4.0
2010 - 2030		6.5

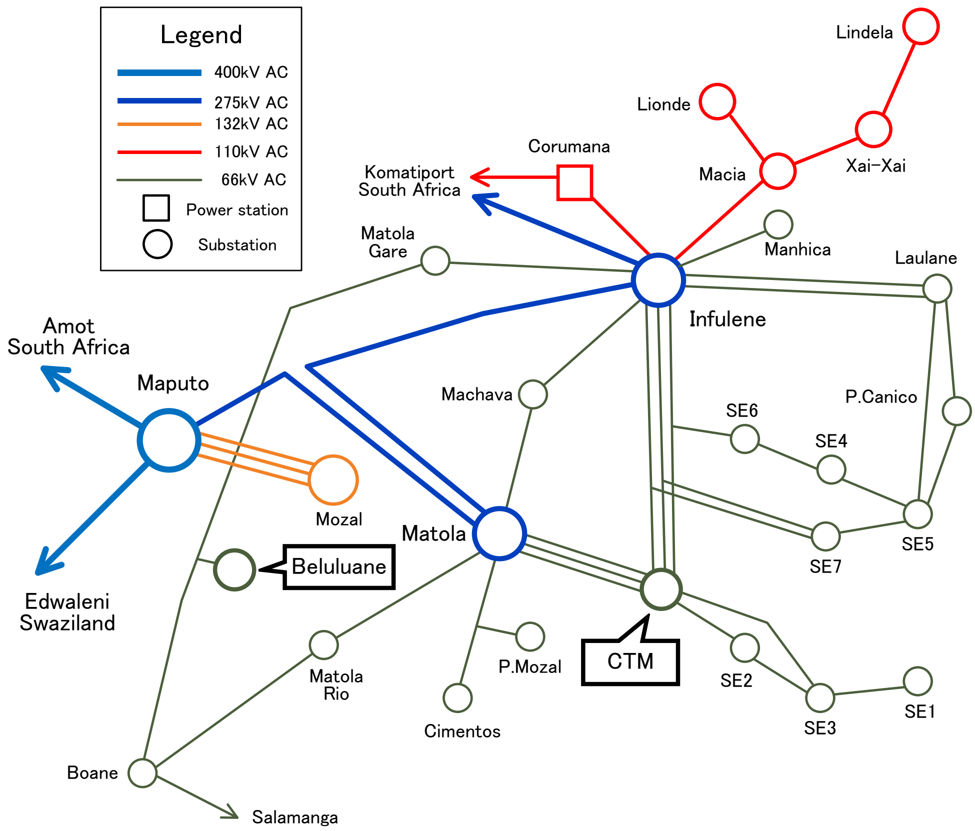
(Source: Final Feasibility Study Report Mozambique Regional Transmission Backbone Project)

(2) Network System to be Connected to the Southern Gas-fired Power Plant

It is assumed, as described above, that the network configuration of 2011 will be maintained in 2017 when the power plant will begin operation. Figure 3.5-1 shows the network system of 2011 including the Beluluane and CTM substations, which are the related substations for the candidate sites. Both the sites use the 66 kV system that is supplied from the 275/66 kV Matola and Infulene substations.

The Beluluane substation is 32 km away from the Matola substation, connected by one circuit of transmission line with a transmitting capacity of 36 to 47 MW. From the Infulene transformer station, the Beluluane substation is located 28 km away and is connected by one circuit of transmission line with a transmitting capacity of 36 MW.

By contrast, the CTM substation is 5 km away from the Matola substation and connected with three circuits of transmission lines with a transmission capacity of 47 to 57 MW, and 8 km away from the Infulene substation and connected with three circuits of transmission lines of 36 to 47 MW. It is also connected to two circuits of 66 kV transmission lines that supply load. This means that the CTM substation is connected with as many as eight circuits of transmission lines and is closer to the 275 kV substation that is the source of supply. This gives an advantage in terms of power transmission to the CTM site over the Beluluane site.

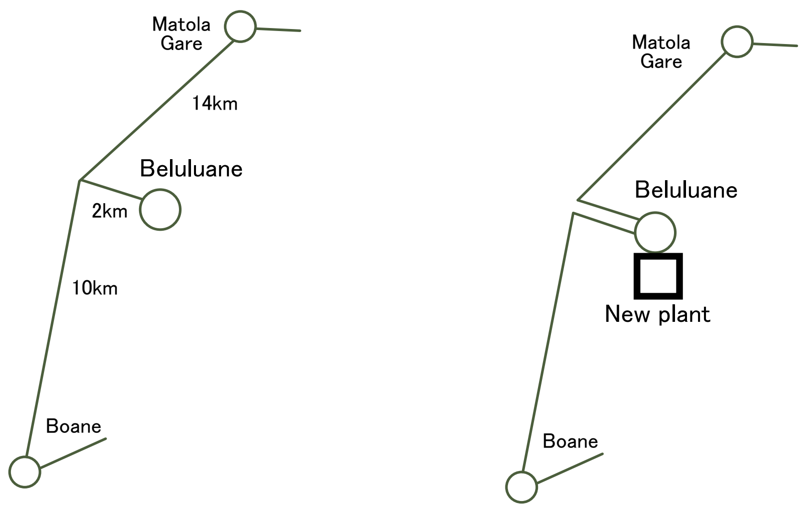


(Source: JICA Study Team)

Figure 3.5-1 Network System of the Southern Gas-Fired Power Plant

(3) Installable capacity of power plant

Power is transmitted to the existing Beluluane substation from the 66 kV Matola Gare-Boane line via a T-shape branching line. If a fault occurs anywhere along the total of 26 km transmission line and the 24 km Matola Gare-Boane line or the 2 km T-shape branching line, therefore, a blackout occurs. The role of the existing Beluluane substation is to supply power to medium to small-size factories and it seems that this level of supply reliability is considered sufficient. If a new power plant is constructed, however, it will be regarded as an important power source for the Southern system and improving its reliability is of vital importance. It is therefore assumed that one circuit of branch transmission line of 2 km will be newly installed as shown in Figure 3.5-2, so that the branch section will consist of two circuits, changing the branch method to a π-shape branching. By changing the branching method in this way, the section that will be affected by any fault can be halved and, even if a fault occurs on one of the transmission lines, power can still be transmitted by the healthy transmission line.



T-Branching π-Branching

(Source: JICA Study Team)

Figure 3.5-2 Interconnected Power System at Beluluane

It is necessary to assume output of the power plant in order to analyze the power system. The Southern gas-fired power plant will be required to generate as much power as possible because the power plant is expected to serve as the main power supply source from 2015 and onward. Therefore, the output of the Beluluane and CTM sites is assumed as follows.

Firstly consideration is given to the capacity of the generator that can be installed on the Beluluane site on the assumption that the branch method will be changed. The transmitting capacity from Beluluane to Matola Gare and Boane is 36 MW in both directions. Even if it is

assumed that the transmission lines in both directions are healthy and power generated by the generator flows equally in both directions, the capacity of the generator that can be installed is the sum of the total transmitting capacity of 72 MW in both directions plus the Beluluane substation load (i.e., 5 MW according to the records of 2011). The actual power flow in the transmission lines is unequal because power flow is determined by the load distribution and power distribution of the total system. In addition, considering that the remaining healthy transmission lines are used to transmit power in the case of any transmission line faults, it is assumed that the capacity of the generator that can be installed at the Beluluane site is 50 MW.
On the other hand, the capacity of the generator that can be installed at the CTM site is assumed to be 100 MW because this site is connected to a total of eight circuits with transmission capacity of 36 to 57 MW.

(4) Power Flow Analysis Results

Figure 3.5-3 shows the results of the power flow analysis and Table 3.5-2 shows the main overloaded transmission lines. The pink lines in this figure indicate overloaded transmission lines. Even though demand has increased to about 1.7 times that of 2011, the system has not been reinforced and there are as many as 15 overloaded transmission lines in the case of the Southern gas-fired power plant.
In the case that a 50 MW plant is developed in Beluluane, the overload of the Infulene-Matola Gare line and Matola-Matola Rio line can be eliminated and the number of overloaded lines can be decreased to 13. However, the effect is limited only to the Beluluane neighborhood.
In the case that a 100 MW plant is developed at the CTM site, the overload of seven transmission lines around CTM can be solved and the overloaded lines can be decreased in number to eight. This is effective for eliminating the overload to some extent but cannot be a fundamental solution to the problem. Overloading occurs on load supply lines such as the CTM-SE2 and CTM-SE3 lines and is attributable to increasing demand. Moreover, after installing 100MW CCGT, overloading caused by generator stoppage due to periodic inspection or sudden stoppages by faulty occurrence should be considered. These indicate the necessity of drastic measures for reinforcing the transmission lines.

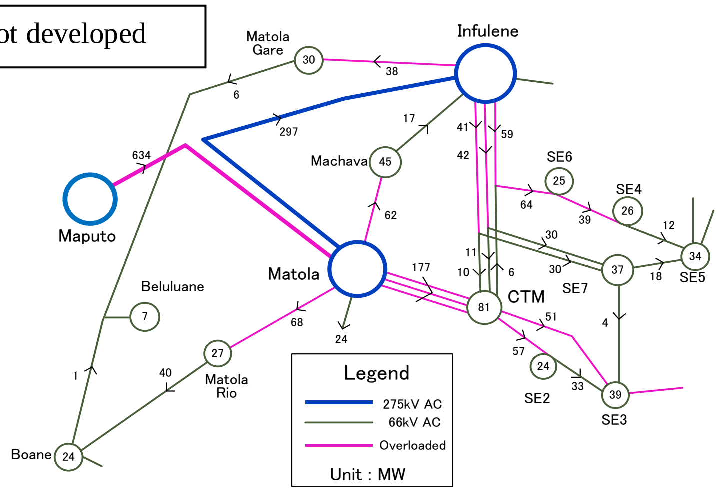
Table 3.5-2 Main Overloaded Transmission Lines

Line	Voltage (kV)	Capacity (MW)	Power Flow (MW) Red: Overload		
			Without Power Plant	Beluluane 50 MW	CTM 100 MW
Maputo－Matola	275	455	634	584	535
Infulene－Matola Gare	66	36	38	12	36
Matola－Matola Rio	66	47	68	44	70
Matola－Machava	66	47	62	71	46
Matola－CTM	66	161	177	172	133
CTM－SE2	66	47	57	57	59
CTM－SE3	66	47	51	51	53

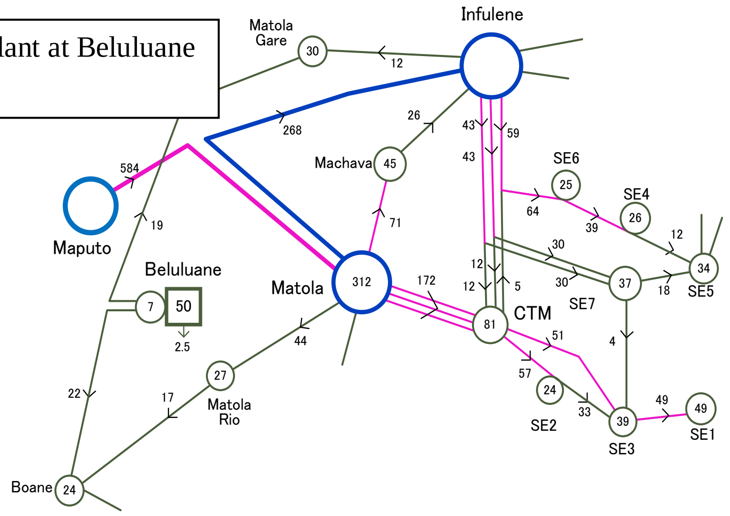
Line	Voltage (kV)	Capacity (MW)	Power Flow (MW) Red: Overload		
			Without Power Plant	Beluluane 50 MW	CTM 100 MW
Infulene－SE7	66	36	42	43	31
Infulene－SE6	66	36	64	64	65
SE6－SE4	66	36	39	39	40

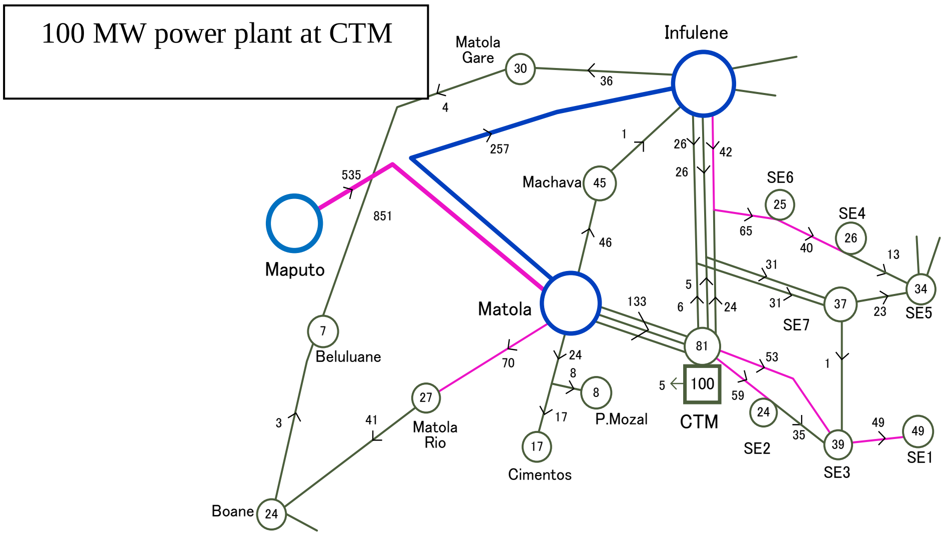
(Source: Network analysis results from the JICA Study Team using data provided by EDM）

Power plant not developed



50 MW power plant at Beluluane





(Source: Network analysis results from the JICA Study Team using data provided by EDM)

Figure 3.5-3 Power Flow Analysis Results (2017)

(5) Fault Current Analysis Results

Table 3.5-3 and Figure 3.5-4 show the results of analyzing fault currents. The maximum fault current of the 275 kV bus is sufficiently low at 9.4 kA in Maputo if a 100 MW power plant is installed at the CTM site, indicating that there are no problems such as an excess of the break current. The maximum fault current of the 66 kV bus is at 17.0 kA in Infulene substation and lower than 25 kA of the breaking capacity of the breaker if a 100 MW plant is installed at the CTM site, indicating there are no problems.

A change in the fault current when a power plant is installed is a 2.0 kA increase from 4.3 kA to 6.3 kA at the 66 kV bus in Beluluane in the case of a 50 MW power plant development at Beluluane, and a 3.4 kA increase from 13.2 kA to 16.6 kA at the 66 kV bus in CTM in the case of a 100 MW power plant development at CTM. In either of the above cases, there will be no excess breaking capacity caused by the installation of the power plant.

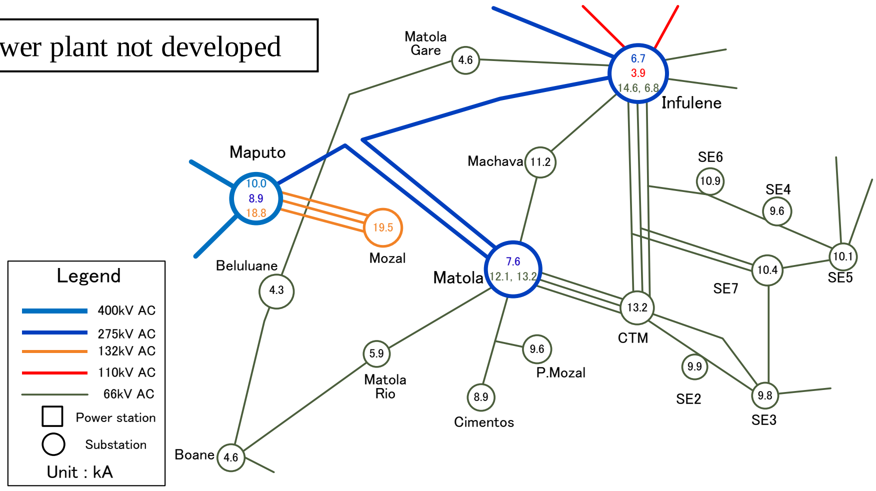
Table 3.5-3 Fault Currents at the Main Substation

Station	Voltage (kV)	Fault Current (kA)		
		Without Power Plant	Beluluane 50 MW	CTM 100 MW
Maputo	275	8.9	9.1	9.4
Matola	275	7.6	7.8	8.2
	66	12.1 13.2	12.9 13.6	13.0 15.8
Infulene	275	6.7	7.0	7.3
	66	14.6 6.8	15.1 7.6	17.0 7.1
Beluluane	66	4.3	6.3	4.5
CTM	66	13.2	13.6	16.6

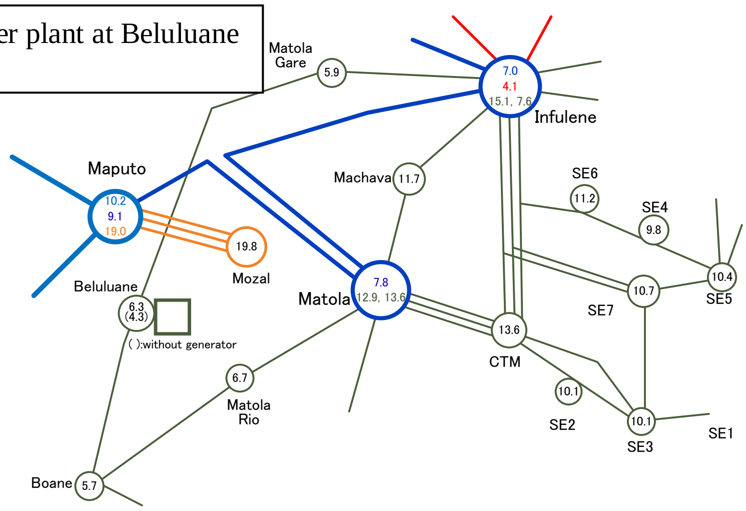
Station	Voltage (kV)	Fault Current (kA)		
		Without Power Plant	Beluluane 50 MW	CTM 100 MW
SE3	66	9.8	10.1	11.6
SE7	66	10.4	10.7	12.1

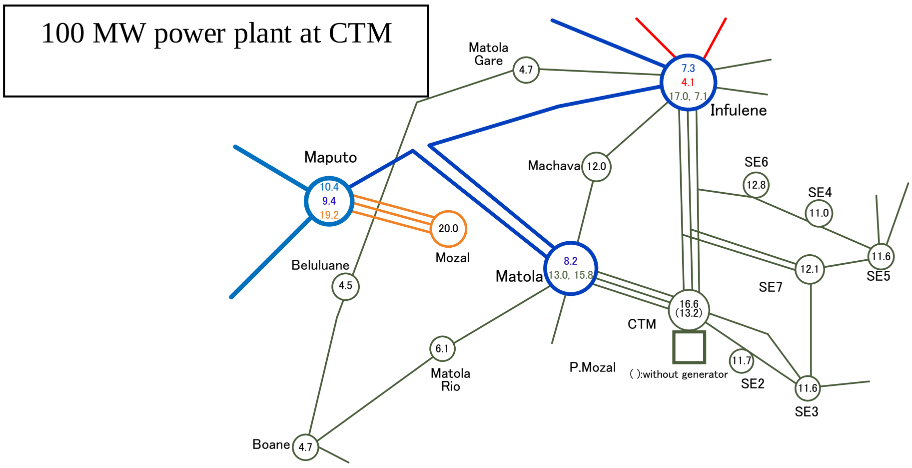
(Source: Analysis results using PSSE network data provided by EDM)

Power plant not developed



50 MW power plant at Beluluane





(Source: Network analysis results from the JICA Study Team using data provided by EDM)

Figure 3.5-4 Fault Current Analysis Results (2017)

(6) Stability Analysis Results

Transmission lines are subject to faults from lightning and contact with trees. After the faulted line is isolated from the system by opening a breaker, the disturbance of the fault must settle down and the system must be able to return to the original stable condition. For stability analysis, it was assumed that the fault occurred at the closest to the power plant, where fault conditions for stability are severe, ignoring control systems such as the automatic voltage regulator ("AVR") and governor control unit ("GOV"), in order to assess stability inherent in the system. In addition, it was assumed that the fault clearing time of the 66 kV transmission line was 0.1 to 0.15 seconds from the records of EDM shown below.

Distance from bus to fault point:

0 to 80% of transmission line length	Zone 1: 0.1s
Greater than 80% of transmission line length	Zone 2: 0.1 to 0.4s

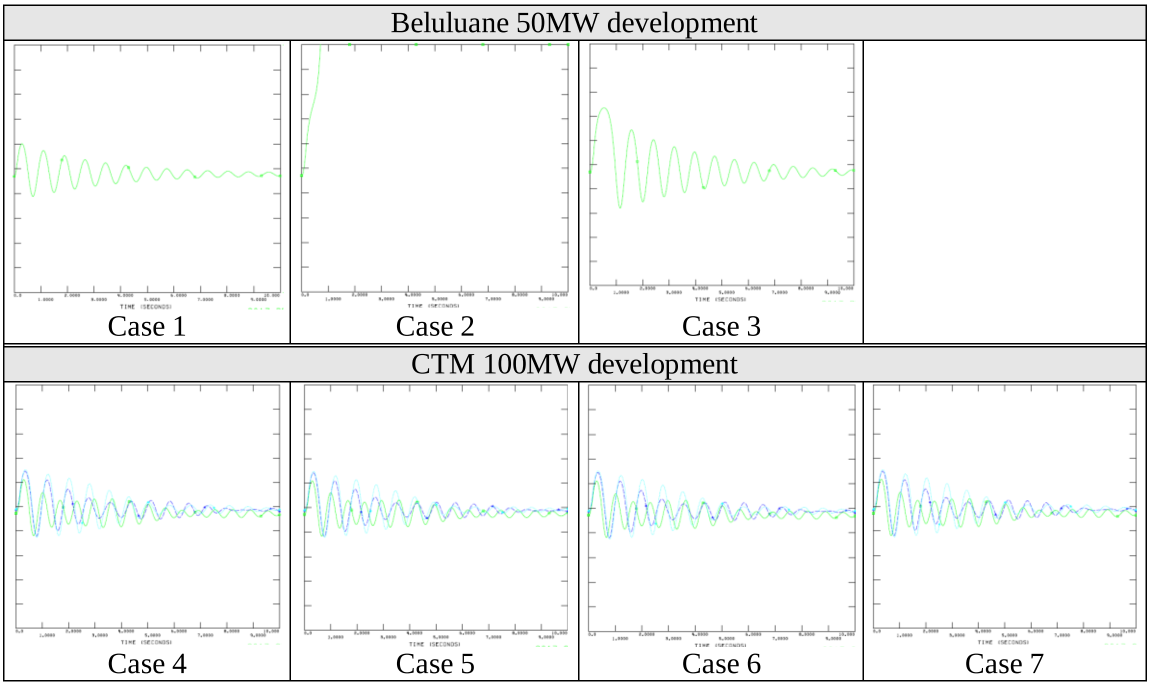
Table 3.5 4 shows the results of stability analysis and Figure 3.5-5 shows the fluctuation curve of the generator voltage angle. In the case where a 50 MW power plant is installed at the Beluluane site, the network will be stable if the fault clearing time is 0.1 second. If the clearing time is 0.15 seconds and in the case where a fault occurs at the Beluluane end of the Beluluane-Boane line (Case 2), fluctuation of the generator voltage angle diverges, and the system cannot be kept stable. This is because the Beluluane-Boane line will be opened after the fault and thus there is no choice but to transmit power with one circuit of the Beluluane-Matola Gare line.

Conversely, in the case where a 100 MW power plant is installed at the CTM site, fluctuation converges in all fault cases even if the fault clearing time is 0.15 seconds. This is because a total of eight circuits of transmission lines – three circuits to Matola substation, three circuits to Infulene substation, and two circuits to SE3 substation – are connected to CTM, therefore, even if one circuit of transmission line is opened due to a fault, connection to the main system is ensured by the remaining seven circuits. This is substantiated by the fact that the fluctuation amplitude after the fault is smaller than that at the Beluluane site.

Table 3.5-4 Stability Analysis Results

Plant	Faulted Line	Fault Point	Fault Clearing Time	Stability	Case No.
Beluluane 50 MW	Beluluane-Boane	Beluluane	0.1 sec	Stable	1
			0.15 sec	Unstable	2
	Beluluane-Matola Gare		0.15 sec	Stable	3
CTM 100 MW	CTM-Matola	CTM	0.15 sec	Stable	4
	CTM-SE2		0.15 sec	Stable	5
	CTM-SE3		0.15 sec	Stable	6
	CTM-SE6		0.15 sec	Stable	7

(Source: Network analysis results from the JICA Study Team using data provided by EDM)



(Source: Network analysis results from the JICA Study Team using data provided by EDM)

Figure 3.5-5 Fluctuation Curve of Generator Voltage Angle

(7) Conclusion

Table 3.5-5 provides the results of the network analysis. Installable generator capacity is limited to 50 MW at the Beluluane site due to constraints of the transmitting capacity, whereas approximately 100 MW can be installed at the CTM site. While there are two transmission lines that are set free from overload by installation of a generator at the Beluluane site, there are seven circuits if a generator is installed at the CTM site. The fault current after installation of a generator is sufficiently smaller than the current breaking capacity of the breakers, and there is no problem in both cases.

In the case of installation of a generator at the Beluluane site and if a fault occurs on the Beluluane-Boane line and is cleared 0.15 seconds later, the network is deemed unstable. By contrast, in the case where a generator is installed at the CTM site, the network is stable in all fault cases. It can be judged from the above that installing a generator at the CTM site is advantageous over the installation at the Beluluane site.

Moreover, in the case that the CCGT plant is developed at the CTM site, a generator of 110 MW capacity can be developed for the following reasons:

1) increase of generator capacity does not encourage overloading of transmission lines because overloading is caused in supply lines,

2) fault currents are much lower than permissible value, and

3) no small margin for stability limits seems to exist because the fluctuation curve of the generator voltage angle converges well.

Table 3.5-5 Results of the Network Analysis

	Beluluane	CTM
Installable capacity	Max. of 50 MW	Approx. 100 MW
Improvement of overload problem	2 lines	7 lines
Fault current	Much lower than CB rating	Much lower than CB rating
Stability	Depends on fault clearing time	Stable
Overall evaluation	—	Advantageous

(Source: JICA Study Team)

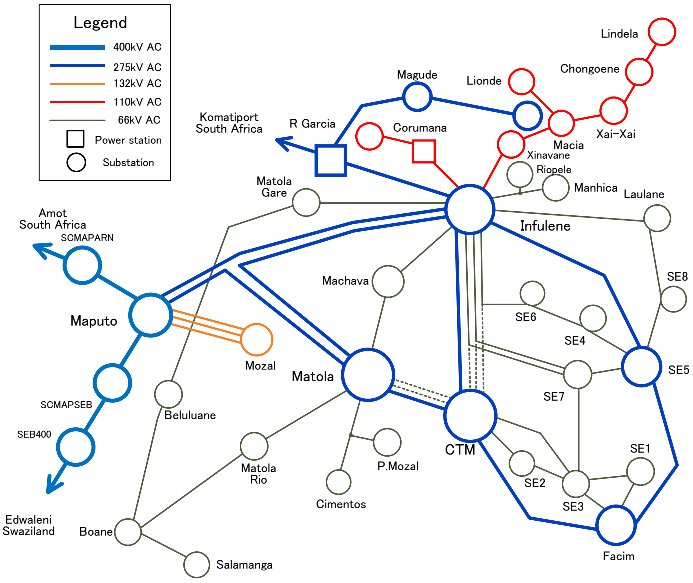
3.5.4 Reference Case (Based on EDM's Current Network Expansion Plan)

EDM is currently making a network expansion plan to be completed at the end of 2012, and in October 2012 the JICA Study Team obtained the network analysis data reflecting the current network expansion plan, as this data can be used as reference for studying methods to connect the Southern gas-fired power plant. The JICA Study Team analyzed the network system based on this data. As the obtained data is still in draft version, it is possible that the final version may have different content.

(1) Network Configuration

The Southern gas-fired power plant is expected to start operation in 2016 or 2017. EDM's current network expansion plan predicts that power demand will substantially increase in the future, to 794 MW in 2016, which is greater than the value of 653 MW for 2017 estimated by the CESUL project, described in (1) of 3.5.3. Therefore, the system for 2016 was selected as the subject analysis reflecting EDM's current network expansion plan.

Figure 3.5-6 shows the 2016 system of EDM's current network expansion plan. According to the plan, a 275 kV Matola-CTM line using the transmission route of the existing 66 kV Matola-CTM line and a 275 kV Infulene-CTM line will be installed. A 275 kV system leading to the CTM substation will be introduced to the demand center area, and new 275 kV transmission lines that go around Maputo City from CTM via a new Facim substation and SE5 substation, that will be upgraded from the existing 66 kV to 275 kV, will be introduced. Moreover, a new 275 kV transmission line that goes from the existing 400/275/132 kV Maputo substation to the Infulene substation will be installed. As a result, overloading of the 66 kV transmission lines can be eliminated and reliability of supply to the capital city can be expected to improve.



(Source: Diagram drawn by the JICA Study Team based on EDM's current network expansion plan provided by EDM)

Figure 3.5-6 System of EDM's Current Network Expansion Plan (2016)

(2) Power Flow Analysis Results

Table 3.5-6 and Figure 3.5-7 show the results of power flow analysis before and after the start of operation of the 100 MW plant of CTM under the system of EDM's current network expansion plan (2016). Before the 275 kV transmission line is reinforced, fifteen lines are overloaded. Overloading of the transmission line around CTM will be solved by introducing a 275 kV transmission line to the capital city and the number of overloaded lines will decrease to three: the Matola-Matola Rio line, Infulene-Matola Gare line and SE5-SE8 line.

The main function of all these overloaded transmission lines is to supply power to regional loads which have become overloaded as regional loads increase. Measures, such as circuit additions, will have to be taken as these overloaded transmission lines will not receive the benefits of the introduction of a 275 kV transmission line to the capital city.

If a 100 MW plant is installed at CTM, the CTM-SE2 line will be newly overloaded. This is because the power flow of this transmission line before installation of the plant is 43 MW against the transmission capacity of 47 MW, which is a small margin, and because the power flow increases in the directions of SE2, SE3, and SE7 as a result of the installation of the plant at CTM.

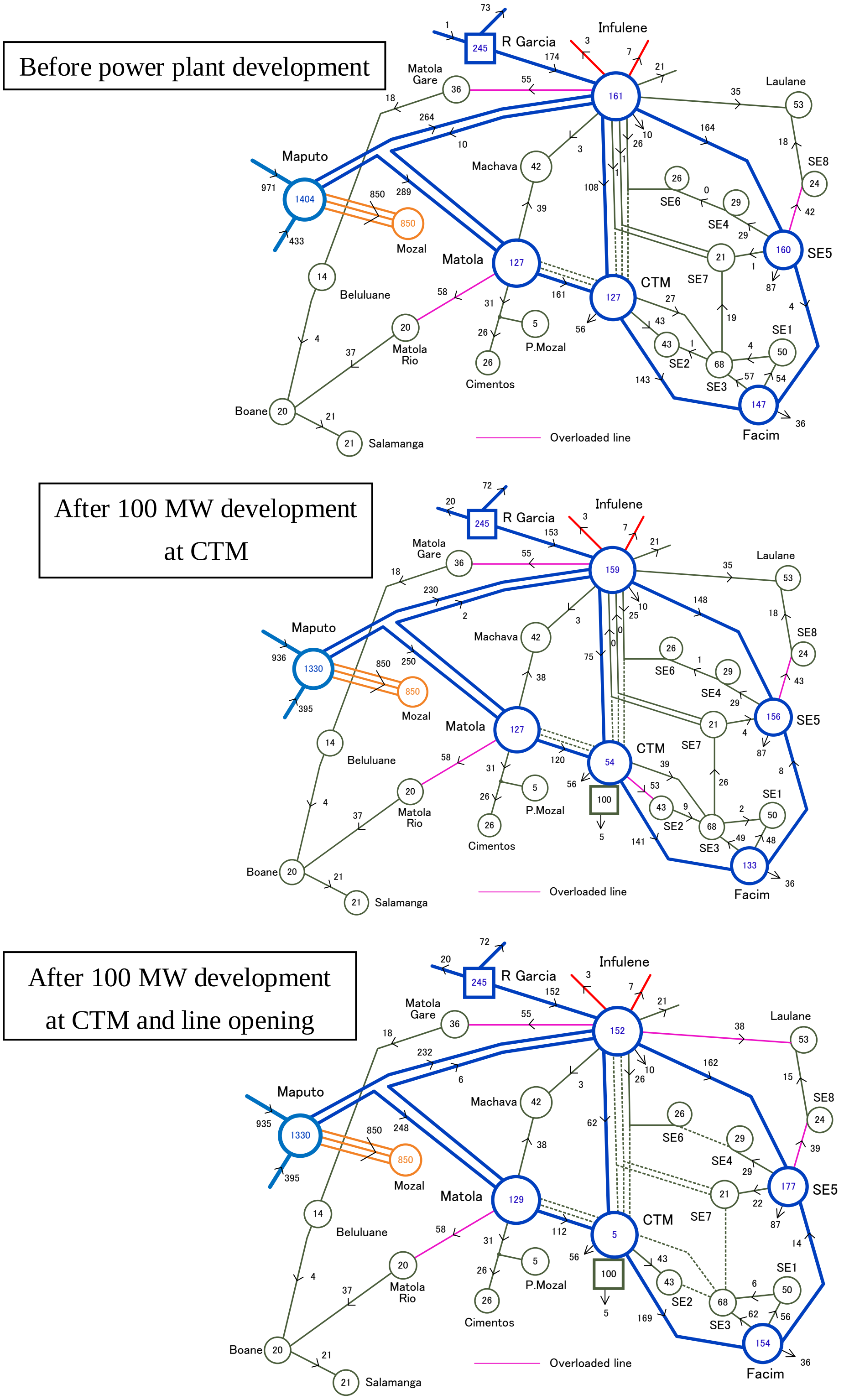
As a countermeasure against this overloading and exceeding the permissible value of fault current, which will be described later, the case in which the CTM-SE3, SE2-SE3, SE3-SE7, SE4-SE6, and Infulene-SE7 lines are always open and each 66 kV network is operated radially in 275 kV substation units, is considered. This countermeasure solves the overloading of the CTM-SE2 line.

However, overloading of the Matola-Matola Rio, Infulene-Matola Gare, and SE5-SE8 lines is not solved. In addition, the Infulene-Laulane line is newly overloaded. The essential cause of overloading of the 66 kV transmission lines is that the transmission line constructed in the early years had a capacity as small as 36 MW, which was used without being reinforced. Fundamental measures such as thickening conductors of the lines and circuit additions will be needed in the future.

Table 3.5-6 Results of the Power Flow Analysis for EDM's Current Network Expansion Plan System (2016)

Line	Voltage (kV)	Capacity (MW)	Power Flow (MW) Red: Overload		
			Before CTM 100 MW	After CTM 100MW	
				Closing Lines	Opening Lines
Maputo－Matola	275	455	289	250	248
Matola－Infulene	275	455	10	2	6
Matola－CTM	275	>455	161	120	112
Infulene－CTM	275	>455	108	75	62
Infulene－Matola Gare	66	36	55	55	55
Matola－Matola Rio	66	47	58	58	58
CTM－SE2	66	47	43	53	43
CTM－SE3	66	47	27	39	-
Infulene－SE7	66	36	1	0	-
Infulene－SE6	66	36	26	25	26
Infulene－Laulane	66	36	35	35	38
SE5－SE8	66	36	42	43	39

(Source: Analysis results using PSSE network data provided by EDM)



(Source: Analysis results using PSSE network data provided by EDM)

Figure 3.5-7 Results of Power Flow Analysis using EDM's Current Network Expansion Plan System (2016)

(3) Fault Current Analysis Results

Table 3.5-7 and Figure 3.5-8 show the results of fault current analysis using EDM's current network expansion plan system (2016). The fault current of the 66 kV bus will substantially increase as a result of introducing the 275 kV system to the metropolitan area but its value will not exceed the permissible value, i.e., 25 kA, although it will come close, before the 100 MW plant at CTM starts operating. After the plant is up and running, however, the fault current will increase 3.3 kA at CTM to 26.2 kA, exceeding the permissible value. It will also exceed the permissible values in Facim, SE5, SE3, and SE7, and the maximum value will be 26.7 kA in SE3.

The reason for exceeding the maximum value of 25 kA is that the 66 kV substations are closely interconnected to each 275 kV substation through the 66 kV transmission lines. Before the 275 kV transmission line will be introduced to the metropolitan area, there is no choice but to use all 66 kV transmission lines in parallel because it will be necessary to supply power from Matola and Infulene substations to the metropolitan area with transmission lines having small transmitting capacity. After the 275 kV line is introduced to the metropolitan area, however, it will transmit power to the metropolitan area and the 66 kV transmission line will change its role to supplying power regionally to the 66 kV substations from 275 kV/66 kV substations of CTM, Facim, and SE5. Consequently, the reliability of supply is not greatly influenced even if the 66 kV system is divided into plural systems by opening the 66kV transmission lines.

Therefore, the case in which the CTM-SE3, SE2-SE3, SE3-SE7, Infulene-SE7, and SE4-SE6 transmission lines are opened is considered as an example of a countermeasure against overloading of the CTM-SE2 line. In this case, the maximum value of the fault current significantly falls to 21.9 kA at the CTM and Infulene substations.

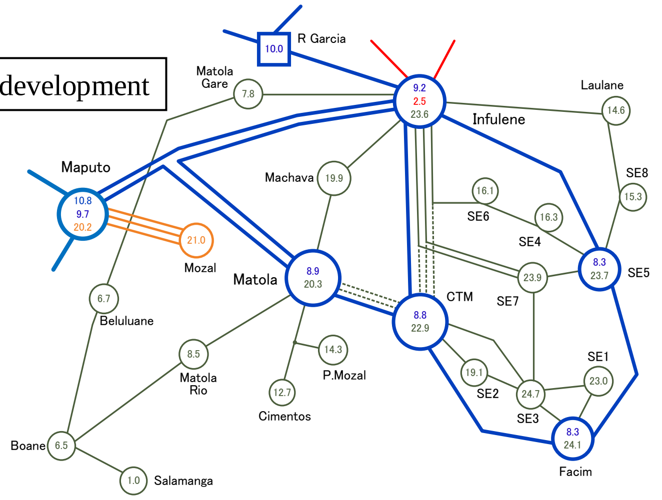
Table 3.5-7 Results of Fault Current Analysis using EDM's Current Network Expansion Plan System (2016)

Station	Voltage (kV)	Fault current (kA)		
		Before CTM 100 MW	After CTM 100 MW	
			Closing Lines	Opening Lines
Maputo	275	9.7	10.4	10.3
Matola	275	8.9	9.6	9.6
	66	20.3	21.2	20.5
Infulene	275	9.2	9.9	9.9
	66	23.6	25.0	21.9
CTM	275	8.8	9.5	9.5
	66	22.9	26.2	21.9
Facim	275	8.3	8.9	8.8
	66	24.1	26.0	17.8
SE5	275	8.3	8.9	8.8
	66	23.7	25.1	19.9
SE3	66	24.7	26.7	16.7

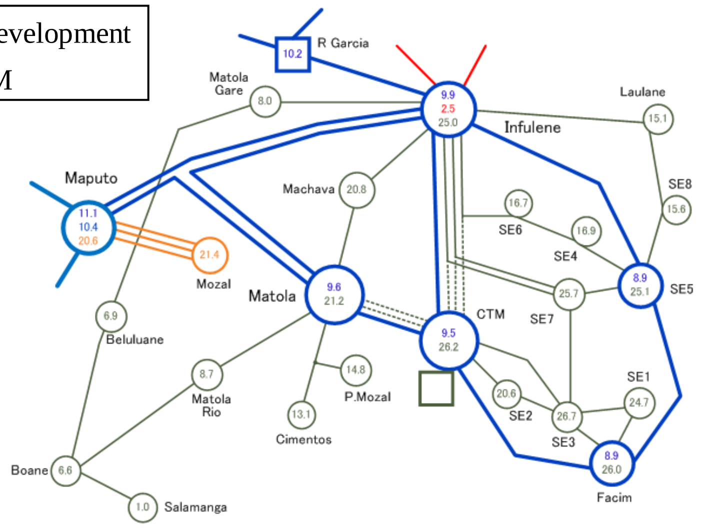
Station	Voltage (kV)	Fault current (kA)		
		Before CTM 100 MW	After CTM 100 MW	
			Closing Lines	Opening Lines
SE7	66	23.9	25.7	13.2

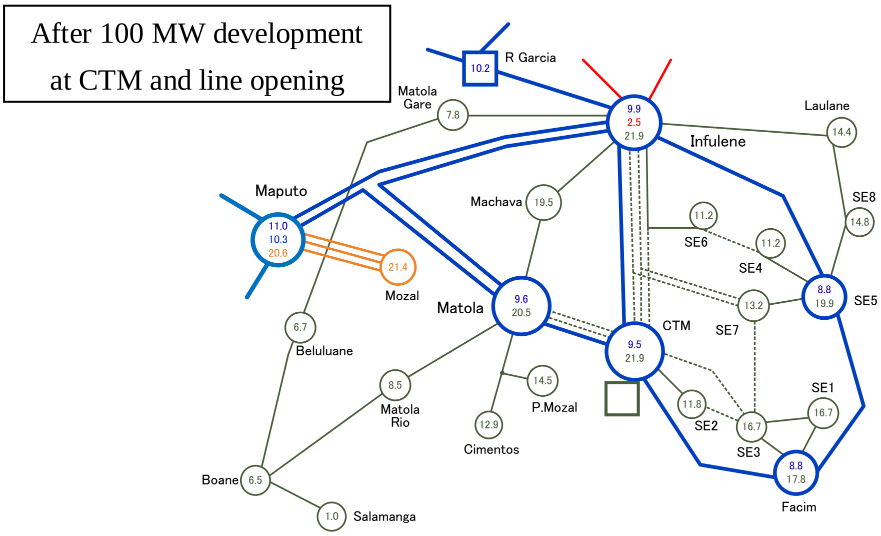
(Source: Analysis results using PSSE network data provided by EDM)

Before power plant development



After 100 MW development in CTM





(Source: Analysis results using PSSE network data provided by EDM)

Figure 3.5-8 Results of Fault Current Analysis using EDM's Current Network Expansion Plan System (2016)

(4) Stability Analysis Results

The stability of the system that opens transmission lines, such as the CTM-SE3 and SE2-SE3 lines, as a countermeasure against the excess of permissible values of the fault current after a 100 MW plant is installed at CTM was analyzed. In regards to the control systems of the generator, such as AVR and GOV, both the case where the control systems were ignored in order to identify the stability inherent to the system and the case where they were considered were analyzed. In addition, both fault clearing times of 0.1 second and 0.15 seconds were considered.

Table3.5-8 shows the result of stability analysis. Figure 3.5-9 shows the fluctuation curve of the generator voltage angle.

In the case where the control systems were ignored and the fault clearing time was 0.10 second, the network was stable in all cases including the case where it was assumed that a fault occurred on the CTM 275 kV bus or 66 kV bus, the closest end to the generator which is severe in terms of stability. In the case where the fault clearing time was 0.15 seconds, however, the effect of introducing the 275 kV transmission line to the metropolitan area could not be seen and the network was unstable in all cases.

Comparing these results with the case described in (6) of 3.5.3 where the CTM power plant was connected to the 66 kV system before the introduction of the 275 kV system and the network was stable with the control systems ignored and fault clearing time being 0.15 seconds, it can be said that introducing the 275 kV system will not be effective for improving stability. The reason for this is considered as follows: Before the 275 kV system will be introduced, the CTM plant will be connected to eight circuits of 66-kV transmission lines. Even if one of the circuits will be opened as a result of a fault, the generator will be kept connected to the main system by the other seven circuits. After the 275 kV system will be introduced, however, the case where the CTM-SE3 line will always be opened to suppress the fault current is assumed. After the CTM-SE2 line will be opened to remove faulted lines, connection to all the 66 kV transmission lines will be lost and the generator will be connected to the main system only by a 275/66 kV transformer with high impedance.

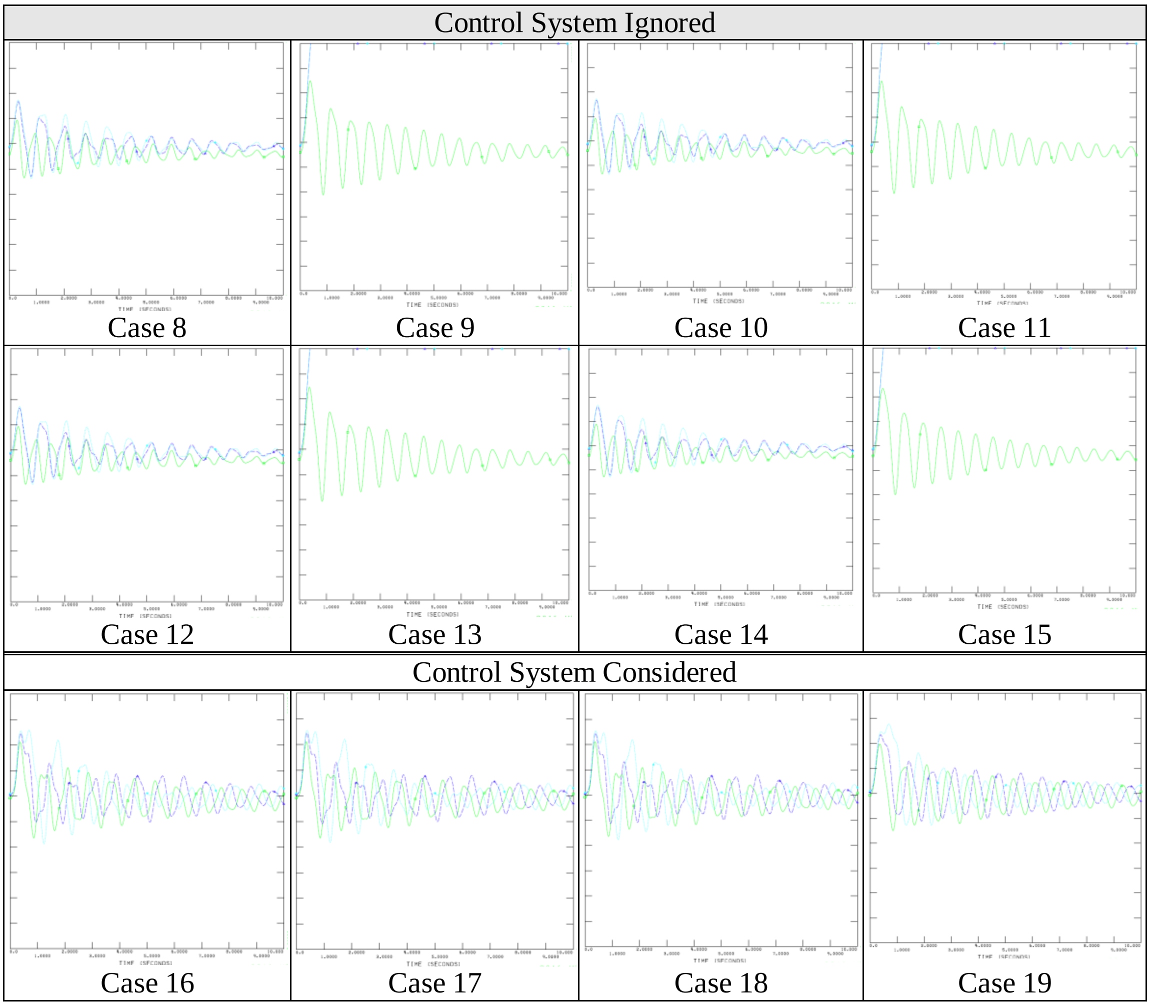
In practice, the fault clearing time of the 275 kV transmission line will be 0.1 second or less, shorter than that of the 66 kV transmission line, and it is expected that stability will be maintained even if a fault occurs on the 275 kV transmission line.

In the case where the control systems of the generator are considered, stability will be maintained in all cases where a fault on all the 275 kV and 66 kV transmission lines is assumed, even if the fault clearing time is assumed to be 0.15 seconds. In general, a control system will be installed for all generators, and it is considered that the network will not become unstable.

Table 3.5-8 Results of Stability Analysis under EDM's Current Network Expansion Plan System (2016)

<table>
<tr><th>Control System</th><th>Faulted Line</th><th>Fault Point</th><th>Fault Clearing Time</th><th>Stability</th><th>Case No.</th></tr>
<tr><td rowspan="8">Ignored</td><td rowspan="2">275 kV Matola-CTM</td><td rowspan="6">CTM 275kV</td><td>0.10 sec</td><td>Stable</td><td>8</td></tr>
<tr><td>0.15 sec</td><td>Unstable</td><td>9</td></tr>
<tr><td rowspan="2">275 kV Infulene-CTM</td><td>0.10 sec</td><td>Stable</td><td>10</td></tr>
<tr><td>0.15 sec</td><td>Unstable</td><td>11</td></tr>
<tr><td rowspan="2">275 kV CTM-Facim</td><td>0.10 sec</td><td>Stable</td><td>12</td></tr>
<tr><td>0.15 sec</td><td>Unstable</td><td>13</td></tr>
<tr><td rowspan="2">66 kV CTM-SE2</td><td rowspan="2">CTM 66kV</td><td>0.10 sec</td><td>Stable</td><td>14</td></tr>
<tr><td>0.15 sec</td><td>Unstable</td><td>15</td></tr>
<tr><td rowspan="4">Considered</td><td>275 kV Matola-CTM</td><td rowspan="3">CTM 275kV</td><td>0.15 sec</td><td>Stable</td><td>16</td></tr>
<tr><td>275 kV Infulene-CTM</td><td>0.15 sec</td><td>Stable</td><td>17</td></tr>
<tr><td>275 kV CTM-Facim</td><td>0.15 sec</td><td>Stable</td><td>18</td></tr>
<tr><td>66 kV CTM-SE6</td><td>CTM 66kV</td><td>0.15 sec</td><td>Stable</td><td>19</td></tr>
</table>

(Source: Network analysis results from the JICA Study Team using data provided by EDM)



(Source: Network analysis results from the JICA Study Team using data provided by EDM)

Figure 3.5-9 The Fluctuation Curves of Generator Voltage Angles under EDM's Current Network Expansion Plan System (2016)

(5) Conclusion

Table 3.5-9 provides the analysis results under EDM's current network expansion plan system.

The ascertained results by power flow analysis are as follows:

Overloading of many existing 66 kV transmission lines will be solved by introducing 275 kV transmission lines to the metropolitan area but some overload will remain for some transmission lines for regional supply to which the effects of introducing the 275 kV lines are not reached. This is an intrinsic problem that rises as demand grows. To solve this problem, the conductors of existing transmission lines need to be changed to thick ones or new transmission lines must be installed.

The ascertained results by fault current analysis are as follows:

As a result of introducing the 275 kV transmission line, the fault currents of the 66 kV bus will substantially increase, exceeding the maximum permissible value of 25 kA at five stations. As a countermeasure against this, replacing the existing breaker with a new one having a high rated current breaking capacity may be a solution. However, it is recommended to open some 66 kV transmission lines and divide the 66 kV system into plural systems. In this way, the power, which flows into the 275 kV transmission line before any faults, can be prevented from shifting into the 66 kV system and the 66 kV transmission lines can be prevented from being overloaded. Usually, when a high voltage system and a low voltage system operate in parallel, power flow before fault occurrence shifts to the low voltage system, overloading the low voltage system is caused and the effects of a fault expands one after another. Dividing the 66 kV system in units of 275/66 kV substations has the effect of limiting the range of the influence of a fault.

The ascertained results by stability analysis are as follows:

When the 275kV transmission line will be introduced and the 66 kV transmission line will be opened, the connectivity of the generator installed on the CTM 66 kV bus with the 66 kV system will drop. In the case where a 66kV transmission line fault occurs and the fault clearing time is 0.15 seconds, inherent network stability that does not consider the control system of the generator will become unstable. If the fault clearing time is 0.10 seconds, the network will be stable. If the generator control system is taken into consideration, the network will be stable even if the fault clearing time is 0.15 seconds and no problems of stability are considered to arise in the actual system.

Table 3.5-9 Conclusion of Analysis Results under EDM's Current Network Expansion Plan System (2016)

Item	Results
Power flow	･Number of overloaded existing lines will decrease because of introducing 275 kV lines ･Some lines to mainly supply to local load will remain overloaded
Fault current	･Fault currents will exceed permissible maximum value 25 kA at 66 kV bus in many stations ･In order to reduce fault currents, some of the 66kV lines should be opened continuously to configure radial network
Stability	･Inherent stability without control system depends on fault clearing time ("FCT"), stability cannot be maintained at FCT 0.15s ･Stability with control system can be maintained

(Source: JICA Study Team)

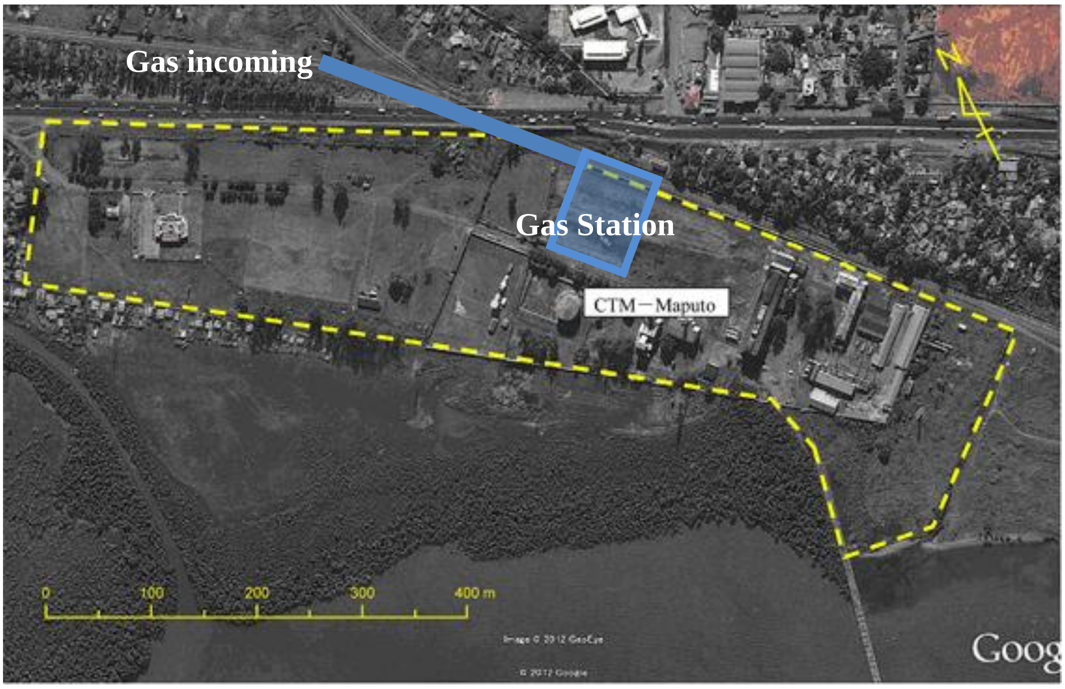
3.6 Fuel Gas Volume Constraints

3.6.1 Fuel Gas Volume Constraints

Fuel gas supply is considered as a part of the natural gas distribution project to Maputo by Empresa Nacional de Hidrocarbonetos de Mocambique ("ENH", English name - Mozambican National Hydrocarbon Company). Therefore, any construction cost for gas feeding to the CCGT Project is basically out of the scope of the CCGT Project . Since natural gas supply volume is limited to 6 MGJ per year, the power output of the new CCGT is also limited to approximately 100 MW.

3.6.2 Gas Supply Contract Constraints

The CTM can be fed by a gas substation to be built by ENH at the site of the CTM, while at the Beluluane site it may be required to build a dedicated 3.5 km pipeline. This requires further agreements with the concession holders like Matora Gas Company that may delay the project implementation.



(Source: JICA Study Team)

Figure 3.6-1 Location of Gas Station and Gas Pipeline Route

3.6.3 Constraints for Environmental and Social Consideration

The Environmental Impact Assessment ("EIA") for the gas pipeline construction works from PRS-2 to CTM and Maputo City have already been approved by the government. In the meantime, in the case of the Beluluane site, it is necessary to newly install a gas pipeline from PRS-2 to the Beluluane site and a concession agreement with Matola Gas Company, etc., may be required and thus another EIA for this work may also be required. Therefore, it is anticipated that it would take a longer time to construct a power plant at the Beluluane site. Getting approval for the EIA and making a concession agreement would likely cause a delay of construction of the power plant at Beluluane.

3.7 Potential CCGT Product

According to the sections on "Development area and general layout", "Fuel gas volume constraints" and "Transmission constraints," one block multi-shaft 1-on-1 CCGT, with capacity of Maximum 50 MW can be installed at the Beluluane site and one block of multi-shaft 2-on-1 110 MW CCGT can be installed at the CTM site. Applicable CCGT models for each site are shown Tables 3.7-1 and 3.7-2 from the 2012 GTW Handbook. At the CTM site, a GGCT model can be selected from many manufactures. However, at the Beluluane site, only a few applicable CCGT models can be selected.

Table 3.7-1 Major Combined Cycle Power Generation Plants for Beluluane (GT One-shaft Configuration)

Manufacturer	Model	Output (MW)	Efficiency (%] (LHV)
GE	106F	118.4	55.0
Siemens	SCC800	66.1	53.7
GE	106B	64.8	50.4
IHI (GE licensee)	LM6000PD	55.2	53.3
Hitachi	1025(H-25)	43.8	50.1
Rolls-Royce	RB211-GT61	42.6	52.8

(Source: JICA Study Team)

Table 3.7-2 Major Combined Cycle Power Generation Plants for CTM (GT One-shaft Configuration)

Manufacturer	Model	Output (MW)	Efficiency (%) (LHV)
GE	206B	130.9	50.9
IHI (GE licensee)	2 x LM6000PD	111.0	53.6
Hitachi	2025(2 x H-25)	87.8	50.3
Rolls-Royce	2 x RB211-GT61	85.3	52.8
Pratt &Whitney	SWIFTPAC60	74.2	51.3
Siemens	SCC600	73.4	50.9

(Source: JICA Study Team)

3.8 Comparison of the Candidate Sites

In selecting a power plant construction site, the necessary layout of the site area, present situation, accessibility, topography, geology, and weather conditions of the site, constraints of the system, fuel supply constraints, condenser cooling method, and selectivity of CCGT equipment were objectively and comprehensively compared and studied, based on the items of assessment stated above.

The results of the comparison and study of the two power plant construction sites are shown in

Table 3.8-1. The CTM site was selected as the project site for a power plant up to 100 MW. The major determining factor was transmission network capacity constraint. The results of the comparison and study of the two power plant construction sites are shown below.

Table 3.8-1 Comparison of the Candidate Sites

	CTM	Beluluane
Development area and general layout	3.7ha -> 110 MW X 2 units	1.5ha -> 110 MW X 1 unit
Land preparation and accessibility	Easy land clearance and access	Easy land clearance and access
Topographical, geological, and meteorological conditions	Special care required for potential floods by heavy rain -> 0.5-1m high embanking	Moderate condition
Transmission line constraints	Relatively higher capacity approx. 100 MW	Lower capacity at max. 50 MW
Fuel gas volume constraints	6.0 MGJ/yr -> up to 110 MW	6.0 MGJ/yr -> up to 110 MW
Steam turbine condenser cooling	Easy access to sufficient water resources -> 3 types (Once-through, Wet Cooling Tower, Air Cooled Condenser)	Insufficient water resources -> Only Air Cooled Condenser
Potential CCGT products	For 70-110 MW -> Wide selection	For 50MW -> Few options
Conclusion	Up to 110 MW CCGT with Once-through, Wet Cooling Tower, or Air Cooled Condenser	Up to 50 MW CCGT with Air Cooled Condenser

(Source: JICA Study Team)

3.9 Output from Workshop for Site Selection

Based on the above results of the study of site selection, a workshop was held (October 4, 2012) to officially decide the development point of EDM, with Mr. Adriano Jonas (in charge of generation, transmission/distribution, and sales), a board member of EDM, participating. In this workshop, the CTM site was officially decided as the development point and conditions for basic design were determined.

(1) Mojor specifications

- Rated generation capacity: 70 to 110 MW
- Thermal efficiency: More than 50%
- Capacity factor: More than 80% (for base power supply)
- Fuel: Natural gas from Pande gas field

(2) Major equipment

- Combined Cycle Gas Turbine ("CCGT") plant
  a. GT and generator: 2 units
  b. ST and generator: 1 unit
  c. Heat recovery steam generator: 2 units
  d. Air cooled condenser: 1 unit
  e. Auxiliary facilities such as 11 kV switch gear, step-up transformer, fuel gas supply facility, water supply tank , etc.
- Civil works such as foundation piling, buildings
- Other facilities for water treatment, wastewater treatment, and fire fighting

(3) Other

The location of the CCGT power plant at CTM requires environmental approval from MICOA. Prior to the approval, an application for determining the category of a social EIA must be filed. In accordance with the intentions of EDM to promptly advance these administrative procedures, the basic specifications of the CCGT power plant were assumed as follows and local applications were moved forward in parallel and simultaneously.

- Generated electricity is delivered to mainly Maputo City via the existing CTM 66 kV substation ajacent to the CTM power station.
- The monitoring and control system will be integrated into the exisiting Supervisory Control and Data Aquisition ("SCADA") at the Southern region load dispatch center adjacent to the power station.
- The power plant is expected to start construction in 2014 and be put into commercial operation in 2017 using Japan's Offical Development Assistance ("ODA") financial source.
- The power plant is expected to achieve a lower production cost of approximately 0.07 – 0.08 USD/kWh, and its construction cost on EPC contact basis is estimated to be approximately USD 120 million in consideration of international practices so far.

Chapter 4

Suitable rated power and General Specification

Chapter 4 Suitable Rated Power and General Specification

4.1 Suitable Rated Power

4.1.1 Fuel Gas Supply Amount

As stated in the already concluded electric power sector investigation results, the new gas-fired power plant is assumed to have base load operation with 100% load and high capacity factor because of continuous operation, except for planned outages for periodic inspections and facility maintenance.

CCGT capacity is restricted by the amount of fuel natural gas that will be supplied. Since the gas supply amount to the new gas-fired power plant is 6.0 MGJ/year, the power plant capacity is calculated at approximately 114 MW.

The available generation capacity (MW) = $6.0 \times 10^6 \times 10^9 \times (50/100) / (24 \times 365 \times (83/100) \times 3.6 \times 10^9)$
where the plant thermal efficiency and capacity factor are assumed to be 50% and 83%, respectively.

4.1.2 Power Plant Area

The power plant capacity is also restricted by the scale of the plant to be installed at the planned site. For the CTM Maputo thermal power station, a new power plant candidate, a total of about 3.7 ha (i.e., the former coal-fired thermal power plant area plus the diesel oil tank area for existing gas turbines) will be needed for the new power plant. As described in Section 3.2, two blocks of 110 MW class 2-on-1 type CCGT can be installed in the CTM Maputo power station.

4.1.3 Gas Turbine Manufacturer

The CCGT rated capacity is determined by the gas turbine (“GT”) and steam turbine. The GT output is determined by the type of the GT manufacturer, i.e., not arbitrarily decided by the user. Normally, the EPC contractor selects a GT suitable for the output and shaft configuration of the power plant from the manufacturer’s GT models and combines it with a steam turbine suitable for the steam condition and steam amount generated in the Heat Recovery Steam Generator (“HRSG”).

Table 4.1-1 shows applicable CCGTs which can support the power generating possible output of 114 MW calculated from the gas supply amount in the CCGT with the multi-shaft 2-on-1 CCGT in the order from larger output. Each CCGT output and efficiency is from under ISO conditions (i.e., 15°C, humidity 60%, 1013hPa).

Table 4.1-1 Applicable major CCGT model

Manufacturer	Model	Output (MW)	Efficiency (%] (LHV)
IHI (GE licensee)	2xLM6000PD	111.0	53.6
Hitachi	2025(2 x H-25)	87.8	50.3
Rolls-Royce	2 x RB211-GT61	85.3	52.8
Siemens	SCC-700 2x1	83.6	52.5
Pratt &Whitney	SWIFTPAC60	74.2	51.3

(Source: 2012 GTW Handbook)

For CCGT rated capacity, the CCGT range for selection can be expanded by making a setting with a margin of 70-110 MW and the promotion of proper and active competition bidding among EPC contractors.

4.2 Power Block Configuration (2-on-1, 1-on-1)

4.2.1 CCGT Configuration

The CCGT configurations with the rated capacity of 70-110 MW consisting of one or two gas turbines and Heat Recovery Steam Generator (HRSG), and one steam turbine are evaluated. The CCGT configurations to be evaluated will consist of two gas turbines and HRSGs, for the following reasons:

(1) One 70-110 MW class CCGT consisting of one gas turbine, one HRSG and one steam turbine is impossible to operate continuously during planned outages of GT periodical inspections, maintenance and forced outages by GT breakdown in which the GT has higher breakdown risk than the main facility.

(2) Fair competitive bidding is not likely because of the limited amount of applicable CCPP manufacturers, i.e., GE and Ansaldo, and the EPC cost is higher.

There are two types of CCGT configurations: one-shaft configurations and multi-shaft configurations. One-shaft configurations connect the GT, steam turbine, and the power generator on the common shaft. If the common shaft is not shared by the GT and compressor, a one-shaft configuration cannot be used.

In Japan, nuclear power plants operate 100% load as the base load of power demand, and thermal power stations operate for middle and peak loads for changing electric power demand. For one-shaft configurations it is possible to quickly stop and start high thermal efficiency at plant partial loads, therefore one-shaft configurations are adopted in great quantities in Japan. Multi-shaft configurations use different shafts for the GT generator and for the steam turbine generator. They are used in the world in great quantities.

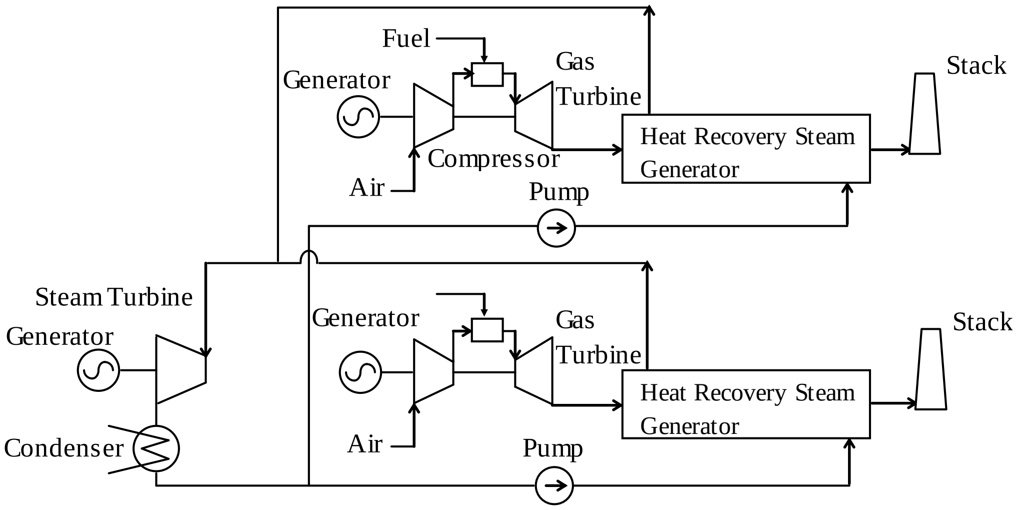
In addition, multi-shaft configurations include 1-on-1 types having one block of one GT generator, HRSG, and one steam turbine generator and 2-on-1 type including two GT generators, two HRSGs, and one steam turbine generator.

Table 4.2-1 shows shaft configuration.

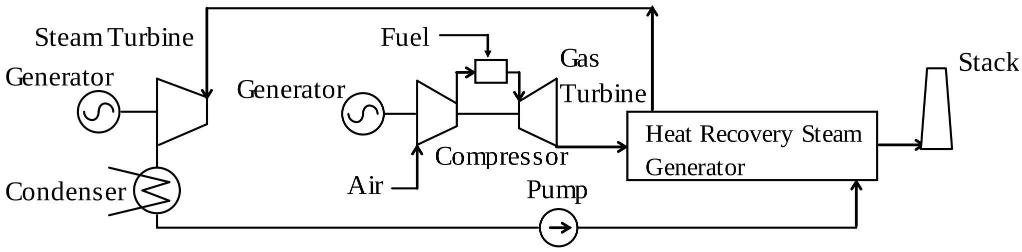
Table 4.2-1 Type of CCGT configuration

	Type A	Type B	Type C
Configuration	Multi-shaft 2GT + 2HRSG and 1ST (2-on-1)	Multi-shaft 1GT + 1HRSG and 1ST (1-on-1)	One-shaft 1GT + 1HRSG + 1ST

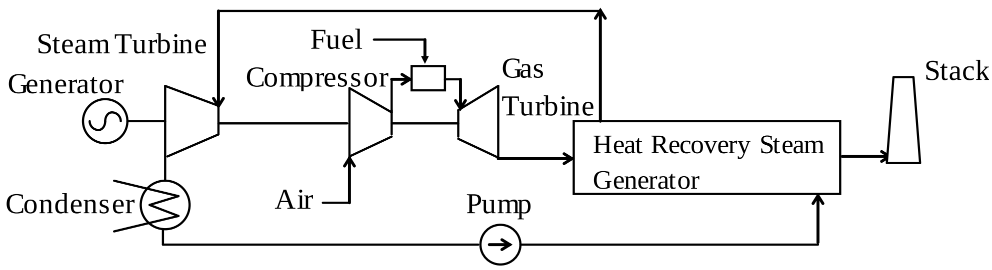
(Source: JICA Study Team)



Type A: Multi-shaft CCGT (2-on-1)



Type B: Multi-shaft CCGT (1-on-1)



(Source: JICA Study Team)

Type C: One-shaft CCGT

Figure 4.2-1 Type of CCGT configuration

4.2.2 Main Characteristics of CCGT Shaft Configurations

(1) Output and Thermal Efficiency
Two blocks of multi-shaft type 1-on-1 or one-shaft type CCGT use two small-capacity steam turbines but multi-shaft type 2-on-1 use one large-capacity steam turbine, i.e., a small loss of steam. If capacity is increased, the output and efficiency of the entire plant will become higher than the other two types. For CCGT efficiency, GT efficiency suddenly drops at about 80% of the rated output. For partial loads of the plant, since high-load operation can be done in each block in multi-shaft 1-on-1 and one-shaft CCGT, they have higher efficiency than multi-shaft 2-on-1 in partial load operation.

The following compares the output and efficiency between one block of multi-shaft type 2-on-1 CCGT and two blocks of multi-shaft 1-on-1 type and one-shaft type CCGT.

Table 4.2-2 Comparison of performance of CCGT configuration

Manufacture	Model	Multi-shaft 2-on-1 x 1		Multi-shaft 1-on-1 x 1	
		Output (MW)	Efficiency (%) (LHV)	Output (MW)	Efficiency (%) (LHV)
IHI (GE Licensee)	2 x LM6000PD	111.0	53.6	110.4	53.3
Hitachi	2025 (2 x H-25)	87.8	50.3	87.4	50.1
Rolls-Royce	2 x RB211-GT1	85.3	52.8	No data available	
Pratt %Whitney	SWIFTPAC60	74.2	51.3	73.1	50.6
Siemens	SCC-600 2 x 1	73.4	50.9	72.0	49.9

(Source: 2012 GTW Handbook)

(2) Operability
CCGT is operated only by automatic control of the fuel flow to the GT and starting, normal operation, and stopping operation can be automated completely regardless of the shaft configuration. The difference of shaft configuration does not mean any essential difference of operability. For one-shaft CCGP, since auxiliary steam is ensured from the auxiliary boiler and operating unit and both the GT and steam turbine are started or stopped, it can start or stop more quickly than the multi-shaft type.

For multi-shaft 2-on-1, even if other GTs stop because of maintenance, it can continue to operate with about 50% of the load in the plant.

(3) Start-up Steam
For multi-shaft CCGT, the GT generator can be started together with HRSG when the steam turbine is disconnected. If steam necessary to start the steam turbine is available from HRSG after a certain time elapses after the gas turbine start-up, the steam turbine can be started up with its own steam for flow passage cooling and gland sealing.

In case of the single-shaft configuration, however, the steam for the flow passage cooling and gland sealing of the steam turbine which must be started up together with the GT is required from any external source or the operating unit. For this purpose, any auxiliary steam from the existing boilers or a standalone auxiliary boiler will be needed.

(4) Footprint Area for Instruction

Since the GT generators and the steam turbine generators are installed individually for multi-shaft CCGT, the space usage ratio is inferior to one-shaft CCGT. In particular, two blocks of multi-shaft 1-on1 have more facilities than the other types, i.e., requires a larger installation area.

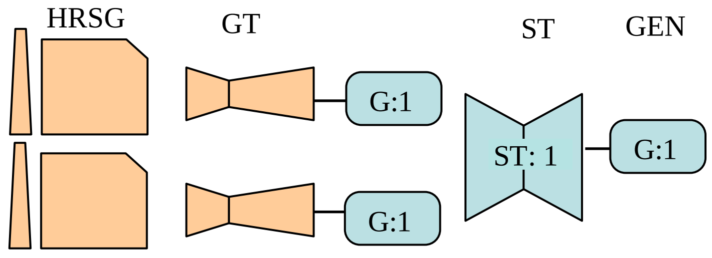
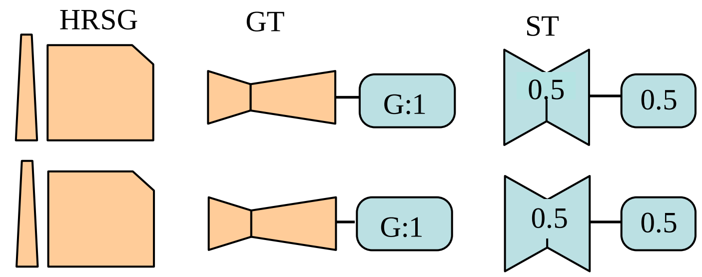
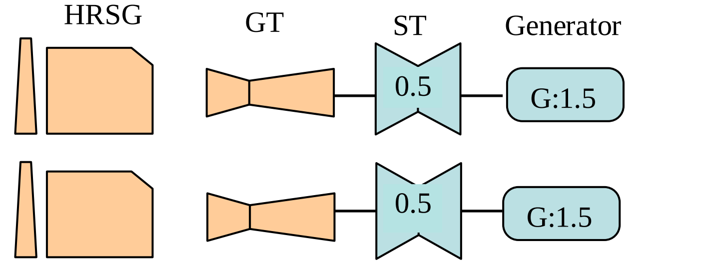
(5) Construction Costs

The construction costs of multi-shaft 2-on-1, multi-shaft 1-on-1, and two blocks of one-shaft CCGT will be compared and evaluated. Each configuration has the same number of GTs and HRSGs (i.e., two GTs and two HRSGs) and each configuration has a different number of power generators and steam turbines. The following assumptions are made in order to make a comparison:

- The construction cost is proportionate to the physical scale of the plant to the power 0.6. i.e., (scale of the plant)$^{0.6}$
- Cost of steam turbine generators is regarded as 1, of which 30% is for the generator and 70% is for steam turbine.

Table 4.2-3 shows the results of the comparison and examination. As shown in the table, the constructions costs of the multi-shaft 1-on-1 is the highest because it has many facilities and the multi-shaft 2-on-1 has the lowest cost.

Table 4.2-3 Construction cost of CCGT

	Configuration	Cost for GT and ST
Multi shaft 2-on-1 (Type A)		ST = 0.7 GT = 3 x 0.3 Total = 1.6
Multi shaft 1-on-1 (Type B)		ST = 0.66 x 0.7 x 2 GT = (1+0.66) x 0.3 x 2 Total = 1.92
Single shaft (Type C)		ST = 0.66 x 0.7 x 2 GT =1.28 x 0.3 x 2 Total = 1.69

Note: ST is steam turbine.
(Source: JICA Study Team)

(6) Maintainability and Maintenance Costs

Since the structure of one-shaft CCGT is more complicated than the multi-shaft type because GT and steam turbine share a common shaft, the disassembly and assembly of the main equipment are troublesome. In regards to maintenance costs, since two blocks of multi-shaft 1-on-1 have more main equipment than the others, more manpower and processes are required for maintenance, i.e., higher costs can be assumed.

(7) Effect y of Gas Turbine Outage

As explained above, multi-shaft 2-on-1 CCGT consists of two GTs, two HRSGs and one steam turbine. CCGT can operate continuously 50% of rated capacity and high efficiency during the outage of one GT for periodic inspections and trouble. One block of multi-shaft 1-on-1 and one-shaft CCGT cannot operate during its own gas turbine outage.

(8) Requirements from EDM

EDM has requested that the new power plant shall be as follows:

- Plant can operate 100% of rated capacity with high thermal efficiency
- Lowest EPC costs
- As the fuel gas contract is “Take-or-Pay”, the plant can operate continuously during outages of one GT for periodic inspections and trouble. Periods of plant outages should be as short as possible.

(9) Summary of Examination Results

A summary of the results of the evaluation is shown in the following table. As shown in this table, each CCGT configuration has merits and demerits.

Table 4.2-4 Feature of Type of CCGT Configuration

Comparison Item	Type A Multi-shaft (2-on-1)	Type B Multi-shaft (1-on-1) × 2	Type C One-shaft × 2
Output	Base	-0.4 to -1.4MW*	-0.4 to -1.4MW*
Thermal efficiency	Base High total plant efficiency	-0.2 to -1.0%* High efficiency at plant partial load	-0.40 to -1.0%* High efficiency at plant partial load
Operability	Base	Equivalent	Rapid start/ stop
Auxiliary steam at start	Own steam	Own steam	Auxiliary steam from outside
Number of main facilities	Base GT: 2 HRSG: 2 ST: 1 GEN: 3	Many GT: 2 HRSG: 2 ST: 2 GEN: 4	Equivalent GT: 2 HRSG: 2 ST: 2 GEN: 2
Installation area	Base	Slightly wide	Slightly compact
Construction costs	Base	High	Slightly high
Actual results	Many	Many	Limited manufacturers and remodeling required
Maintainability	Base	Equivalent	Disassembly of main equipment is slightly complicated

Comparison Item	Type A Multi-shaft (2-on-1)	Type B Multi-shaft (1-on-1) × 2	Type C One-shaft × 2
Maintenance cost	Base	Slightly high because of many operating equipment and facilities	Almost equivalent

(Source: JICA Study Team, 2012 GTW Handbook)

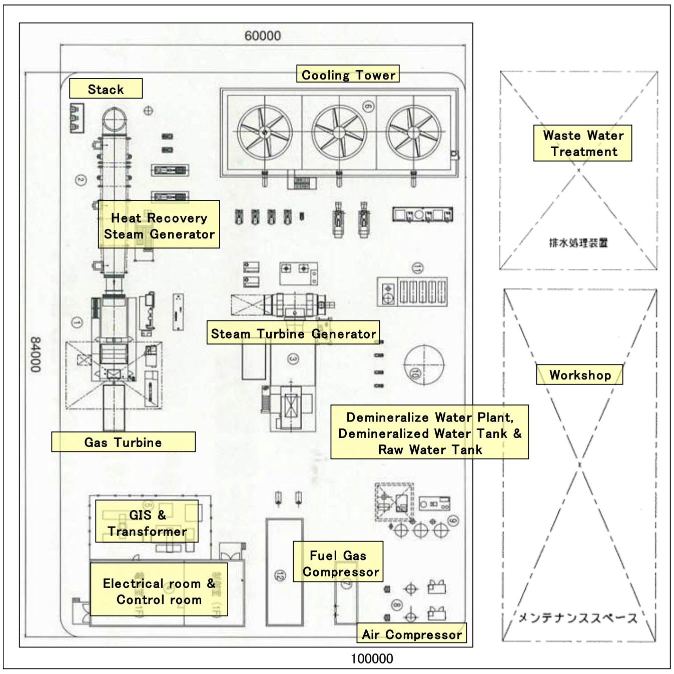
The concerned power generation plant will be built in southern Maputo city in Mozambique to cope with the tight power demand in Mozambique. For this plant, one unit operation is assumed for the present and continuous operation of the power plant with as high efficiency as possible is required.
Globally, in the case of plants that require high efficiency operation and high capacity factor, multi-shaft 2 and more-on-1 CCGTs are installed.

The JICA Study Team recommends multi-shaft 2-on-1 CCGT since it is superior in the total efficiency of the power plant and it allows partial load operation with high efficiency of about 50% even if a GT stops because of periodic maintenance, etc., and it has maintenance costs. In addition, after an investigation of the gas supply amount, site area, and applicable CCGT models to be supported, 70-110 MW of CCGT rated capacity was recommended to EDM in the first workshop and was approved.

4.2.3 The Layout of CCGT

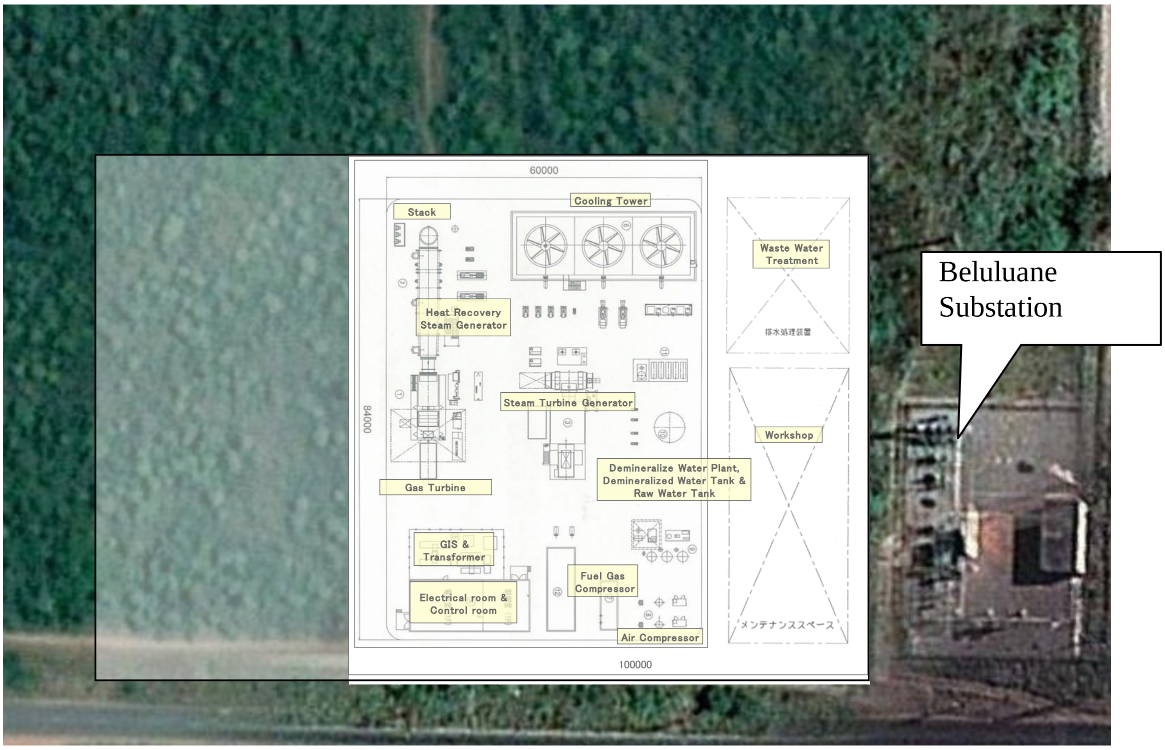
(1) Beluluane site

An example of a 50 MW class CCGT plant layout and its installation at the Beluluane site are shown in Figure 4.2-2 and Figure 4.2-3. The main equipment, related equipment, and work area for periodic inspection can be located in a 1 ha area (100 m x 100 m) with remaining land of 100 m x 50 m still available.



(Source: JICA Study Team)

Figure 4.2-2 An example of a 50 MW class CCGT Plant Layout



(Source: JICA Study Team)

Figure 4.2-3 An example of a CCGT Layout at the Beluluane site

(2) The layout of CTM Maputo site

a. Site Conditions

As a result of a hearing with EDM and measuring the actual site, the following land is available for the power plant:

(i) Former coal-fired power station: Yard of 270 m x 96 m (approx. 2.6 ha)

EDM has the intention of separating the power station from the substation located to the east of the power station and plans to install a fence at the boundary and a road to access the substation along the boundary to the north of the power station.

(ii) Diesel oil tank yard (approx. 1.1 ha)

The existing GTs will be modified to use natural gas and the existing 5,000 kl and two 220 kl diesel oil tanks will be removed.

(iii) Existing No. 3 gas turbine area (approx. 0.3 ha)

EDM has approved the installation of the utilities of the new plant. However, some space for maintenance for No. 3 GT will be left untouched.

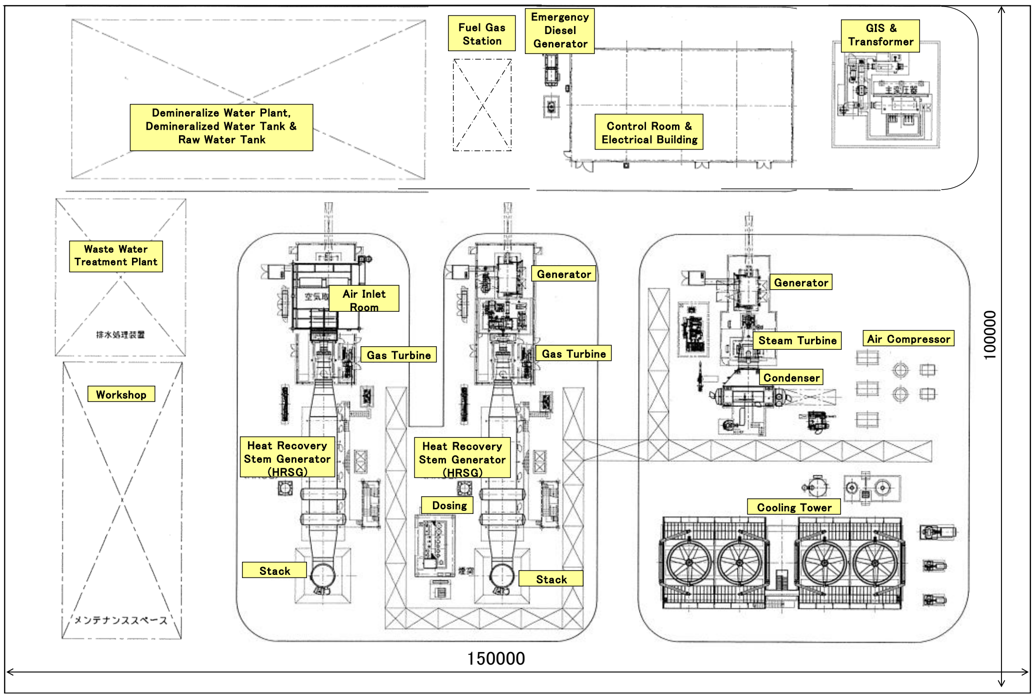
(iv) Terminal points for fuel gas and portable water

Fuel gas: To branch from a new gas station

Water: To branch from the vicinity of the booster pump in the northwest of the CTM Maputo power station

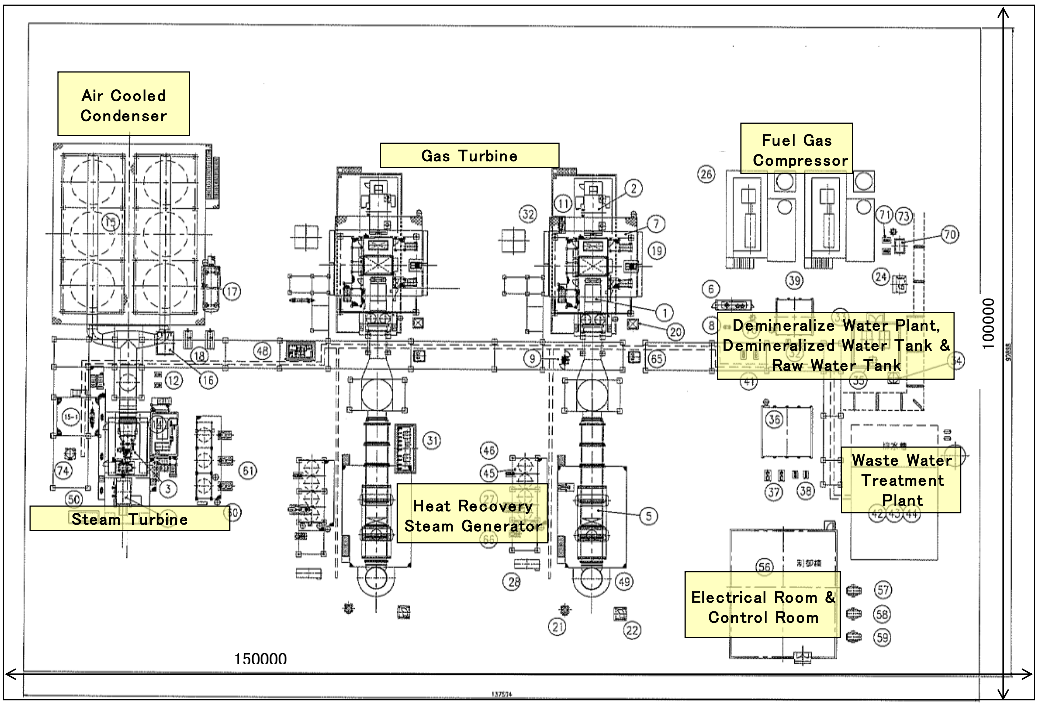
b. Power Plant Layout

Aero-derivative GTs or heavy duty industrial GTs can be used for the 110 MW class multi-shaft type 2-on-1 CCGT. Typical CCGT layouts using each GT are shown in Figure **4.2-4** and Figure 4.2-5. In either case, two GT Generators, two HRSGs, one steam turbine generator, and utility equipment such as switching gear, water treatment equipment, and wastewater treatment equipment fit in an area of 150 m x 100 m.



(Source: JICA Study Team)

Figure 4.2-4 Typical CCGT Layout of a heavy duty GT



(Source: JICA Study Team)

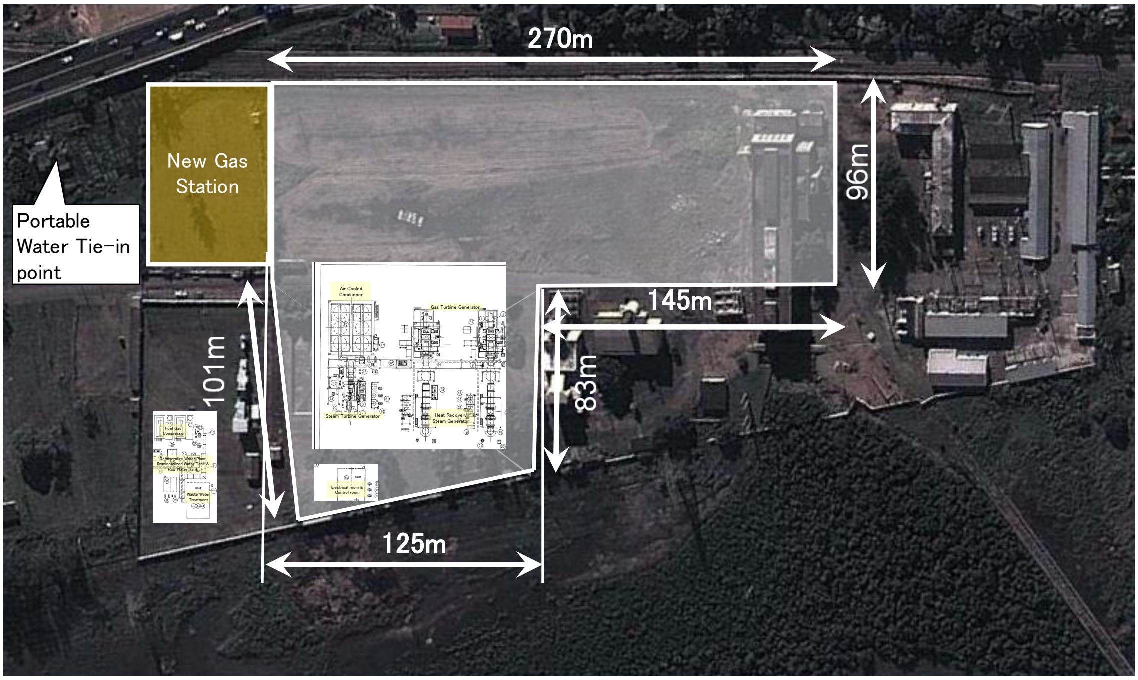
Figure 4.2-5 Typical CCGT Layout of an aero-derivative GT

Using the site conditions of CTM Maputo and a typical plant layout for reference, three cases of plant layouts were studied.

1) Case 1: Installing the main facility in the diesel oil tanks area and the utility facility in the existing No. 3 gas turbine area

In case 1, the area of the former coal-fired power plant facilities can be used as the site for future plant extension. In addition, expenses for land clearing and demolition removal can be reduced because the foundation of the thermal power plant facilities is available at the site of the former coal-fired power station. The tie-in point of portable water and fuel gas are close by. Sufficient space is also available for construction and maintenance for the power plant facilities. Moreover, because the site is far from the northern boundary of the power station where residents live, there is no need to protect against noise, such as installing soundproof barriers.

EDM intends to modify the control equipment of the existing Nos. 2 and 3 GTs and install a distributed control system ("DCS") in the central operation room of the new power plant, so that the existing GTs can be started from the central operation room in case of an emergency shutdown, e.g., if the new power plant stops due to trouble. Both the equipment and site can be operated and managed combining the existing Nos. 2 and 3 GTs and new power plant.



(Source: JICA Study Team)

Figure 4.2-6 Plant Layout (Case 1)

2) Case 2: All facilities installed at the former coal fired power plant area

Taking into consideration any future construction for power plant extensions, the power plant will be constructed from the side of the former coal fired power plant turbine building behind the power station. The longitudinal direction is 96 m, i.e., narrower than 100 m. It will be even narrower if an access road to the switching yard is built along the northeastern boundary fence. Consequently, sufficient work area will not be available during power plant construction work and for maintenance and inspection. In addition, the former coal fired power plant site needs to be demolished and cleared for construction of the new power plant. The site is closest to the substation as compared with the other cases and the distance over which cables would be laid down to the substation is short. As there is a nearby residential area, noise prevention measures may be necessary. For future extension of the power plant, both the part of the former coal fired power plant site that will become available after construction and the diesel oil tank area will be reserved.

(Source: JICA Study Team)

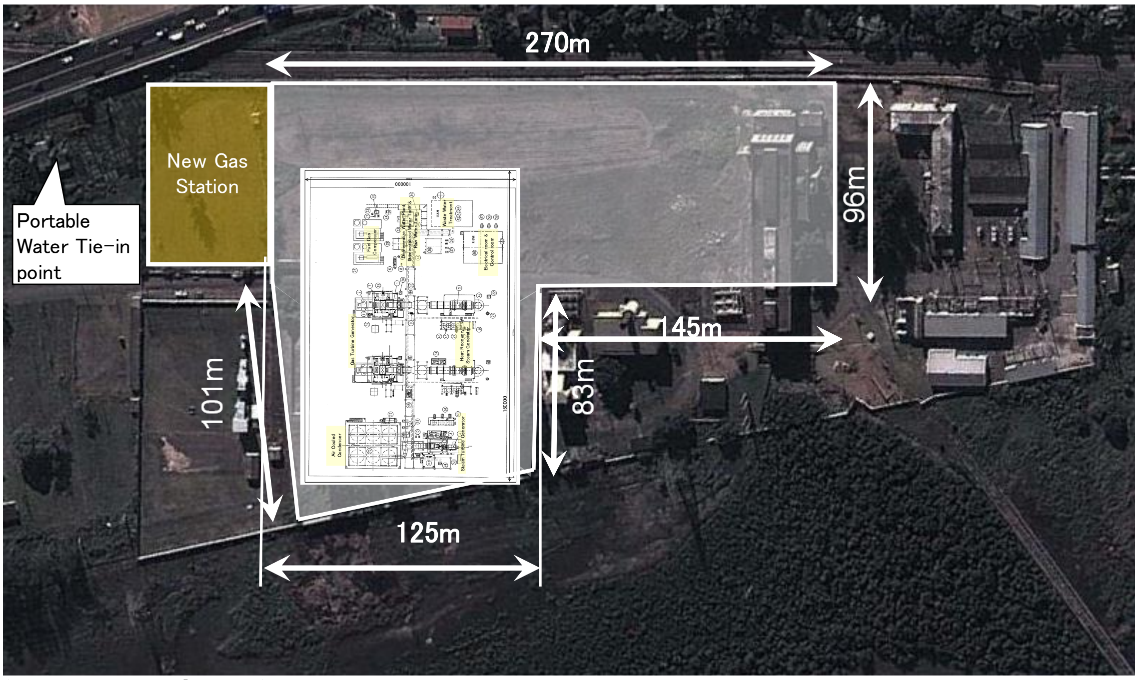
Figure 4.2-7 Plant Layout (Case 2)

3) Case 3: All facilities installed in the current diesel oil tank area

The 110 MW class multi-shaft 2-on-1 CCGT does not fit into the diesel oil tank area. The equipment that spills over must be installed in the former coal fired power plant area. It is therefore necessary to demolish the former coal fired power plant area. The area for future power plant extension will be smaller than case 1 and the land area will be an odd shape.

In case 3, the tie-in points of fuel gas and portable water are close, like in case 1, and the distance over which pipes must be laid down is short. There is a sufficient work area for construction work and inspection and maintenance work for the equipment and power plant extension.

Since the plant is far from the northern boundary of the power station where residents live, there is no need to have any noise protection such as installing soundproof barriers.



(Source: JICA Study Team)

Figure 4.2-8 Plant layout (Case 3)

Table 4.2-5 shows the results of studying cases 1) to 3) above. Case 1, which does not need the former coal fired power plant area to be demolished nor any countermeasures taken against noise and ensures that a large area of land is available for future power plant extensions, was recommended by the JICA Study Team to EDM at the Workshop and it has been approved. It has been decided that a detailed layout study of this case will be advanced.

Table 4.2-5 Feature of Each Case of CCGT

Case		Results
Case 1	Advantages	・Area of former coal fired power plant can be used for any power plant extensions in the future. ・Very close to the new gas station and portable water tie-in point. ・No need for any noise protection on the boundary line. ・Sufficient construction and maintenance work area.
	Disadvantages	・Existing No. 3 GT area is used.
Case 2	Advantages	・Site area can be reserved for future extensions of the power plant. ・Close to substation.
	Disadvantages	・Site for the power plant is slightly narrow. ・Therefore, sufficient construction and maintenance work area is not available. ・Noise protection is needed on the site boundary line.
Case 3	Advantages	・Very close to the new gas station and portable water tie-in point. ・No need for any noise protection on the boundary line. ・Sufficient construction and maintenance work area
	Disadvantages	・Area for future power plant extension is narrower than the other two cases. ・Facility protrudes into the former coal fired power plant area, making layout inappropriate.

(Source: JICA Study Team)

4.3 Condenser Cooling System

4.3.1 Outline

There are three types of cooling facilities for the condenser of the steam turbine in this power generation plant, i.e., once-through cooling system, wet cooling tower system, and air-cooled condenser system. The merits and demerits of the cooling systems vary depending on the site peripheral conditions, operation conditions, and economic conditions such as power cost and fuel cost. This examination of the three types of cooling facilities has been done from the viewpoint of mechanical and constructional technology, and economic and environmental influences to select the cooling system suitable for this project.

While the performance of the GT which is the topping cycle in CCGT has no influence on the type of cooling system, the performance of the steam turbine which is the bottoming cycle has an influence on it.

4.3.2 Mechanical examination of condenser cooling system

Table 4.3-1 summarizes the characteristics of the three types of condenser cooling systems.

Table 4.3-1 Features of Condenser Cooling Systems

Cooling Method	Once-through Type	Wet Cooling Tower	Air-cooled Condenser
Cooling medium	Sea water, river water	Fresh water	Air
Characteristics of construction	- High construction costs - Environmental assessment required	- Construction costs cheaper than once-through type	- Construction costs cheaper than once-through type
Characteristics of O&M	- Highest output and efficiency - High operation maintenance costs	- Needs a lot of water for makeup to the cooling tower - Slightly bad vacuum and plant efficiency - Water quality needs to be maintained and managed	- No cooling water - Relatively bad output and efficiency - Low operation maintenance costs
Main facilities	Water supply/ discharge channel/ tube/ facility, circulating water facility, screen	Cooling tower, circulating water facility	Air-cooling condenser, fan
Facility cost	Highest costs	Cheaper than once-through type	Cheaper than once-through type
Cooling medium costs	None	High	None
License of harbor usage	Required	None	None

(Source: JICA Study Team)

(1) Once-through Cooling System

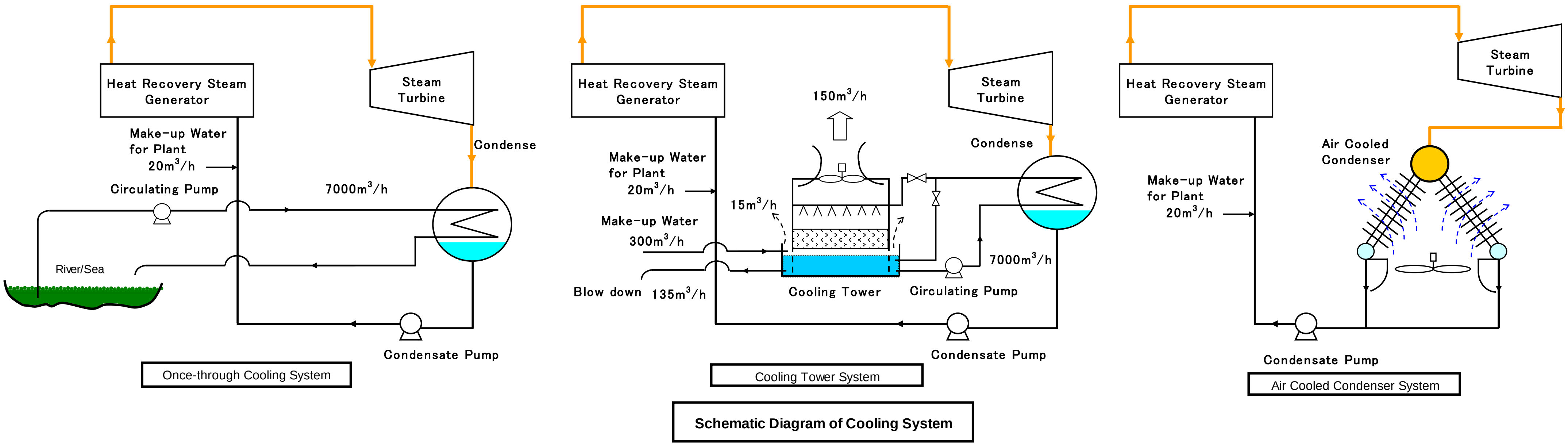
The once-through cooling facility uses seawater or river water as the coolant to return steam to condensate.

Since the cooling medium of water is abundant and the vacuum of the condenser can be lowered, the output and efficiency of the steam turbine are the highest of the three cooling systems. However, facility costs, maintenance costs, and management costs are the highest because of the construction facility for water intake and discharge, equipment to remove debris from the sea, and the facilities to keep the tube in the condenser clean. In addition, because of hot drainage, environmental impact studies and permits/ licenses from harbor authorities, etc., are required.

(2) Wet Cooling Tower System
Since the forced ventilating cooling facility does not require any water supply/ discharge facilities, the construction costs of this system are cheaper than those of the once-through type but a large amount of water is required for makeup water to the cooling tower. In addition, since the vacuum of the condenser is slightly lower than that of the once-through type, the output and efficiency of the steam turbine is slightly lower. Since no hot water is discharged into the sea, an environmental impact study and permits/ licenses from the harbor authorities, etc., are not required. Since the circulating water in the cooling tower makes direct contact with the air and part of it is evaporated to discharge heat, impurities and gas absorbed in the circulating water and impurities in the supply water are condensed causing bad effects, e.g., corrosion of devices and sticking of scales and slime, etc. To prevent these bad effects, water quality management and chemicals are needed to maintain water quality.

(3) Air-Cooled Condenser System
Since air-cooling condenser systems use the air as the coolant and a higher vacuum is required compared to the other two types, the output and efficiency of the steam turbine are low. Since no water is used as the coolant, there is no need for a water supply/ discharge facility or a pump to circulate a large amount of water. In addition, water quality does not need to be maintained. The construction costs, operation costs, and maintenance costs are cheap. Since this system does not use seawater as the coolant similar to the cooling tower type, an environmental impact study and permits/ licenses from the harbor authorities, etc., are not required.

The figure below shows the schematic system diagrams of the three types of cooling facilities.



(Source: JICA Study Team)

Figure 4.3-1 Schematic diagram of cooling system

4.3.3 Overall study of water intake facilities

Three types of cooling systems may be used as the condenser cooling system of a steam turbine: once-through cooling system, mechanical draft cooling tower system, and air-cooled condenser system. This section studies the applicability of these three condenser cooling methods from the viewpoint of civil engineering technology.

(1) Cooling water consumption and intake facilities

1) CTM Maputo site

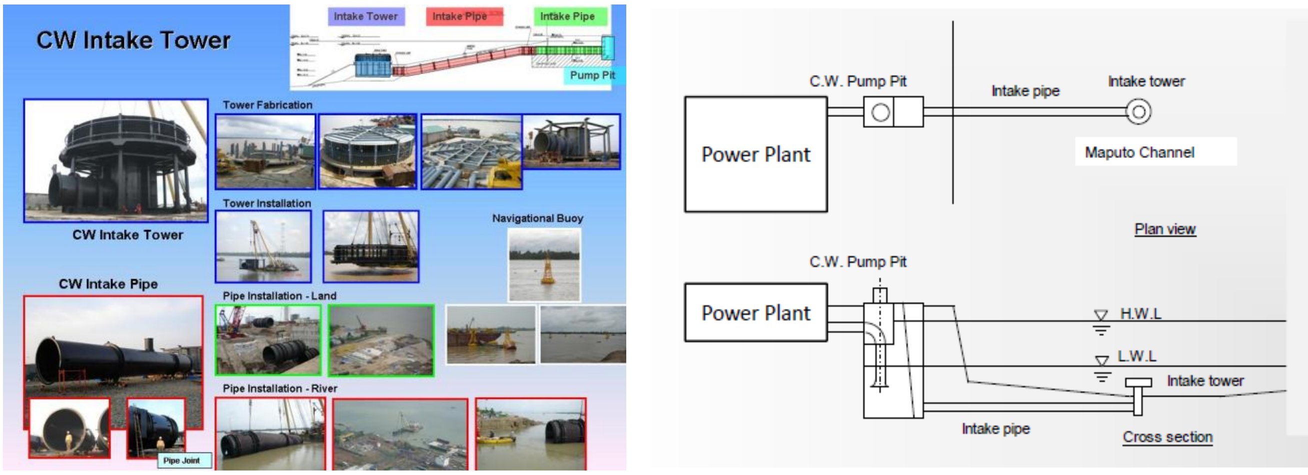
If a once-through cooling system is employed at the Maputo site, condenser cooling water of 7,000m^3/h will always be necessary in addition to make-up water of 20m^3/h for the plant. Consequently, an inlet channel of about 1.2 km long and an intake tower must be constructed. In the case of a wet cooling system, cooling make-up water of about 300m^3/h will be necessary. However, because the city water pipeline continues to the neighborhood of the site, no large-scale, additional facilities connecting to a water source will have to be constructed. If an air-cooling condenser is used, no water other than the make-up water for the plan will be necessary.

Water intake point of former coal fired power plant (complete view)

Intake/outlet facilities (expanded view)

(Source: JICA Study Team)

Figure 4.3-2 Water intake facilities for the old Maputo coal-fired power plant

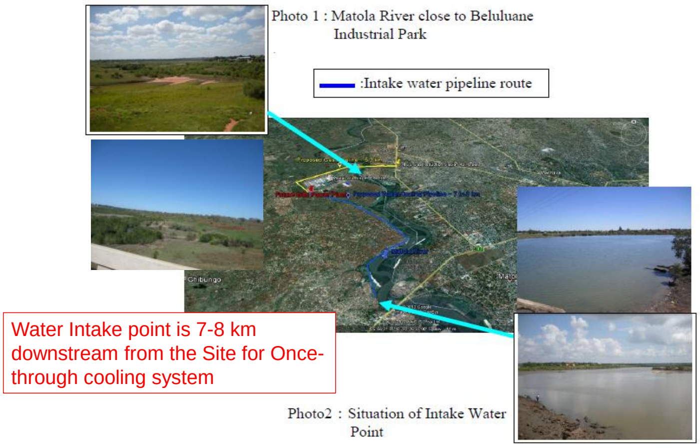


(Source: JICA Study Team)

Figure 4.3-3 Intake facilities (conceptual drawing)

2) Beluluane site

At the Beluluane site, water of 3,500m^3/h will always be necessary for cooling the condenser in addition to make-up water of 10m^3/h for the plan if a once-through cooling system is employed. However, there is no water source near the site nor is there a place where river water or sea water can be used. It will therefore be necessary to construct an inlet channel of 7 to 8 km long connecting to the Matola River. In the case of a wet air cooling system, about 150m^3/h of cooling water is necessary and, like the once-through cooling system, constructing water conveyance facilities will be necessary. Water other than make-up water for the plant will not be needed if an air-cooling condenser is used.



(Source: JICA Study Team)

Figure 4.3-4 Intake facilities (conceptual drawing)

3) Comparisons

Comparisons of intake facilities in both locations are as shown in the table below.

Table 4.3-2 Comparisons of intake facilities

Site	Cooling Method	Item	Once-through Type	Wet Cooling Tower	Air-cooled Condenser
CTM Maputo Site	Expendable water	Make-up water	20m^3/h	20m^3/h	20m^3/h
		Cooling water	-	300m^3/h	-
		Water for cooling condenser	7,000m^3/h (sea water) Need to construct inlet channel of 1.2km	-	-
Beluluane Site	Expendable water	Make-up water	10m^3/h	10m^3/h	10m^3/h
		Cooling water	-	150m^3/h Need to construct inlet channel 7-8km from Matola River	-
		Water for cooling condenser	3,500m^3/h (river) Need to inlet channel 7-8km from Matola River	-	-

(Source: JICA Study Team)

(2) Assessment of soundness of existing intake facilities

Since the Maputo power plant had coal-fired power facilities, it used sea water to cool the condenser. The water on the sea area in front of the Maputo power plant recedes to a considerable distance at low ebb and sea water was pumped up at a point of about 1.2 km from the shore. At present, the intake pump and pipeline have been removed and only a pipe bridge of steel-reinforced concrete and a pump house are left. As a result of the site survey, the facilities have been found to have been substantially degraded and a conclusion has been reached that it would be difficult to reuse the existing structures.(Figure 4.3-5 shows photographs of the current situation of the intake facilities at the old coal-fired power plant.

Intake bridge for old Maputo coal-fired power plan (partially damaged)

Conspicuous exposure of reinforcing bars

(Source: JICA Study Team)

Figure 4.3-5 Assessment of soundness of existing intake facilities

4.3.4 Study from viewpoint of economics

This section evaluates the economics of the three cooling systems described above in terms of life time cost of the necessary total costs, including construction costs, O&M construction, fuel costs, and make-up water costs, converted into present values.

(1) Setting conditions

This study is applied to CCPPs that use 30- to 40-MW GTs currently available on the world market. Of the five models of CCGTs, LM6000PD has the highest capacity. Therefore, this model is used to advance our study on the selection of a cooling system.

(2) Ambient conditions for study of conditional site

The thermal load of the cooling system of a CCGT significantly varies depending on the ambient conditions. Therefore, this study is conducted under the annual average ambient conditions. For this reason, it was decided to calculate the average ambient conditions of the site based on the results of the site survey. The specific values of these conditions are as follows:

Average dry bulb temperature	23.0°C
Average relative humidity	63.4%
Average wet bulb temperature	18.3°C
Average river water temperature	23.2°C

(3) Economic conditions

The following economic indexes are used:

Fuel price	5.6 USD/GJ
Water expense	1.0 USD/m^3
O&M expense	Fixed: 4.0 USD/MW/Y, flexible: 8.8 USD/kWh/Y
Discount rate	10.0%
Assessment period (years)	25.0 years
Construction period (years)	3.0 years
Facility utilization rate (%)	83%

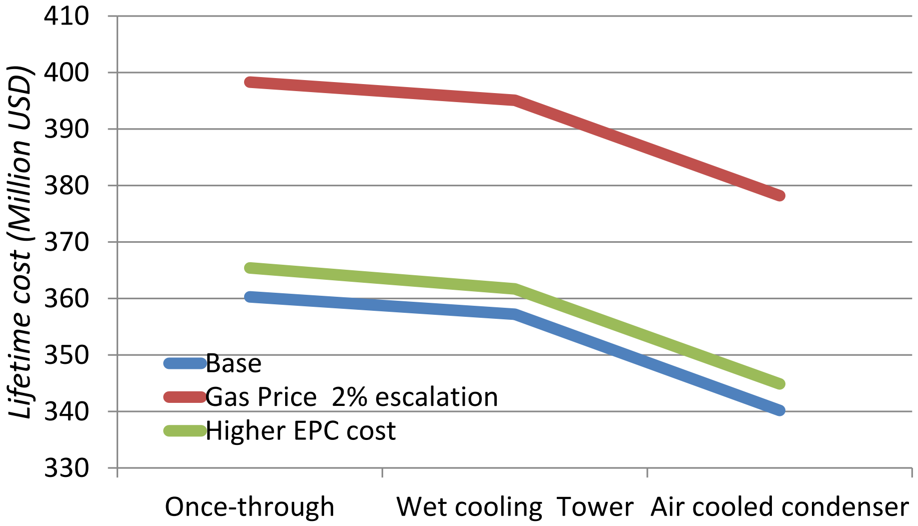
(4) Study results
The results of the assessment are shown below. The kWh cost is the lowest if the air-cooled condenser method is employed.

Table 4.3-3 Feature of condenser cooling system

Cooling System		Once-through Cooling System	Cooling Tower System	Air-cooled Condenser System
Efficiency (%)		51.86	51.71	50.49
Output	Gross (MW)	96.8	96.5	94.2
	Net (MW)	94.4	93.8	92.2
	Salable (GWh/y)	661.6	657.4	646.1
Cost	EPC Cost (USDmil)	130	109	112
	Fuel (USDmil/y)	26.4 (Annual gas consumption: 4.71MGJ)		
	O&M (USDmil/y)	3.9	3.9	3.5
	Water (USDmil/y)	0.14 (0.14 Mm^3/y)	2.24 (2.25 Mm^3/y)	0.14 (0.142 Mm^3/y)
Lifetime cost	USDmil	360.3	357.2	**340.2**
kWh cost	USc/kWh	7.31	7.30	**7.06**

(Source: JICA Study Team)

(5) Sensitivity analysis
The sensitivity of the Higher EPC Cost case in which civil engineering costs, which accounts for about 15% of the EPC cost, increase 30%, and the Gas Price 2% escalation case in which fuel gas prices rise 2% were compared against the above base case. As a result, the air-cooled condenser system was found to be economically advantageous over both the other cases. The difference tended to be conspicuous especially when fuel prices rise.



(Source: JICA Study Team)

Figure 4.3-6 Schematic Diagram of Cooling System

4.3.5 Overall judgment

As a result of comparing and studying the three types of cooling systems for the steam turbine cooling system, i.e., once-through cooling system, wet type cooling tower system, and air-cooled condenser system, the conclusion was reached that the air-cooled condenser cooling system is the most suitable for this site, as shown in the table below.

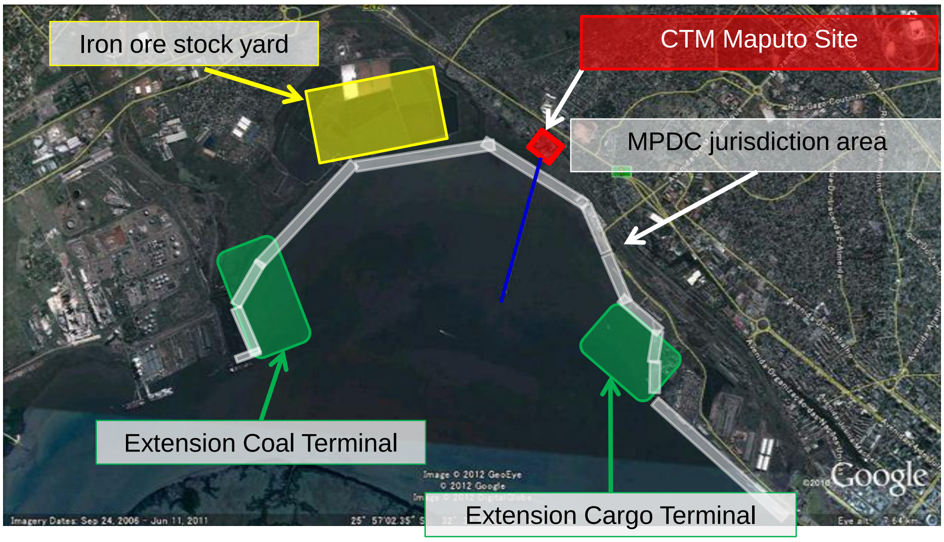
Table 4.3-4 Overall judgment of steam turbine condenser cooling system

Cooling System Method	Once-through Cooling System	Cooling Tower System	Air-cooled Condenser System
	Not Recommended:	**Not Recommended**	**Recommended**
Evaluation	■ Time consuming approval/ permit process from MPDC ■ Consideration of the impact of EDM project from deforming near-shore / moving sediment ■ High construction costs for new intake system and pipeline.	■ Water cost (1USD/m^3) is very high	■ Need to consider impact assessment of noise and vibration

(Source: JICA Study Team)

4.3.6 Risk to water intake of development of surrounding sea areas

At present MPDC holds the rights of developing the Maputo Port through 2033 and any development in this region must be approved and authorized by MPDC. In addition, according to the master plan, MPDC is planning to expand the Maputo Port area near the project. If water intake facilities are installed in this sea area, there is the concern that the water intake may be influenced by changes of the tidal current resulting from changes of the beach profile and encroachment and deposition of marine sediment from the new sea area development. It is therefore necessary in advance to simulate and verify the influences based on the development plan. If the surrounding sea areas are developed after the power generation operation of this project has begun, it will be difficult to avoid or minimize the influences on the water intake. From the viewpoint of long-term operation, it is considered that constructing new intake points in the area where there is a possibility of development is not the best policy, except in the cases where there are no alternatives.



(Source: JICA Study Team)

Figure4.3-7 Sea area development around project site

Chapter 5

Site Conditions

Chapter 5 Site Conditions

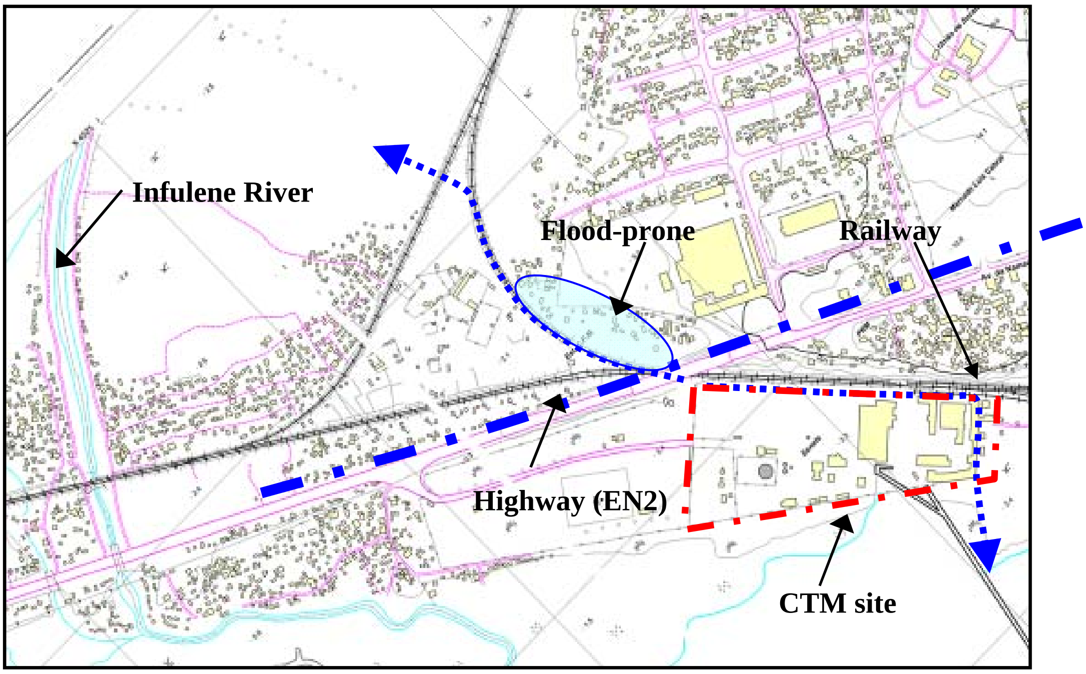
5.1 Topography and Geology

5.1.1 Topography

The proposed site is located in the existing Maputo Thermal Power Station (CTM site), which is approximately 3 km west of the city center of Maputo city and close to the border of Matola city. A railway linking Port Maputo and Swaziland runs immediately north of the CTM site and a highway (EN2) is situated to the north of the railway.

The ground level of the site was raised by 1.5 to 2.0 meters when the former coal-fired power plant was constructed in the 1950s, and the present ground level is approximately 3.3 m above MSL of Port Maputo. Since the embankment of the highway located to the north acts as a topographic divide, rain that falls on the north side of the highway generally does not flow in the direction of the CTM site.

As shown in Figure 5.1-1, the area surrounded by the railway embankment once suffered from inundation caused by heavy rain. Several years ago, drainage channels with sufficient capacity were provided on both sides of the railway embankment. Since then, no flood damage has been reported in this area.



(Source: JICA Study Team)

Figure 5.1-1 Topographical situation around CTM site

5.1.2 Geology

As shown in Figure 5.1-2, the stratigraphic sequence occurring at the site location consists of Holocene superficial deposits that overlie Pleistocene (Congolote and Machava formation) and Pliocene (Ponta Vermelha formation) geological units as described in the following paragraphs.

Holocene deposits make up all of the surface soils of the surveyed area, comprising landfill materials used to modulate terrain morphology in previous interventions. These materials are mainly constituted by silty-sandy soils with coal fragments and vegetal residues.

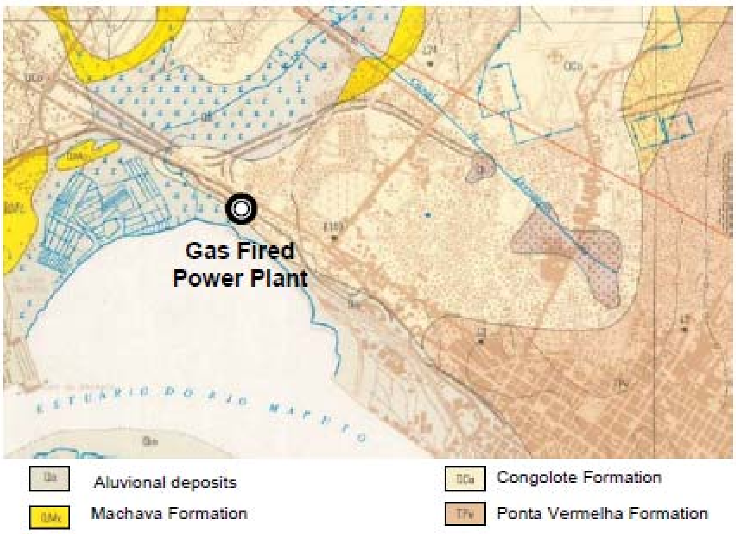
By this description, one assumes that most of it is of alluvium nature, which might also occur in the depths beneath the landfill deposits. Given these circumstances, it will be extremely difficult to differentiate one from the other and all should be treated as one unit.

The Pleistocene unit, known as the Congolote formation (Qco), is mainly described as a coarse to fine-grained sandy soil, poorly consolidated, of white, yellow or orange coloration. It represents aeolian materials of continental dunes, constituting a sandy stratum that overlies succeeding geological units.

Underlying the Congolote formation is the Machava formation (Qmc), mainly described as an interbedded sedimentary deposit of clayey sands with carbonated, salty and ferruginous formations and with a basal conglomerate.

Although its lateral limits are generally well defined, this geological unit may not be represented throughout all of the lower Pleistocene, enabling the Congolote formation to settle directly on the Pliocene unit Ponta Vermelha through a stratigraphic unconformity.

Ponta Vermelha formation (TPv) comprises sand, siltstones and sandstones of reddish to yellowish coloration, occasionally with a ferruginous hard cover.



(Source: Mozambican National Department of Geology)

Figure 5.1-2 Geological setting around the Project site

Given the presented geological conditions, there are no structural evidences of tectonic nature on the referred geomorphologic unit as the deposited sediments overlie any bedrock that may exhibit any type of fragmentation. For this reason, there are no geological structural constraints at the proposed site.

Field investigation by standard penetration test (SPT) was conducted at CTM site. The locations of the boreholes (11 nos.) are exhibited in Figure 5.1-3.

(Source: JICA Study Team)

Figure 5.1-3 Location of boreholes

The results of the SPT are summarized in the following table.

Table 5.1-1 Results of standard penetration test

Ref. \ Depth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
S1	11	11	-	-	9	7	8	57	-	29	22	60	60	60	31	60	60	60	60	60
S2	-	-	-	-	51	9	51	57	10	15	60	60	60	60	60	-	-	-	-	-
S3	2	3	5	-	30[(1)]	26	37	57	57	57	60	60	-	-	-	-	-	-	-	-
S4	11	10	11	-	19	51	57	57	57	57	-	-	-	-	-	-	-	-	-	-
S5	5	6	2	-	51	51	57	57	57	-	-	-	-	-	-	-	-	-	-	-
S6	5	4	8	-	9[(1)]	34	42	27	36	57	60	60	60	60	60	-	-	-	-	-
S7	2	2	2	5[(1)]	51[(2)]	51	57	57	57	57	-	-	-	-	-	-	-	-	-	-
S8	8	10	8	13	-	9[(2)]	57	57	57	57	60	-	-	-	-	-	-	-	-	-
S9	12	14	2	2	-	49	30	24	10	57	60	60	60	60	-	-	-	-	-	-
S10	14	13	45	34	-	51	57	39	29	57	60	60	60	60	-	-	-	-	-	-
S11	2	6	14	-	16	19	24	45	57	57	60	39	48	42	60	60	60	60	60	-

(1) - True SPT depth is 4.5m
(2) - True SPT depth is 5.5m

(Source: JICA Study Team)

The following points highlight the results obtained by the field investigation.

- The geological model is generally represented by superficial landfill deposits in a loose density state, with a generalized thickness of 2-3 m that overlies Pleistocene sandy soils with occasionally interbedded weathered sandstone and calcarenite.
- In general, the N-value, which represents soil resistance, increases with depth with occasional breaks, particularly when intersected with clayey interbeds.
- All boreholes feature a minimum of 4 consecutive SPT refusals (> 50 blows per 25 mm penetration), starting at depths ranging between 5 m and 15 m.

For sandy soils, a layer with an N-value greater than 50 is deemed suitable for foundation support[1]. Accordingly, it is concluded that only the geological layer with an N-value of more than 50 is rated well enough for the foundation of heavy loads, such as major machines and structures.

[1]Specifications for Highway Bridges (2002), Japan Road Association.

5.2 Meteorological Conditions

5.2.1 General

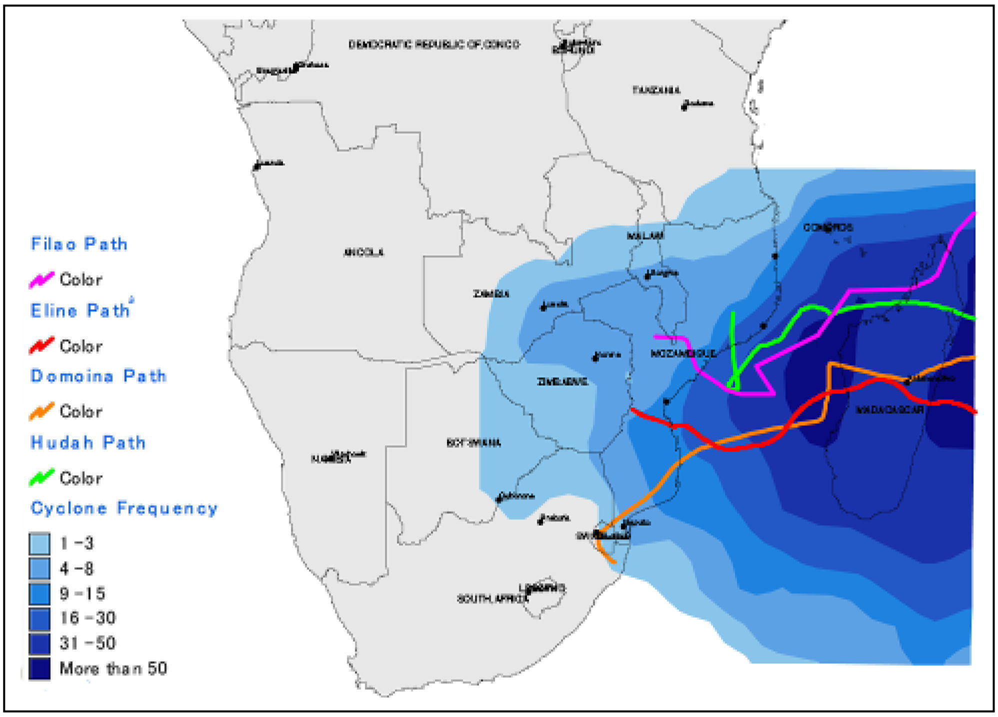
For general information about meteorological conditions of the site, see Section 11.2.1 of this report, "Natural Environment Conditions."

5.2.2 Characteristic of Tropical Cyclones that hit Mozambique

Tropical storms[2] originating from the Southwest Indian Ocean Basin hit Mozambique once a year on average and lesser-magnitude tropical depressions hit three to four times per year.

The most frequent destinations of Mozambique-bound cyclones are the coastal area between Pemba and Angoche and the area near Beira. In Mozambique, the cyclone season lasts from November to April but more than 90% of the tropical cyclones that hit Mozambique occur from December to March.

Figure 5.2-1 shows the frequency of cyclone occurrences during the 75-year period from 1911 to 2000 and the path of the four major cyclones that hit Mozambique recently.



(Source: Atlas for disaster preparedness and response in the Limpopo Basin)

Figure5.2-1 Cyclone frequency and paths

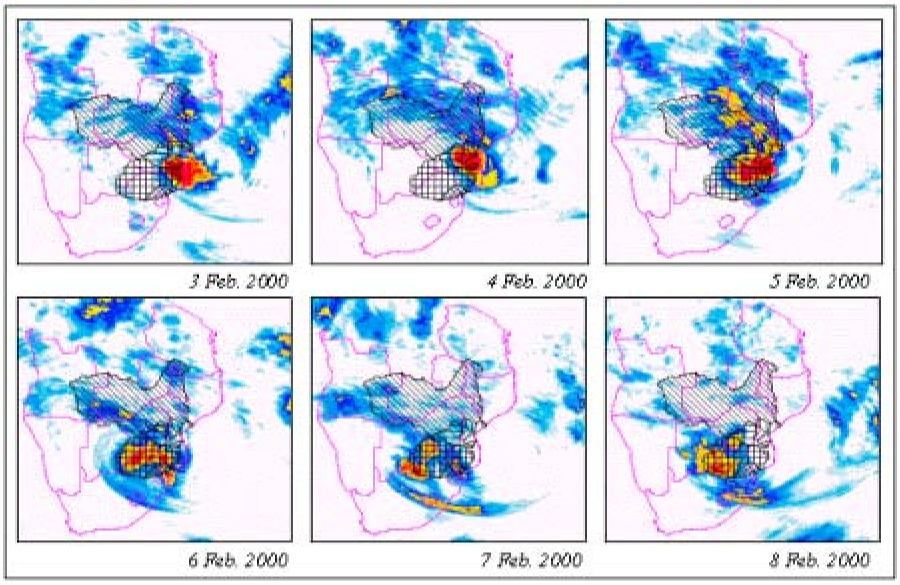
[2] A tropical storm is defined as a tropical cyclone with a maximum wind speed of 34 knots or higher. A tropical cyclone with a maximum wind speed of less than 34 knots is called a tropical depression and is given a specific name. The two types of tropical cyclones are differentiated by whether the maximum wind speed is lower or higher than the threshold of 34 knots.

It is inferred that the southern coast of Mozambique, which includes Maputo city, receives fewer cyclones than the northern and central coasts do. Furthermore, it has been reported that tropical cyclones that hit southern Mozambique tend to lose strength, since they dissipate energy while crossing Madagascar before hitting Mozambique.

5.2.3 Tropical Storms in Early February

In February 2000, two tropical cyclones[3] landed in Mozambique and devastated the economic and social infrastructure across the country and displaced millions of people. The maximum total precipitation of 653 mm was a record for this month and accounted for approximately 80% of Maputo's normal annual precipitation of 800 mm. About 70% of the normal annual precipitation fell in just three days (from February 5 to February 7).

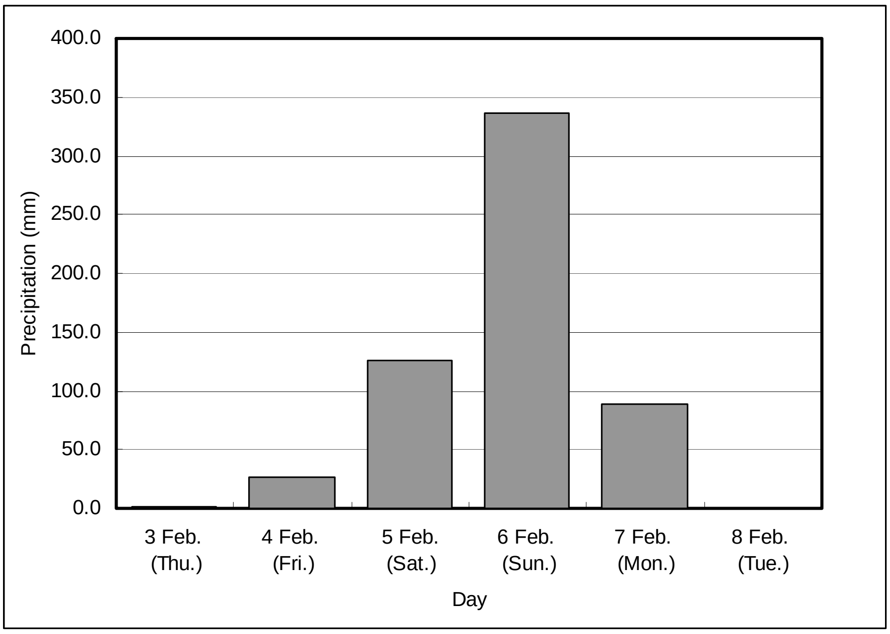
Figure 5.2-2 shows satellite images showing the progression of the first tropical depression that hit Mozambique in early February. In this figure, the red and orange colors show the position of the depression. Figure 5.2-3 shows the daily precipitation recorded at Maputo city from February 3 to February 7.



(Source: Atlas for disaster preparedness and response in the Limpopo Basin)

Figure 5.2-2 Satellite image showing the progression of the first tropical depression that hit Mozambique in early February

3 One of these was Cyclone Eline, which traversed almost the entire Indian Ocean and made devastating strikes on Madagascar and Mozambique.



(Source: Atlas for disaster preparedness and response in the Limpopo Basin)

Figure 5.2-3   Daily precipitation recorded at Maputo City from February 3 to 7, 2000

On February 6, the No.1 GT and No.2 GT buildings in CTM site suffered from flood damage. As explained in Section 6.7.6, it can be concluded that the damage was not caused by inundation from river water or storm surges, but was due to the poor drainage within the CTM site.

The tropical storms of early February were followed by Cyclone Eline, which moved into the central region of Mozambique and caused excessive rainfall in that area. However, the southern region including Maputo was not severely affected by this cyclone.

Chapter 6

Basic Design

(A part of this chapter has been removed because of confidential information.)

Chapter 6 Basic Design

6.1 Design Philosophy

6.1.1 Project Outline

The planned CCGT, which is the first combined cycle power plant in Mozambique, will be installed in the CTM Power Station. The multi-shaft, 2-on-1 CCGT will consist of two GTs/generators, two HRSGs, one steam turbine/generator and related facilities and its net output will be 70-110 MW.

(1) The maximum average air temperature in Maputo is expected to be 28.4°C over the next five years with many days of 35°C or above. Therefore we will evaluate the effectiveness of the GT intake cooling system with water spray and plan the installation if it is found to be effective.

(2) The fuel natural gas will be supplied by ENH.

(3) As to the cooling system of the steam turbine condenser, as a result of the JICA Study Team's evaluation of technologies and economics of a once-through cooling system, a wet cooling tower system, and an air-cooled condenser, it was determined to use the air-cooled condenser.

6.1.2 Operation Requirements

The main components and their auxiliaries shall be designed to ensure that trouble free starts and operation are achieved throughout the design life of the new plant. Adequate redundancies for auxiliary facilities and equipment shall be made available to achieve high availability. The main components and their auxiliaries shall be designed to be able to start and go to full load by the push of a single start button. The entire plant shall be suitable for continuous power load operation.

(1) Plant Duty

The new plant shall have high efficiency and reliability based on proven advanced technology. The new plant shall be so designed as to withstand the anticipated annual operating scheme specified in this specification with an annually averaged availability factor not less than 86.8%, which is defined in ISO 3977-9:1999(E) Gas turbines - Procurement - Part 9: Reliability, availability, maintainability and safety.

(2) Start-up Time Schedule Requirements

The start-up time shall be as short as possible to cope with the function of this new plant. The new plant shall be designed to meet such start-up times as specified in the following table.

The start-up time shall be defined as the time required from the push of the start button to the full load conditions, provided that a condenser vacuum is built and the new plant is ready for start. The time for air purging of special volume post GT and synchronization shall be excluded

Table 6.1-1 Requirement unit starting hours of each mode

Type of Start-up	Time (min.)
Cold start after stop of more than 36 hours	Max. 240
Warm start after stop of less than 36 hours	Max. 180
Hot start after stop of less than 8 hours	Max. 120
Very hot start after stop of less than 1 hour	Max. 60

(Source: JICA Study Team)

(3) Service Life Time

The new plant and associated equipment shall be designed and constructed for the service time as specified below:

Minimum Service Time = 30 years

Equivalent Service Hours = 218,124 hours on a full load basis 1

The new plant shall be designed for a continuous load operation with more than 6,132 actual operating hours per year on the basis of a full load. The necessary hours for starting and shut down cycle are not included in the above operating hours.Through the service time, the new plant and associated equipment shall continue to be operated with high efficiency, high reliability and excellent economy.

Any components of which service lives may be less than the above figures shall be designed for ease of replacement and maintenance.

(4) Start-up and Shut Down Times

The start-up and shut down operation of the new plant shall be performed automatically from the Central Control Room (“CCR”).

Full supervisory and control functions shall be provided for the safe, reliable and efficient operation of the new plant.

The new plant shall be capable of being auto-synchronized and initial-loaded from the CCR.

As a basis for design of the new plant, it is assumed that the new plant shall operate on a full load basis for the service time of 30 years, during which the high efficient and reliable operation shall be maintained.

[1]) Equivalent Service Hours: 24 x 365 x 30 x Plant Load Factor 83%

For the design requirements as stated above, the following annual start-up times shall be considered:

Table 6.1-2 Requirement Plant Start Times for Design

Type of Start	Annual Times	Total Times through Service Time
Cold start (shut down > 36h)	2	60
Warm start (shut down < 36h)	5	150
Hot start (shut down < 8h)	30	900
Very hot (shut down < 1h)	5	150
Total	42	1,260

(Source: JICA Study Team)

6.1.3 Control and Operation Philosophy

(1) Plant Automation

The degree of automation is such that the start-up/shut down sequential control and the protection of the new plant shall be fully automated to enable overall supervision of the new plant by operators at the CCR. However, the start-up/shut down control sequence shall include break points to allow the operator to intervene and provide normal assistance as needed.

The start-up/loading procedures, including draining and venting of the new plant, shall be selectable and controlled automatically dependent upon such state conditions of the new plant as very hot, hot, warm, or cold status.

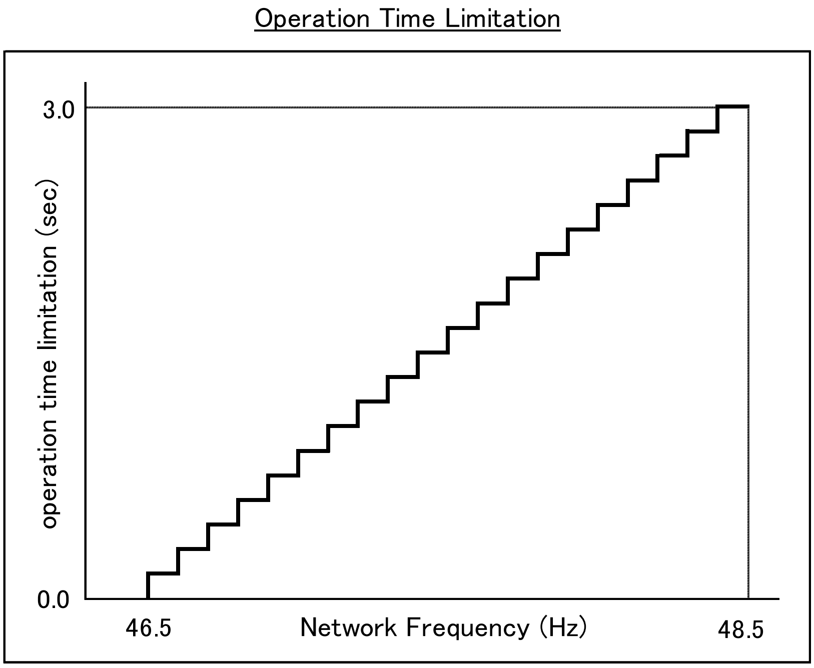
(2) Plant Operation

The CCR shall be located in the new turbine building of the new plant and be equipped with state-of-the-art Distributed Control System (“DCS”) with a data logging system so that generated power can be automatically controlled to meet demand. The operator console, which consists of a Liquid Crystal Display (“LCD”) for monitoring of operating conditions and keyboard panels with mouse for operation of the new plant, will be installed as the operator console in the CCR. The LCD operation will be employed to make a man-machine interface easier and to facilitate monitoring and operation and higher operating reliability.

The Central Processing Unit (“CPU”) shall be of duplicate configuration using the standby redundant system to ensure the reliability of the control system. A Switching operation of generator circuit breaker shall also be performed from the DCS located in the CCR. A Switching operation of electrical circuits in 132/230 kV substations shall be performed from the DCS located in the substation control room.

(3) Under and Over-frequency Operation

The GT/generator and the steam turbine/generator shall be so designed that they can withstand continuous operation under and over frequency from 48.5 to 51.5 Hz under load condition. They shall also be capable of load operation under the frequency range of 46.5 to 48.5 Hz with operation time limitation. Control devices required to limit the load operation time as shown below, shall be provided in consideration of the requirements of the Mozambique Network System.



(Source: JICA Study Team)

Figure 6.1-1 Operation time limitation

(4) Operational Vibration Levels

The relative shaft vibration levels of the GT/generator and steam turbine/generator shafts under any load conditions at the rated speed shall be limited. The measurement method of the shaft vibration shall be in accordance with ISO 7919 or equivalent standards. The vibration shall be measured as the unfiltered relative shaft peak-to-peak displacement in the vicinity of the main journal bearings of the said shafts. The operational vibration levels shall be such as tabled below, as per ISO 7919-2:2001(E) Part 2 "Large land-based steam turbine generator sets" and ISO 7919-4:1996(E) Part 4 "Gas Turbine Sets".

Table 6.1-3 Shaft Vibration Limits

Type of Equipment	Vibration Level (p-p μm)
GT/Generator	≦80
Steam Turbine/Generator	≦80

(Source: JICA Study Team)

The vibration levels of the GT/generator and steam turbine/generator shafts shall not exceed 80 μm throughout the Reliability Test. Should the vibration level of any equipment exceed the specified value during the Reliability Test of two weeks, then the Test shall be cancelled and a new two weeks Test shall be repeated after the vibration level problem has been rectified. After taking-over of the new plant, vibration levels shall not exceed the values during the Defect Liability Period.

The relative vibration level at the alarm point shall be set at the level not more than 120 μm for both the GT/generator and the steam turbine/generator. The trip value shall be set at 240 μm, if it is acceptable depending upon the operating experience of the same types of the GT/generator and the steam turbine/generator.

(5) Power Control

The plant power load will be indirectly controlled by the supervisory control and data acquisition (“SCADA”) system from the load dispatch center, through the power stations, to the new plant. The new plant shall be automatically operated after setting the plant power load demand into the DCS through the operator console by the operator of the new power plant so that the plant power load demand will be satisfied.

6.2 Study of Basic Technical Issues

6.2.1 Expected Performance of the Mozambique Combined Cycle Gas Turbine

(1) Candidate Models of CCGT

In the international market, there are five models available as combined cycle gas turbines (“CCGTs”) having a shaft configuration of 2-on-1 and offering a rated capacity of 70-110 MW. From the viewpoint of operating experience, the GTs of four original equipment manufacturers (“OEMs) are mature with large operating experience and are deemed to be best suited for the Project. According to the Gas Turbine World 2012 GTW Handbook, the five models of combined cycle power plants are as tabulated below:

Name of OEM of GT	Model of CCGT
IHI (GE licensee)	2 x LM6000PD Sprint
IHI (GE licensee)	2 x LM6000PD
Hitachi, Ltd.	2025(2 x H-25)
Rolls-Royce	2 x RB211-GT61
Siemens Power Generation	SCC700 2 x 1(2 x SGT-700)

(2) CCGT Performance Data on ISO Conditions

In the said GTW Handbook, performance data of the above models of CCGTs are described at ISO conditions (101.33 kPa, 15°C, 60% RH) on natural gas, although necessary conditions other than ambient temperature and pressure are not always specified. The performance data of the five CCGT models are described below:

Model of CCGT	Net Plant Output (kW)	Net Plant Efficiency (%)
2 x LM6000PD Sprint	120,220	53.0
2 x LM6000PD	110,970	53.6
2025(2 x H-25)	87,800	50.3
2 x RB211-GT61	85,300	52.8
SCC700 2 x 1(2 x SGT-700)	83,630	52.5

(3) Calculation Results of CCGT Heat Balance on Unfired Conditions

Performances of the five models of CCGTs on rated and maximum capacity site conditions must be predicted to specify the performance requirements of the Plant in the Bidding Documents. For this purpose, the heat balances at the rated and maximum capacity site conditions were calculated using the GT performance data on ISO conditions specified in the said GTW Handbook. The types of GTs to be used for calculation of the CCGT heat balances and their performance data cited from the said Handbook are shown below:

Table 6.2-1 Performance of Applicable GT Model

Model of Gas Turbine	LM6000PD Sprint	LM6000PD	H-25	RB211-GT61	SGT-700
ISO base rating (MW)	47.5	42.6	32.0	38.1	31.2
Efficiency (%)	41.3	41.2	34.8	39.4	36.4
Pressure ratio	31.0	31.0	14.7	21.5	18.6
Air flow rate (kg/s)	131.9	124.6	93.9	94.3	94.3
Exhaust gas temp (℃)	448.3	455.0	563.9	503.8	528.3
Fuel gas flow rate (kg/s)	2.31	2.07	1.85	1.94	1.72

(Source: JICA Study Team)

Where, the net specific energy (lower heating value) of the natural gas is assumed to be 49,826 kJ/kg (40.2MJ/Nm^3 at 15°C) calculated from the fuel gas data received by the JICA Survey Team . The correction of the performance data of the above GTs to the site, inlet and exhaust conditions was conducted in accordance with various correction factors based on the wide experience of the JICA Survey Team in dealing with this type of data. The inlet and exhaust pressure loss changes for combined cycle configuration are also predicted. The site conditions are designated as tabulated below, as per the site survey results:

Type of Site Condition	Rated	Max. Capacity
Dry Bulb Temperature (°C)	28.0	10.0
Relative Humidity (%)	75.0	75.0
Wet Bulb Temperature (°C)	24.5	7.9
Barometric Pressure (kPa)	101.3	101.3

The rated site conditions are specified in accordance with ones for the existing GT power plants, while the maximum capacity site conditions are specified as the monthly averaged minimum ambient temperature and the relative humidity for the time. The installation capacities of electrical and auxiliary equipment must be determined to cope with the GT maximum capacity and the performances of the bottoming system (HRSG and steam turbine) dependent upon it. The GT maximum capacity is widely changeable depending upon the site ambient conditions (especially ambient dry bulb temperature). To determine the installation capacities of electrical and auxiliary equipment, therefore, the site ambient conditions where the GT maximum capacity is defined must be specified.

According to the records for five years from 2007 to 2011 in Maputo International Airport in the suburb of the CTM Power Plant, the average lowest air temperatures in the winter months were +13°C to +14°C and sometimes +10°C to +11°C. From the viewpoint of effective use of the power generation facility, 10°C is considered to be the lowest air temperature. Therefore, the installation capacities of electrical and auxiliary equipment shall be determined to meet the operating performances of GTs and bottoming system at the ambient dry bulb temperature of 10°C. The relative humidity for the ambient temperature is 75%.

To obtain the plant net power output, auxiliary power requirements, including the step-up transformers under steady state conditions at 100% load of the plant, must be predicted. The JICA Study Team calculated the plant net power output by using computer plant analysis software and carrying out calculations for each large-output GT model. The cycle configurations and parameters of the bottoming system may be variable depending upon manufacturers of combined cycle power plants. However, the following cycle configurations and parameters are preliminarily assumed for calculation of CCGT heat balances.

GT Inlet Air Cooling System	Not considered
Exhaust Gas Leakage	0.5%
Cycle Configuration	Double-pressure, Non-reheat
Cooling System	Air-cooled condenser
Type of HRSG	Unfired type
Steam Conditions at Turbine Inlet for Site Rated Conditions	
HP Steam	
Temperature	LM6000PD Sprint: 429°C, LM6000PD: 430°C, H-25: 500°C, RB211-GT61: 450°C
Pressure	6.0MPa
LP Steam	
Temperature	250°C
Pressure	0.5Mpa
Condenser vacuum	Depends on the characteristics of the cooling condenser

At this point, because the temperatures of the exhaust gas from the GTs differ by the model, the high-pressure steam temperatures were calculated taking the exhaust gas temperature of each model into consideration. Leakage of 0.5% of the exhaust gas flow rate from the GTs is assumed for the calculation of the heat balance of the bottoming system.

Table 6.2-2 Performance of Applicable CCGT Model

CCGT Model	2 x LM6000PD Sprint		2 x LM6000PD		2025(2 x H-25)		2 x RB211-GT61	
Site Condition	Rated[1]	Max[2] Cap	Rated	Max Cap	Rated	Max Cap	Rated	Max Cap
Plant Gross Power Output (MW)	108.8	124.2	93.2	116.3	73.8	83.5	74.9	87.9
Gas Turbine (MW)	83.0	94.8	70.9	88.7	48.0	53.8	52.4	61.8
Steam Turbine (MW)	25.8	29.4	23.3	27.6	25.8	29.7	22.5	26.1
Plant Gross Thermal Efficiency (%)	52.5	53.9	52.4	54.3	47.8	50.6	52.4	54.5
Auxiliary Power (MW)	2.3	2.5	1.9	2.2	1.5	1.6	1.6	1.7
Plant Net Power Output (MW)	106.5	121.7	91.3	114.1	72.4	81.9	73.3	86.2
Plant Net Thermal Efficiency (%)	51.4	52.8	51.3	53.1	46.8	49.7	51.3	53.4

Note: 1Rated: Ambient temperature 28°C,

2-Max Cap: Ambient temperature10°C

(Source: JICA Study Team)

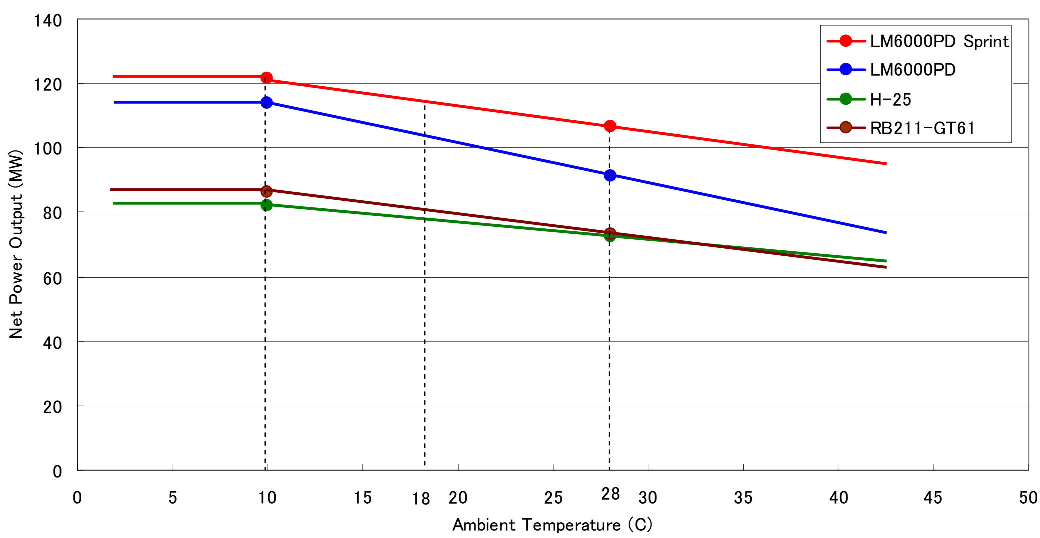
From this table of the calculation results, it was calculated that the net power output of the CCGT models under the rated site conditions is 72.3 to 106.5 MW or 86 MW on average. Therefore, the net output of these power facilities is 85 MW and, taking into consideration the appropriate likelihood for the above calculated value, the net power output will be specified on the purchase specification as 70 MW to 110 MW to encourage many parties to participate in the bidding.

The net thermal efficiency of the power generation facilities under the rated site conditions was calculated to be 46.8 to 51.4%. Therefore, the net thermal efficiency of these power facilities is specified on the purchase specification as 46% or more. The maximum total power output of the power facilities is calculated to be in the range of 73.8 to 108.8 MW.

Air temperature performance characteristics of the two CCGT models are shown below. From this chart, it is evident that each CCGT has similar output characteristics.

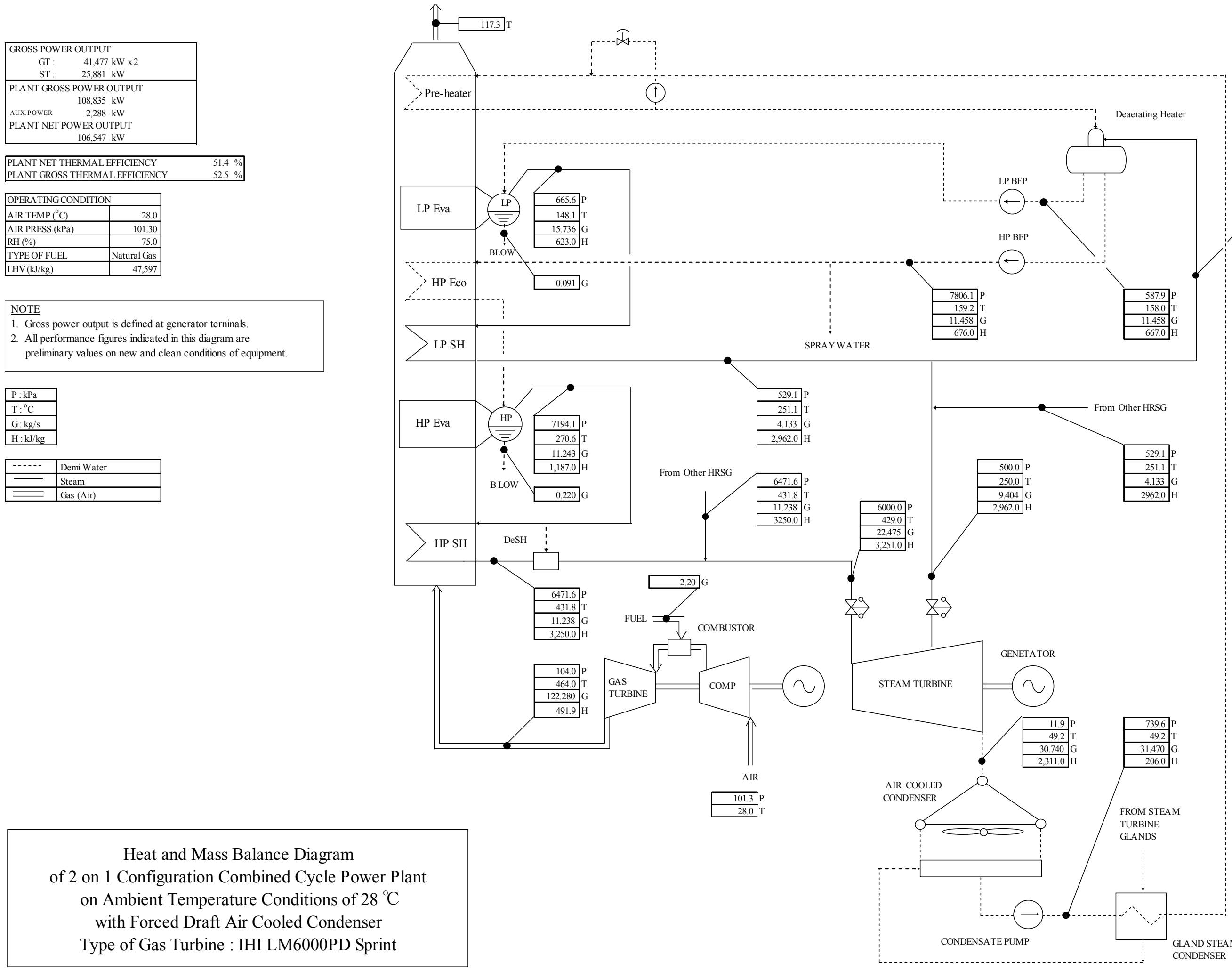
As representative CCGT models using GTs of aircraft conversion types and those of heavy-structural industrial types, LM6000PD Sprint and H-25 were chosen to show below the heat balance diagrams under the rated CCGT site conditions and the maximum capacity CCGT site conditions.

1) Heat Balance Diagram of 2 x LM6000PD Sprint at the rated site conditions
2) Heat Balance Diagram of 2 x LM6000PD Sprint at the maximum capacity site conditions
3) Heat Balance Diagram of 2025(2 x H-25) at the rated site conditions
4) Heat Balance Diagram of 2025(2 x H-25) at the maximum capacity site conditions



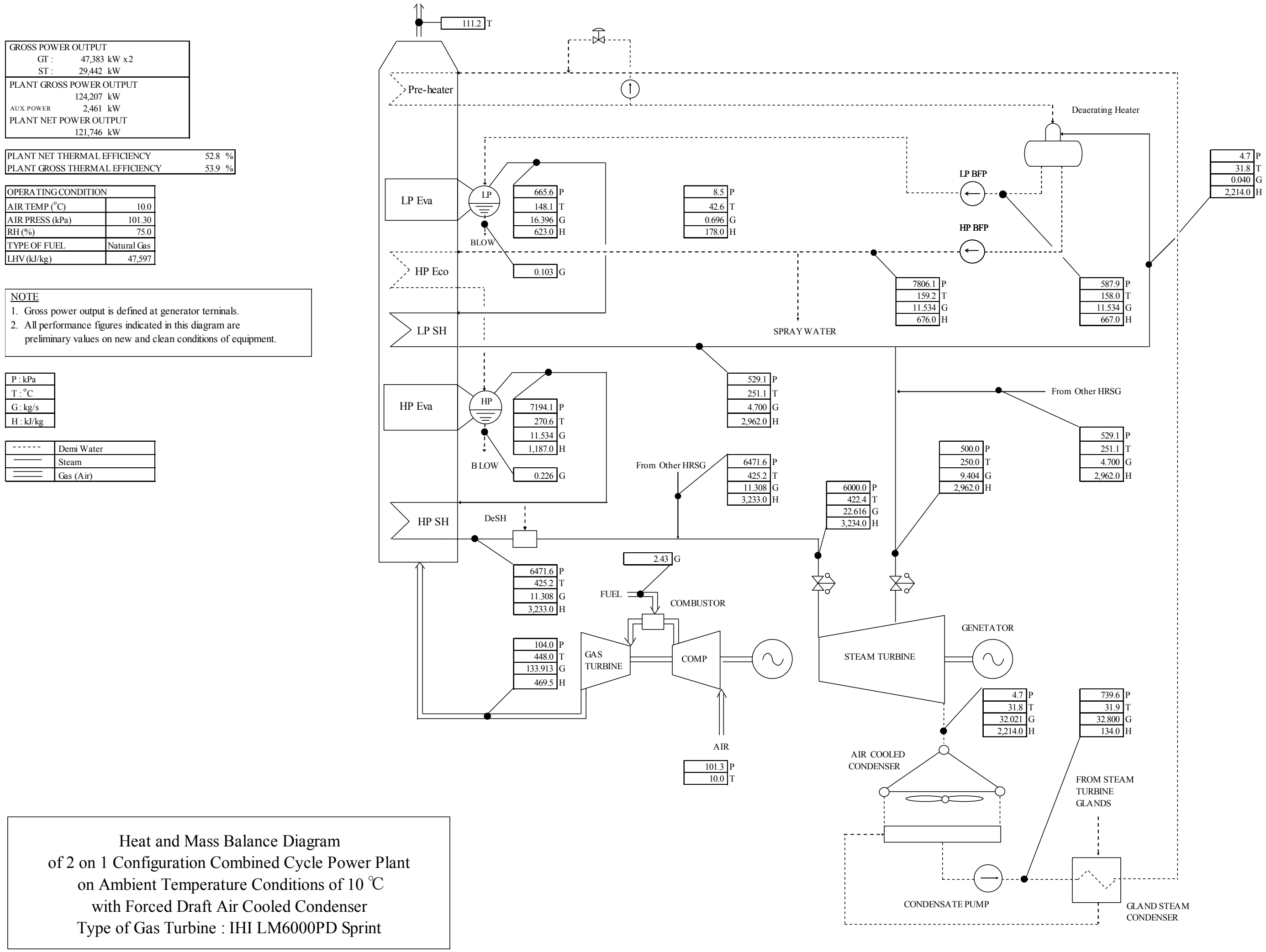
(Source: JICA Study Team)

Figure6.2-1 Ambient Temperature Performance Characteristics Curve



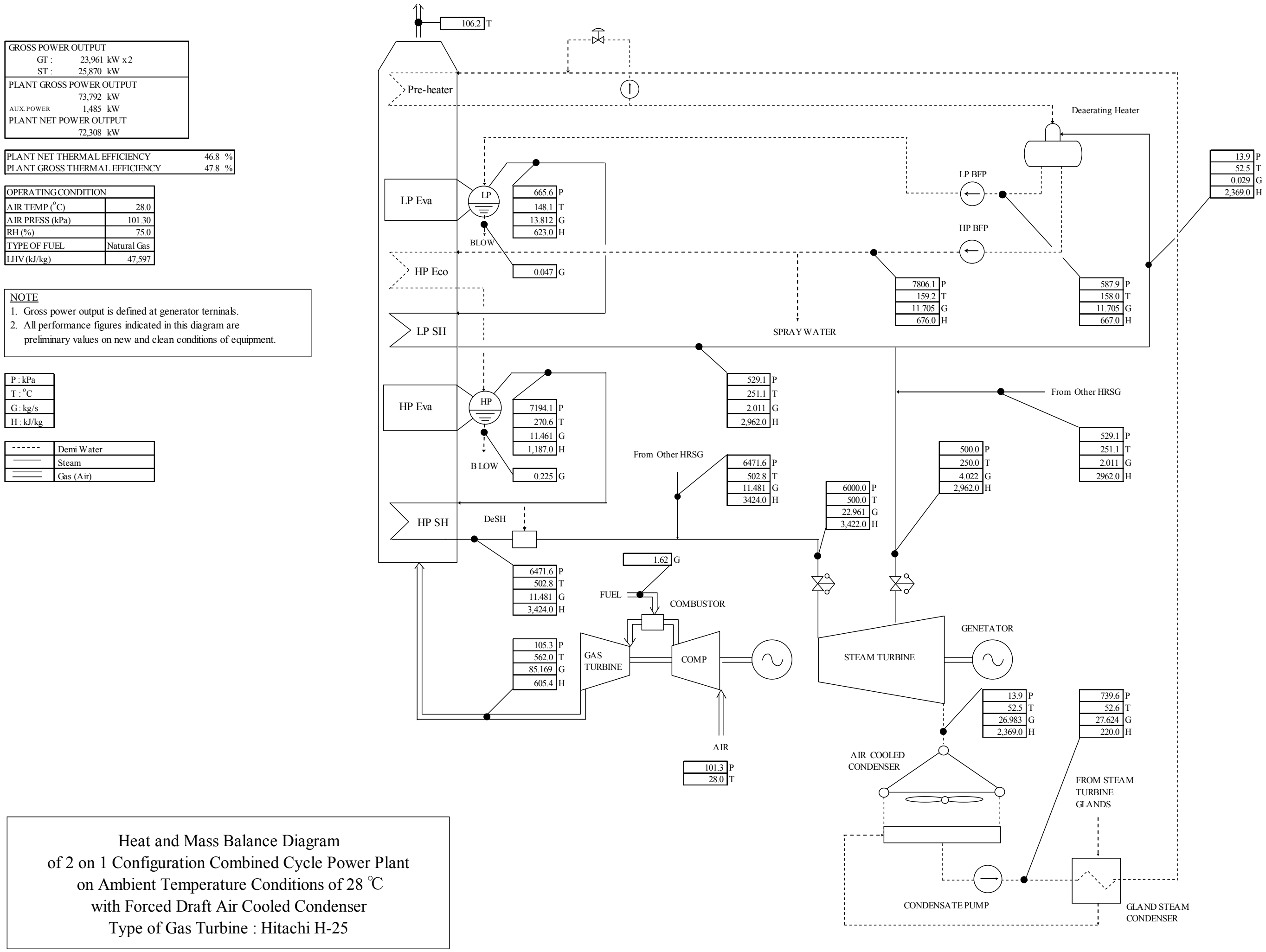
(Source: JICA Study Team)

Figure 6.2-2 Heat Balance Diagram of 2 x LM6000PD Sprint at the rated site conditions performance



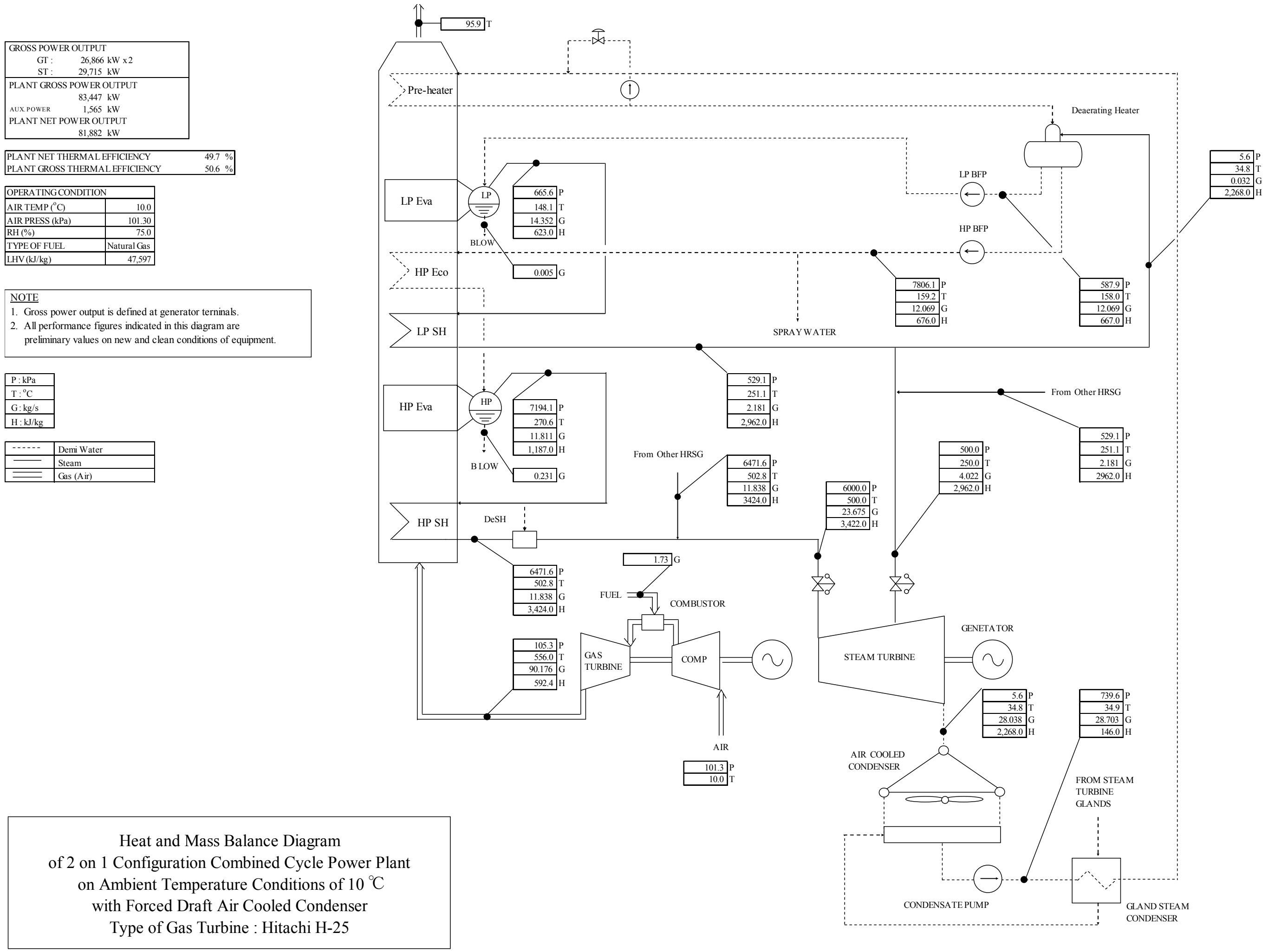
(Source: JICA Study Team)

Figure 6.2-3 Heat Balance Diagram of 2 x LM6000PD Sprint at the maximum capacity site conditions



(Source: JICA Study Team)

Figure 6.2-4 Heat Balance Diagram of 2 x H-25 at the rated site conditions performance



(Source: JICA Study Team)

Figure 6.2-5 Heat Balance Diagram of 2 x H-25 at the maximum capacity site conditions

(4) Trend of 30-40 MW-class GTs

According to the development of refractory metal of GT blades and nozzles, cooling technology for blades and nozzles and the application of thermal barrier coating to hot gas parts and the increase of air compression ratios, gas turbines output and thermal efficiency are increasing daily by GT manufacturers. The 30– 40 MW class GTs are being developed, too. Table 6.2-3 shows the 30-40 MW class new GT models in the most recent order. These GTs have not yet been installed. Attention must be paid to that these GTs installations around the world.

Table 6.2-3 New Models for 30 – 40 MW

Manufacturer	Model	Output	Efficiency (LHV)	Year
Kawasaki	L30A	30.1MW	40.1%	2012
Siemens	SGT-750	35.9MW	38.7%	2012
Rolls-Royce	RB211-H63	42.5MW	39.3%	2012

(Source: Kawasaki brochure, and 2012 GTW Handbook)

6.2.2 Exhaust Gas Bypass System

In the case of a multi-shaft CCGT, the exhaust gas bypass system is usually equipped for a simple cycle operation due to many factors which may occur to the bottoming system. This system will also be required when the GT power package of topping system must be put into commercial operation in advance separately from the bottoming system due to any impending power demand, like in the Mozambique case. For this purpose, a bypass stack and a damper must be equipped in the high temperature gas stream between the GT exhaust system and the heat recovery steam generator. This system must be of a huge shape of mechanical equipment to cope with high temperatures around 500°C. Therefore, the system has the advantage of contributing to flexible operation, although the plant cost is higher with lower operational reliability. Besides, performance loss may occur by leakages of GT exhaust gas into the atmosphere. Such issues are studied below.

(1) Operational Flexibility

The operational flexibility of the CCGT changes depending upon whether or not there is an exhaust gas bypass system. In the case the CCGT has the exhaust gas bypass system, the plant can be transferred to simple cycle operation without power failure when any trouble occurs with the bottoming system. The unit downtime can be reduced as inspections of and repairs to the bottoming cycle can be undertaken while operating the GT. Such operation may be confined to limited hours because it is not deemed to be of normal operation. As stated above, the operational flexibility of the plant shall be limited if it does not have the exhaust gas bypass system.

There are no differences between plants with and without the exhaust gas bypass system as far as the start-up capability of the plant is concerned.

(2) Operational Reliability

Diverter or flap type dampers are normally utilized for GT applications with heat recovery steam generators. The temperature of the exhaust gas to which the damper is exposed is as high as 500°C. The damper shall be designed to stably, smoothly and quickly operate, and to maintain minimized gas leakage loss over the lifetime of the plant. It appears to be significantly difficult to design the damper to operate under such severe conditions so that it can fully meet such contradictory requirements. One reason is because the huge metal constructed damper which will be exposed to high temperature atmosphere cannot keep the originally dimensioned shape over the lifetime of the plant. Specific figures on the operational reliability of the exhaust gas bypass system by users of the plants are not available. However, a decrease in the plant operational reliability due to using the system is inevitable.

(3) Cost Impact

In order to use the exhaust gas bypass system, the following equipment and work are additionally required:

- A bypass stack (3.3 m summit diameter, 28 m height) with a silencer (depending upon environment protection requirements)
- A diverter damper
- A guillotine damper (for maintenance of the bottoming system during the simple cycle operation)
- Longer transition gas ducts and expansion joints
- Related site assembly, erection and civil work
- Other related costs such as shipping, management and commissioning

The total extra cost for the above items is approximately estimated at US$ 2.0 million.

(4) Phased Construction

If the exhaust gas bypass system is used, there will be phased construction of the topping and bottoming systems. Using this system will enable operation of the GT power generation facility to start earlier. This type of construction will usually be adopted when power supply is demanded earlier due to an unexpectedly steep increase of power demand. The completion schedule of the phased construction plant is longer than the single phase construction plant, while the commercial operation of the GT/generator package will start earlier by approximately six months. This advantage shall be evaluated by the plant purchaser depending upon the extent of the strong demand for power supply.

(5) Performance

Excess exhaust pressure loss will occur due to the installation of the bypass system between the GT exhaust and the heat recovery steam generator. Moreover, there will be an amount of exhaust gas leaked into the atmosphere through the bypass damper, which will result in power loss of the steam turbine. Consequentially, both the plant power output and efficiency will be lower in comparison with plants that do not have the bypass system. Depending upon the type, size and system design of the damper, the steam turbine power output drop is reportedly approximately 0.5 – 1.5% as an average value over the lifetime of the plant. It means that the plant efficiency drops by 0.17 – 0.5%.

(6) Other Viewpoints

A wider footprint area is required for the installation of the bypass system. In the case of F-class GTs, an additional 9 m in length would be required.
In the case that there is no silencer in the bypass stack, the noise from the stack is a concern even if the bypass operations will be limited to a short time.

In the case that a silencer is installed in the bypass stack, the steady and proper function over the plant lifetime of the silencer, which is exposed to high temperatures and high velocity of gas, is a concern. Additional deliberate and daily maintenance work is required to maintain the exhaust gas bypass system in good condition so that it can be reliably used whenever it is needed. There are many CCGTs using exhaust gas bypass facilities worldwide.

(7) Study Summary

A summary of the results of the evaluation is shown in the following table. As stated above, it goes without saying that the operational flexibility of the plant will be enhanced due to the employment of the exhaust gas bypass system, however there is the inevitable drop in operational reliability plus the burden of project cost. Because of the large volume of exhaust gas, high temperatures and speed, broad working experience is necessary in order to operate and maintain the exhaust gas bypass system in good condition. However, this CCGT will be the first CCGT in Mozambique. Therefore, in order to operate CCGT to maintain good condition with high output, high efficiency and minimum trouble outage, a CCGT without the exhaust gas bypass system is recommended.

Table 6.2-4 Summary of GT Exhaust Gas Bypass System

Review Items	Without Bypass System		With Bypass System
1. Operational Flexibility	GT single operation impossible		GT single operation possible
2. Operational Reliablity	Base		Low The constructed damper, which will be exposed to high temperature atmospheres, cannot keep the originally dimensioned shape over the lifetime of the plant.
3. Cost Impact	Base Construction cost not necessary		+Approx. USD 2M for facility and construction
	Operation & maintenance cost not necessary		Operation & maintenance cost necessary
4. Footprint	Base Unnecessary		Necessary for the facility
5. Phased Construction	Impossible		Possible
6. Performance (Thermal Efficiency)	Base		0.17 - 0.5% lower due to increase of exhaust pressure loss and leakages of GT exhaust gas
7. Other	Base		Maintenance and operation experience necessary.

(Source: JICA Study Team)

6.2.3 Auxiliary Boiler

(1) Necessity

In the case of a multi-shaft CCGT without a standalone auxiliary boiler, the GT can be started up together with the HRSG separately from the steam turbine/generator. After a certain period of time the necessary steam for start-up will become available from its own HRSG and then the steam turbine/generator can be started up under its own steam; however the HRSG will be started up with a higher oxygen concentration in the HRSG inlet feed water than under normal operating conditions because of the start up without gland sealing of the steam turbine.

In the case of multi-shaft CCGT with a standalone auxiliary boiler, gland sealing of the steam turbine can be supplied from external sources before the GT and HRSG are operated. As the necessary steam for start-up can become available from external sources, the steam turbine/generator can be started up without any loss of time and the HRSG can be started up within permissible oxygen concentration in the HRSG inlet feed water by gland sealing of the steam turbine.

If a standalone auxiliary boiler is applied to this project, then the tender shall recommend the specifications for a standalone auxiliary boiler.

(2) Requirement Study

The HRSG and auxiliary equipment shall be designed to be able to start up in the shortest time.

If a standalone auxiliary boiler is not applied to this project, the tender shall clarify the start up procedure without a standalone auxiliary boiler and the start up time schedule, and the operating and permissible oxygen concentration in the HRSG inlet feed water during start up.

6.2.4 Gas turbine and steam turbine buildings

The GT and steam turbine buildings will protect the facilities from rain, wind and salt from the sea, and prevent facility deterioration due to rust, etc., and enable personnel to carry out maintenance and management work without any effects from the climate, either during the day or at night. However, the buildings will need to have air-conditioning, fire-resistance and other facilities, and the related maintenance costs.

A review of the GS and steam turbine buildings was conducted, and the characteristics of the GT and steam turbine facilities with or without buildings are shown in the table below:

Table 6.2-5 GT and Steam Turbine Facilities With and Without Buildings

Review Items	Without Building	With Building
Building facility	Base	・Building ・Electrical wiring, air-conditioning facility, lighting, etc. ・Overhead traveling crane ・Fire/ smoke sensors ・Fire protection facility
Building facility costs	Base	High
Running costs	Base	High ・ Periodical inspection of overhead traveling crane, fire protection facility, etc.
Operability	Base	Good ・No influence from wind, rain and sea water
Maintainability	Base ・ Need to prepare a crane every work time.	Good ・Repair work is always possible in the case of problems as an overhead traveling

Review Items	Without Building	With Building
	・Bad workability at night. ・Repair work may be impossible due to bad weather. ・Not workable if flooding and submergence occur.	crane will be installed. ・Workable at night. ・No influence from the weather. ・Workable even if flooding and submergence occur.
Equipment facility	Base	Rust can be prevented from seawater, etc.
Noise	Base	Small
Facility reliability	Base	High

(Source: JICA Study Team)

(1) Gas Turbine Building

Case by case, GTs are installed either indoors or outdoors. Outdoor GT power generators are packaged and there are many working examples in the world. The existing GT No. 3, which is also an outdoor type, is approximately 20 years old however it is maintained in good condition. The GT is covered with a compartment, thus offering sufficient durability against the weather. Plant output and efficiency undergo little impact from rain, etc. For the GT power generator, from the viewpoint of broad experience and economics, an outdoor type without a GT building is recommended.

(Source: GE brochure)

Figure 6.2-6 GT Package

(2) Steam Turbine Building

The output and efficiency of a steam turbine are influenced by the steam temperature and pressure. To reduce lowering the steam temperature and pressure, thick thermal insulating materials are applied to the casing and the piping. Rainwater, water, and seawater going inside the insulating materials lowers the steam temperature and pressure, and deteriorates the thermal insulating materials, steam turbine casing, piping, valves and other components. To operate the steam turbine in good condition for a long period of time, the casing, piping and valves need to be protected from the influence of water and, therefore, it is recommended that the steam turbines be installed indoors.

6.3 Scope of Work

6.3.1 Procurement and/or Manufacture

The contractor shall procure and manufacture the following facilities, including progress control and quality control, with regard to all the equipment and materials related to operation, etc. Note, however, that the facilities to be procured and manufactured may not be limited to the following facilities.

(1) GT power generators and related facilities
(2) Steam turbines, power generators and related facilities
(3) Air cooled condenser and related facilities
(4) HRSGs and related facilities
(5) Stacks
(6) Fuel gas accepting facility
(7) Fuel gas pipe line (from tie-in point of gas station to compressor or decompression facility)
(8) Fuel gas compressor or decompression facility (if necessary)
(9) Gas treatment facility (if necessary)
(10) Indirect gas warmer (if necessary)
(11) Inside and control air supply facilities
(12) Generator step-up transformer
(13) Auxiliary transformers
(14) Switch gear for generator
(15) Modify 66kV GIS

(16) Middle and low voltage power supply devices

(17) Emergency generators

(18) UPS and DC power supply devices

(19) Cables (electric power, instrumentation and control ("I&C"))

(20) Cable trays and duct facilities

(21) Control and instrumentation facilities

(22) Facility information system

(23) Continuous environmental monitoring facility

(24) Simple simulator facility

(25) Drain recovery facility

(26) Bearing coolant facility

(27) Water facility and wastewater treatment equipment

(28) Outdoor piping, trenching and covering

(29) Fire protection facility

(30) Ventilation and air conditioning facilities

(31) Outdoor and indoor lighting

(32) Outdoor drainage and clarification facility

(33) Piping and facility foundation

(34) Construction materials

(35) Steam turbine building (steel frame, exterior, roof, windows, louvers, etc.)

(36) Buildings for other facilities

(37) Office building (including central control room and electricity room)

(38) Workers' living quarters

(39) Restrooms and shower rooms

(40) Roads

(41) All civil works including foundations for supplied equipment, buildings and houses

(42) Temporary structure construction and facilities related to construction

(43) Preparation, excavation and leveling work of site area including temporary storage area during construction and preparation of access road for transporting-in heavy components

(44) Fencing around the new plant site, access road to stored equipment, and drainage inside the new plant site

(45) Necessary temporary facilities on the downstream side from the connection points of utilities such as electric power and water, etc., necessary for construction

(46) Paint/coating materials for equipment and materials

(47) Spare parts for periodical repair

(48) Standard and special tools

6.3.2 Works and Services to be provided by Contractor

The construction and work scope that the contractor shall execute shall include the design of a new CCGT including modification of the existing switching station, etc., manufacture of equipment, and tests, transportation, installation, construction, trial operation and performance tests thereof. In the case where such words as “provide”, “furnish”, “supply”, and “furnish and/or install” are used, the contractor shall install equipment and facilities even if the equipment and facilities installed by another party have no special safety features.

The construction scope of the contractor shall include the preparatory construction in the early phase including the power supply for construction, the construction of temporary facilities for trial operation and tests that are necessary for the operation of the power generation facility, and the construction of the permanent facilities.

The work scope of the contractor shall include technical instructions to the sub-contractors and the equipment suppliers so that the operation of the power generation facility can be commenced in addition to the training of the operation and maintenance personnel of the newly-installed power generation facility.

In cooperation with the CTM CCGT operation personnel, the contractor shall start the newly-installed power generation facility and execute early-phase operation thereof. The contractor shall instruct the new operation personnel of the CTM CCGT and, in cooperation with the same personnel, plan smooth technical instructions from construction of the newly-installed power generation facility to commencement of operation thereof. Note that any additional construction and work items shall require agreement by contract.

(1) Engineering services

1) Engineering and structural facilities

2) Architectural facilities

3) Mechanical facilities

4) Chemical facilities

5) Electrical facilities

6) Control and instrumentation

7) Switching station facilities

8) Power flow calculation for electrical facilities

(2) Documents and drawings

The newly-installed power generation facility shall be equipped with all equipment provided in this section. The work items provided in the purchase specifications may not be limited to the creation of the below-listed design documents. The asterisked documents are those that shall be submitted at a minimum for the approval of EDM. If the asterisked documents are submitted, all other documents and drawings shall be submitted as reference. Within thirty days from commencement of construction, the contractor shall submit a list of drawings and documents on which the documents for approval and those for reference shall be distinguished from each other.

*1) Facility design criteria

*2) Premises layout

*3) Floor-by-floor equipment layout

*4) Heat balance diagrams

*5) Skeleton diagrams

*6) Facility piping and measurement drawing

*7) Building front view and elevation

*8) Entire plant control block diagram

*9) Purchase specifications:

- GT
- Steam turbine
- HRSG
- Air-cooled condenser
- Feed and condensate pumps
- Power generator and exciting arrangements
- Transformers (generator step-up, auxiliary and start up transformers)
- Middle-pressure metal clad switch gear
- Dispersed control system (“DCS”) and data storage unit

10) Concrete foundation and structure drawings

11) Purchase specifications of major equipment

12) Design study and evaluation
13) Detailed designs
14) Logic diagrams
15) System diagrams
16) Wiring diagrams
17) Facility instruction manuals
18) Test and inspection schedule
19) Performance test instructions
20) Trial operation instructions
21) Test and inspection report
22) Performance test report
23) Operation manual
24) Maintenance manual
25) Equipment manuals (including catalogs)
26) Installation instructions
27) Complete documentation

(3) Construction and trial operation

The contractor shall execute the following work items with regard to construction and trial operation of the newly-installed power generation facility. Note, however, that the work items in the construction and trial operation phases may not be limited thereto.

1) Supervision of construction
2) Management of construction schedule
3) Preparation and control of construction workers and preparation of tools to be used by them
4) Preparation of construction machines
5) Safety and loss control program
6) Quality assurance program
7) Procurement promotion assurance
8) Receiving, handling and storing devices and materials
9) Preparation condition check, tests, start up and trial operation
10) Supplying lubricants necessary for start up, tests and operation in the early phase and chemicals necessary for water treatment and chemical analyses

11) Supplying lubrication devices and lubricants for flushing and filling in the early phase
12) Performance and reliability tests
13) In-factory and on-site training of operation/maintenance personnel from EDM
14) Support supervision of operation and maintenance for six months after the acceptance test by three engineers resident on site (i.e., mechanical, electrical and control)
15) Completion of construction and finish of site
16) Construction of a storage warehouse
17) Safety and medical aid during construction
18) Participating in arrangement meetings required by CTM CCGT and other meetings
19) Payment of lodging expenses, wages and traveling expenses with regard to factory tests and inspections
20) Obtaining local, provincial and national approvals and authorizations necessary for construction of the newly-installed power generation facility

(4) Participating in design meetings

In order to appropriately execute the designing of the newly-installed power generation facility, it is recommended that three or more meetings be held with EDM, the contractor and the consultant during the project period. These meetings shall be held so that the documents submitted by the contractor for approval can be checked and discussed in an efficient and effective manner.

The period of each design meeting shall be within every four weeks. The meeting shall be separated into four or more working groups including engineering, mechanical, electrical and instrumentation/control working groups. The meetings shall be held in those periods that are effective for promotion of the project in conformity with the contract between EDM and the contractor.

All the documents and drawings to be discussed at each design meeting shall be submitted to EDM at least one month prior thereto. The contractor shall participate in the meetings at its own expense. To obtain the approval of EDM and the consultant, the contractor shall, within one month after commencement of work, submit a list of participants, a list of discussion items, detailed schedule documents and a list of drawings, as well as a design meeting schedule with regard to the requirements from EDM. If it is determined that an interpreter is necessary at the design meetings, the contractor shall prepare an interpreter at its own expense. To complete the CTM CCGT as scheduled, EDM will review and supervise the contractor's designs and construction and, if necessary, make the contractor execute changes, improvements and amendments. Any changes in the contract amount for these design changes shall require the mutual consent of EDM and the contractor.

6.3.3 EDM's construction work and work items

EDM will execute the following construction work and work items with regard to the newly-installed power generation facility:

(1) Supplying drinking water, warm water, natural gas and electric power during construction
(2) Supplying power for start up and auxiliary steam
(3) Preparing an environment assessment
(4) Supporting the obtainment of all approvals and authorizations necessary for the construction and operation of the newly-installed power generation facility
(5) Offering information on natural gas and electric power loads for trial operation and assurance and reliability tests
(6) Evaluation of the periodical items of the operation and maintenance data and information during the two-year guarantee period and operation and maintenance conditions
(7) Preparation of on-site manpower, facilities and tools with regard to inspection to be executed after the expiration of the guarantee period
(8) Removal of the existing oil tanks and relocation of power cables for existing No.3 Gas Turbine

6.3.4 Terminal Points

For the water terminal point, the piping will be split in the vicinity of the booster pump. As the detailed location is not decided yet, it shall be reviewed and decided by EDM and ÃGUAS da REGIÃO de MAPUTO. As to the fuel gas terminal point, because how to draw from the gas station to the power plant side is not decided, too, it shall be discussed and decided by EDM and Empresa Nacional de Hidrocarbonetos de Moçambique ("ENH"). The electrical cables shall be added and connected in the vacant space in the existing switching station.

(Source: JICA Study Team)

Figure 6.3-1 Terminal Point

6.4 Plant Design Considerations

6.4.1 Design conditions

The CTM CCGT shall be designed in accordance with the below-listed design conditions:

Table 6.4-1 Design conditions

Design air temperature (dry-bulb)/ relative humidity (performance guarantee point)	28°C/ 75%
Design minimum air temperature (dry-bulb)/ relative humidity (generator maximum capacity point)	10°C/ 75%
Minimum/ maximum relative humidity	60%/ 95%
Minimum air temperature (dry-bulb)/ maximum air temperature (dry-bulb)	9°C/ 43°C
Atmospheric pressure	0.1013 MPa
Altitude	E.L. + 3.3 m above M.S.L
Seismic criterion	UBC1997, Seismic Zone "2A" Basic aseismic coefficient = 0.071g
Wind-resistant design (avg. of 10 min)	40 m/s
Annual average precipitation	800 mm
Maximum rainfall rate	96.5mm/ hr (value of 1-hour continuation)
Snow load	0 kg/m^2

(Source: JICA Study Team)

6.4.2 Standards and Criteria

(1) Mechanical, electrical and control devices and equipment

Except for the items specially required in Mozambique, the CTM CCGT shall be designed in conformity with the following international standards and criteria:

Japanese Industrial Standards ("JIS")

US standards (ASME, ASTM, etc.)

IEC standards

ISO standards

British Standards ("BS")

German standards ("DIN")

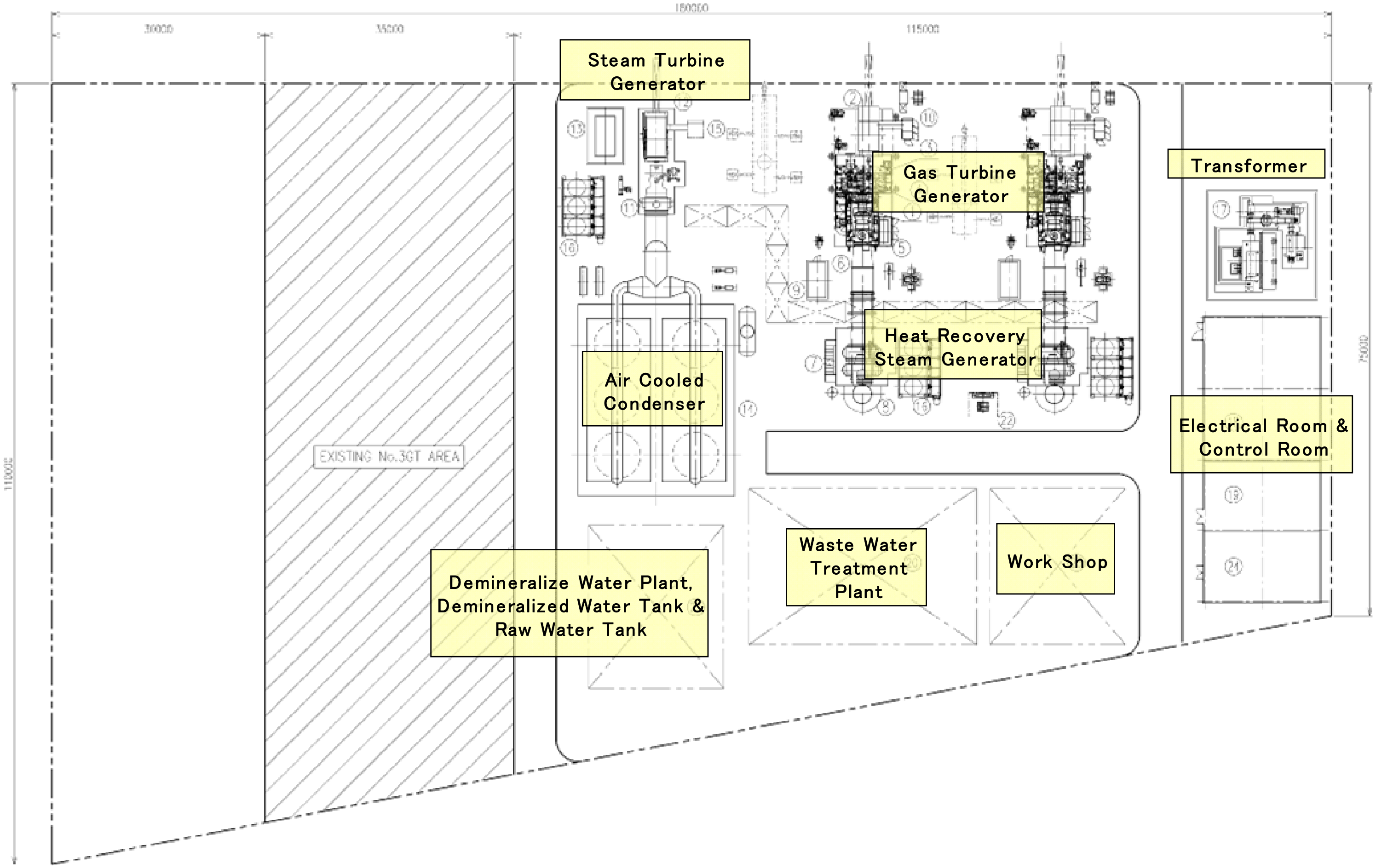
(2) Engineering and construction work

Except in the case where specific standards and criteria shall be applied, engineering, designing and construction for the engineering and construction work shall be in conformity with the related standards and criteria of Mozambique.

6.4.3 Site Layout

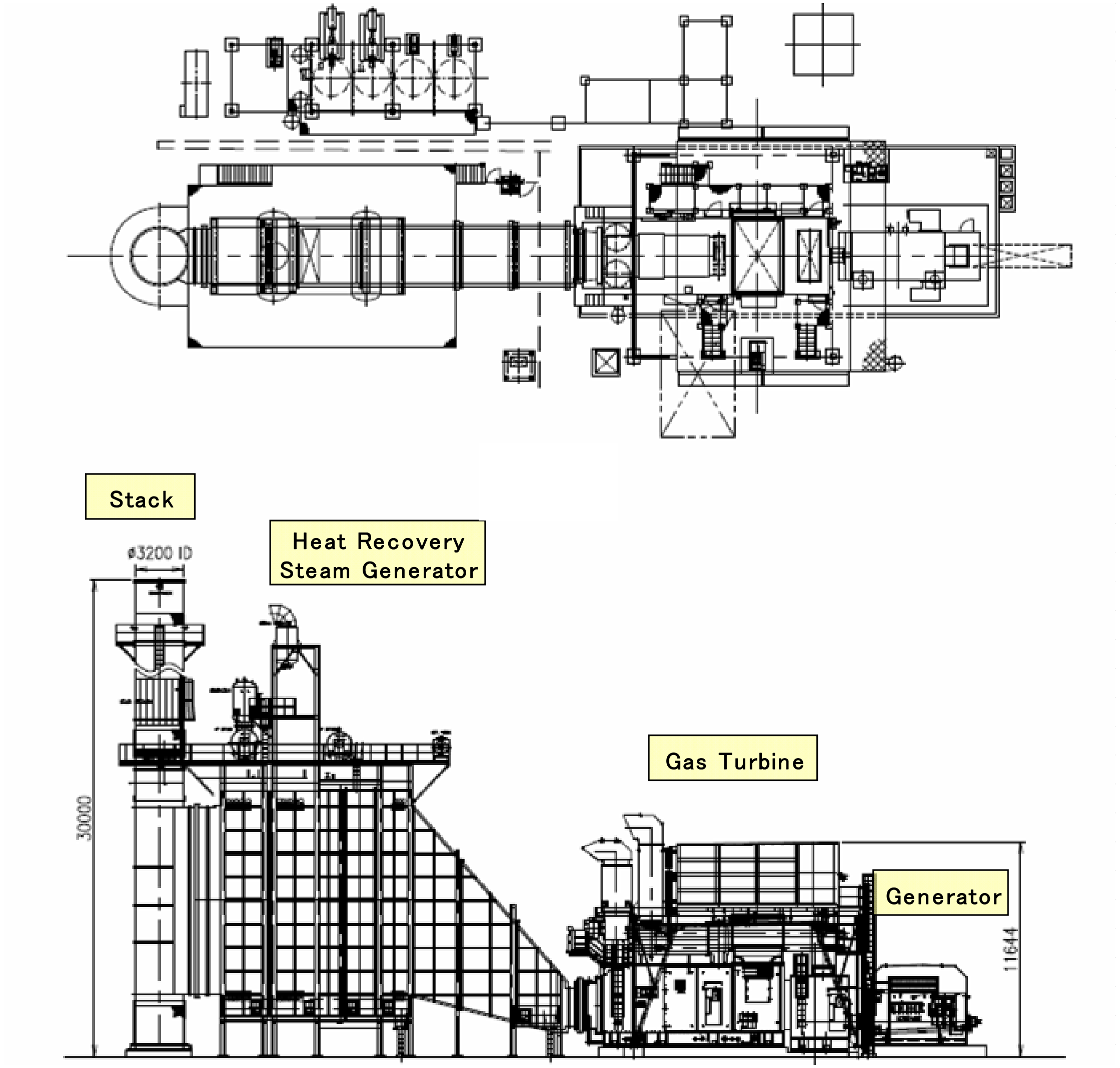
The CTM CCGT layout is planned as shown in Figure 6.4-1. For detailed drawings, see Attachment 1, "Overall Project Plot Plan." The considerations with regard to the layout of the major devices are as listed below:

- To reduce the effects of salt from the sea contained in the intake air, the air inlets of the gas turbines will face the land side and will be laid out taking into consideration consistency with the existing GTs No. 2 and No. 3.
- Taking into consideration the power lines to the switching station and the transformer substation, the power generators will be located on the north-western side in the premises so that the power line routes to the switching station can be appropriate and short.
- From the wind direction data, as it has been found that south-westerly winds frequently occur in the summer, the thermal exchange facility for the air-cooled condenser, including the steam turbine, will be located to minimize the effects of the air-cooled condenser to the GT intake air. In addition, it will be located so as to be separate from the premises border on the north-eastern side that touches the residential area.
- To reduce the loss before the air-cooled condenser, the steam turbine will be located so as to reduce the distance to the air-cooled condenser. Furthermore, the GT generators and HRSGs will be located on the right side of the steam turbine. The steam turbine generator and the GT generators will be installed indoors along with the related facilities for such purposes as noise prevention.
- The central control room, the electrical room and the battery room will be incorporated in the office building.
- The JICA Study Team has recommended to EDM that such facilities as the fuel gas facility and the water and wastewater treatment facilities be located in the area of the existing No. 3 GT. During the 2nd mission, EDM announced that the area of the existing No. 3 GT cannot be used for the new CCGT. Following this, the CCGT layout was reviewed. By locating the fuel gas pressure at the tie-in point required for CCGT, a fuel gas compressor or decompression facility will be not necessary to be installed for this CCGT plant. Water and wastewater treatment facilities will be installed in the area between the GT generator/ steam turbine generator and the seaside boundary. If these related facilities cannot be installed in this area, these facilities will be installed in the area between the existing No. 1/ No. 2 GTs and the seaside boundary.



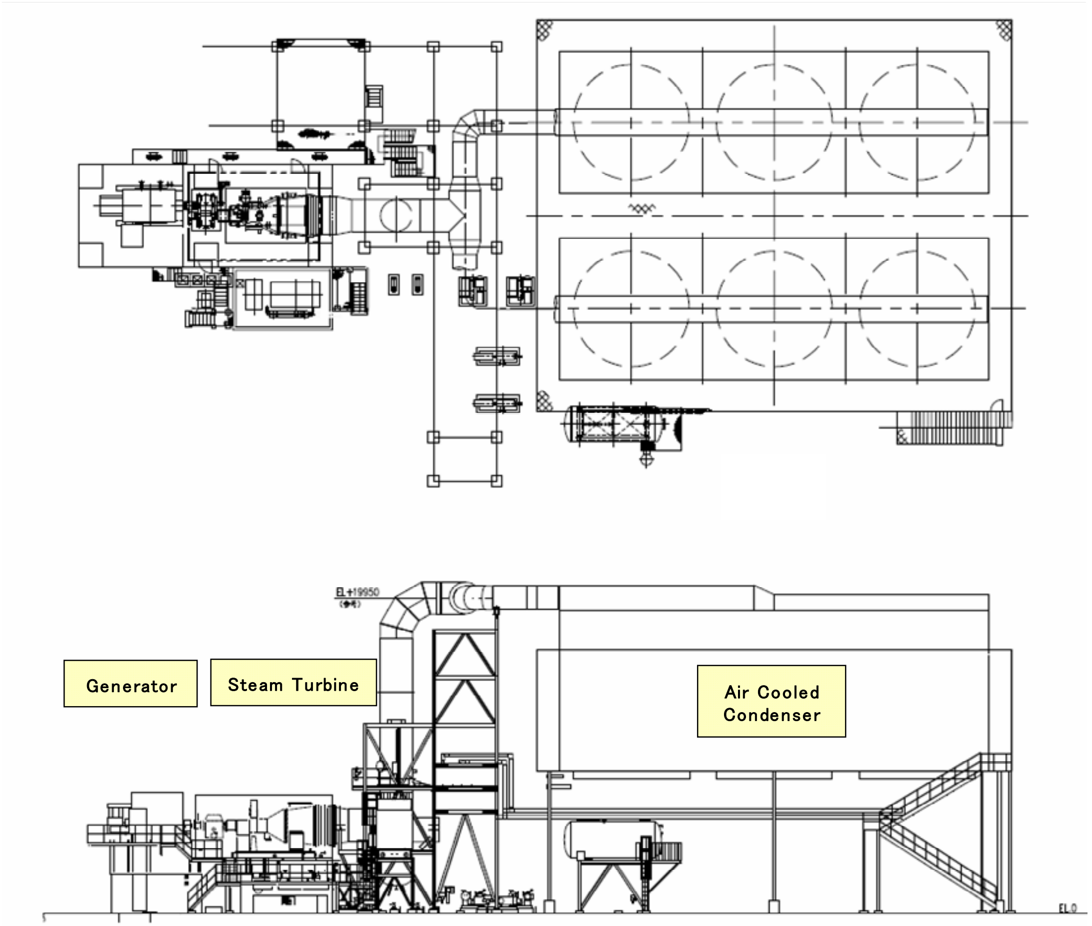
(Source: JICA Study Team)

Figure 6.4-1 Plant Layout



(Source: JICA Study Team)

Figure 6.4-2 Example of Gas Turbine and HRSG



(Source: JICA Study Team)

Figure 6.4-3 Example of Steam Turbine with Air Cooled Condenser

6.4.4 Environmental Requirements

(1) Airborne Emissions

The plant exhaust emissions shall not exceed the emission limits specified in this project shown in Table 6.4-2 based on the power output range of 75-100% of plant capacity with natural gas and diesel oil firing.

Table 6.4-2 Emission Limits of Pollutants

Unit: mg/Nm^3(0 ℃, 101.3 kpa)

Pollutant	Emission Limits	
NOx	Gas-fired	Below 320
CO	Gas-fired	0.1 per day (< 500MW)
Particulates	Gas-fired	Below 50

Note: The above levels are based on 15% O_2 dry conditions.

(Source: JICA Study Team)

(2) Noise Control

Ambient noise levels for all equipment operating under steady state conditions shall not exceed 85 dB(A) at a height of 1 m and a distance of 1 m from the edge of the equipment or the enclosure. Equivalent noise levels at a height of 1 m on the power station boundary shall not exceed 70 dB(A). Maximum noise levels for this project are summarized in Table 6.4-3.

Table 6.4-3 Noise Standards

Conditions	Maximum Noise Levels
At 1m from the edge of the equipment or the enclosure	Not more than 85 B(A)
At the power station boundary	Not more than 70 B(A)

(Source: JICA Study Team)

All measurements of noise and testing shall be done in accordance with ANSI B133.8. To comply with the above stated noise criteria, any modifications necessary, including the installation of additional and/or improved sound attenuation equipment, shall be implemented.

(3) Treated Wastewater Quality

The treated wastewater discharge quality shall meet the standards in Table 6.4-4 World Bank and Mozambique Standards for Effluents.

Table 6.4-4 Effluent Standards

No.	Parameter		Unit	World Bank Standards	Mozambique Standards (for Inland Surface Water)
1.	Ammoniacal Nitrogen (N molecule)		mg/l	-	50
2.	Ammonia (free ammonia)		”	-	0.4
3.	Arsenic (As)		”	-	0.05
4.	BOD_5 20°C		”	-	50
5.	Boron		”	-	2
6.	Cadmium (Cd)		”	-	0.05
7.	Chloride		”	-	600
8.	Chromium (total Cr)		”	0.5	0.5
9.	COD		”	-	200
10.	Chromium (hexavalent Cr)		”	-	0.1
11.	Copper (Cu)		”	0.5	0.5
12.	Dissolved Oxygen (DO)		”	-	4.5 - 8
13.	Electrical Conductivity		micro mho/cm	-	1,200
14.	Total Dissolved Solids (TDS)		mg/l	-	2,100
15.	Fluoride (F)		”	-	7
16.	Sulfide (S)		”	-	1
17.	Iron (Fe)		”	1	2
18.	Total Kjeldahl Nitrogen (N)		”	-	100
19.	Lead (Pb)		”	-	0.1
20.	Manganese (Mn)		”	-	5
21.	Mercury (Hg)		”	-	0.01
22.	Nickel (Ni)		”	-	1.0
23.	Nitrate (N molecule)		”	-	10.00
24.	Oil & grease		”	10	10
25.	Phenol compounds (C_6H_5OH)		”	-	1.0
26.	Dissolved Phosphorus (P)		”	-	8
27.	Radioactive Materials		As determined by Mozambique Atomic Energy Commission		
28.	pH		”	6 - 9	6 - 9
29.	Selenium		mg/l	-	0.05
30.	Zn (Zn)		”	1.0	5.0
31.	Total Dissolved Solids		”	-	2,100
32.	Temperature	Summer	°C	-	40
		Winter	°C	-	45
33.	Total Suspended Solid (TSS)		mg/1	50	150
34.	Cyanide (CN)		”	-	0.1
35.	Total Residual Chlorine			0.2	0.01
36.	Temperature increase		°C	Less than or equal to 3*	-

Source: Pollution Prevention and Abatement Handbook, Word Bank Group, 1998
Schedule 10, Rule 13, Environment Conservation Rules

Note: *The effluents should result in a temperature increase of no more than 3°C at the edge of the zone where the initial mixing and dilution take place. Where the zone is not defined, use 100meters from the point of discharge when there are no sensitive aquatic ecosystems within this distance.

(4) Environmental Monitoring Facilities

The Continuous Emission Monitoring System (”CEMS”) shall be installed to monitor flue gas from the Plant. CEMS shall be required to monitor the amount of the flue gas and its concentrations of NOx, Particulates and CO.

The continuous monitoring system for the amount of effluents from the wastewater treatment system and its pH value and turbidity shall be monitored. The monitoring shall be conducted at the treated water pit of the wastewater treatment system in the Plant.

6.4.5 Gas Turbine

The basic design functions required for the GT which will be employed for this project are described herein. The GT shall be of an open cycle heavy duty or aero-derivative type. The GT shall be supplied by an original equipment manufacturer. This CCGT will be the first CCGT in Mozambique. Therefore, in order to operate CCGT to maintain good condition with high output, high efficiency and minimum trouble outage, this CCGT shall be without the exhaust gas bypass system.

In order to select a GT that satisfies this requirement from the 2-on-1 CCGTs having an output of 70 to 110 MW as described in the “Gas Turbine World 2012 GTW Handbook (Volume 29),” then there are five models listed below as candidate GTs for this project:

Name of OEM	Type of Model
IHI (GE licensed)	LM6000PD Sprint
IHI (GE licensed)	LM6000PD
Hitachi, Ltd.	H-25
Rolls-Royce	RB211-GT61
Siemens Power Generation	SGT700

The GT power output shall be specified on the basis of continuous base load with the load weighting factor of 1.0 for calculation of the equivalent operating hours (“EOH”), which will be a scale of the inspection intervals of hot gas path parts.

The GT shall be operated with natural gas specified in Section 6.5.8, “Fuel supply facility.”
The GT shall be of an advanced design to meet the NOx emission requirement of less than 25 ppm

(15% O_2 basis of dry volume) for dry conditions for operation on specified natural gas under 75 – 100% load.

The GT shall be of proven design with manufacturer's design practices to basically meet the requirements of ISO 21789 Gas turbine applications – Safety.
The GT may be equipped with the evaporative type inlet air cooling system to augment the GT power output. According to climate data recorded for five years from 2007 to 2011 at Maputo International Airport near CTM site, the temperature difference between average dry and wet bulb temperatures is estimated at 3.5^{o}C. This means that the GT inlet ambient temperature could be decreased by at least 2.4^{o}C utilizing the current widely-used evaporative cooling system. As a result, the net power output may be increased by increasing fuel consumption.

The proposed GT shall be of a similar model to GTs, of which at least one GT has the experience of successful commercial operation of not less than 6,500 hours of actual operating hours as of the Bid closing date.

The GT design shall be with a minimum number of bearings, and shall be located on a steel frame or on adequate steel structures and concrete foundation, sized for the transient maximum transmittal torque imposed on the shaft in case of any short circuit of the generator or out-of-phase synchronization, whichever is larger. The power output shall be taken out at the cold end of the shaft.

The GT shall be directly coupled to the generator without any power transmission gear.

6.4.6 Heat Recovery Steam Generator

(1) Type of Circulation

HRSG could be of natural or forced circulation type. In natural circulation units, the thermal head differential between water and steam-water mixture is responsible for the circulation through the system. In forced circulation units, boiler circulating pumps ("BCPs") circulate the steam-water mixture through the tubes of the evaporator to and from the drum. Advantages claimed for forced circulation design are their quick warm/ hot start up capabilities. However, natural circulation designs do not need circulation pumps to maintain the circulation of steam-water mixture through the evaporator tubes, thereby saving operating costs and relieving concerns about pump failure or maintenance. The probability of the usage of natural circulation type HRSGs is higher because of the absence of the critical rotating equipment such as circulation pumps. There is no difference in cold start up time periods due to the fact that in the transient heat up phase, the bulk of the time is spent on heating the metal and water of the evaporator module, which is nearly the same whether it is a natural or a forced circulation HRSG. In summary, both natural and forced circulations HRSGs are widely used in the industry, while the natural circulation design has an edge over the forced circulation design as discussed above. Hence the natural circulation types HRSG are proposed for this project.

A comparison table (Table 6.4-5) for the type of HRSG circulation is provided for reference.

Table 6.4-5 HRSG Circulation Comparison

Item	Natural Circulation	Forced Circulation
1. Features	Simple evaporator circuitry without any pumps or valves	Complicated evaporator circuitry with BCP and valves
	No auxiliary power consumption	Increase of BCP power consumption
	Lower construction and maintenance costs	Increased construction and maintenance costs for BCP and piping for water circulation system
	Simplified control, high reliability and availability (no load restrictions due to pump failure)	Complicated control due to BCP operation
	There is no difference in start up time at cold start up between both types	
	The time for natural circulation force, start up time at warm and hot start up is longer than forced circulation.	Start up time at warm and hot start up is shorter than natural circulation because circulation pumps are applied.
2. HRSG Specification:		
Heating surface:	Base	Same
Steel structure volume:	Base	Same
Boiler circulating pump (BCP):	Not required	To be provided (2 x 100%)
Stability of water:	Base	Same
Drum size:	Base	Same
Steam/ water side pressure drop:	Base	Higher

(Source: JICA Study Team)

(2) Flue Gas Flow Direction

HRSG is available for both horizontal and vertical flow directions. Vertical flow directional HRSG occupy less floor space. Also, the HRSG forms part of the main stack and hence the main stack requires less material. A comparison of both types of HRSGs is furnished in Table 6.4-6.

Table 6.4-6 Gas Flow Orientation Comparisons

Description	Horizontal Gas Flow Type	Vertical Gas Flow Type
Arrangement: Installed Area Distance from GT Outlet to Stack Inlet Height Stack	 Base Base Base Taller stack is mandatory	 Smaller Shorter Same or a little higher Independent higher stack is not required
Circulation System	Natural circulation system	Natural or forced circulation system
Heating Surface Support System	Top support system by hanger (free to slide lower)	Same
Operability	Base	Same
Maintenance and Inspection	Base	Easier for natural circulation system but a little complex for forced circulation system
Economics: Equipment Cost Operation Cost	 Base Base	 A little higher Same for natural circulation system but higher for forced circulation system

(Source: JICA Study Team)

(3) Conclusion

In view of the above reasons, HRSG of natural or forced circulation types are both acceptable for this project. However, the natural circulation type HRSG is preferred.

With regard to flue gas flow direction, horizontal or vertical gas flow types are both acceptable for this project. The flue gas flow direction will be decided based on the manufacturer's recommendation and the layout proposed during the contract stage, etc.

6.4.7 Steam Turbine

The steam turbine shall be a double-pressure, condensing type directly connected to the generator. The steam shall be downward or axially exhausted to a surface condenser which is cooled by the fresh circulating water, which is in turn cooled with a forced draft wet type cooling tower.

The steam turbine shall be of the manufacturer's standard proven design and construction to allow economical and reliable service with minimum maintenance work. The steam turbine to be proposed shall be of similar design to the steam turbines of which at least one unit has the commercial operation hours of not less than 6,500 hours as of the Bid closing time.

The steam turbine and auxiliary systems shall be designed to run continuously under all specified operating conditions over the specified lifetime of the plant. The steam turbine maximum capability shall satisfy the conditions of steam pressure, temperature, and flow as developed by the HRSG when the GT is operated on maximum capability ambient conditions. In case that the HRSG is supplementary fired, the steam turbine shall be sized to cope with the maximized capability of the HRSG in consideration of the supplementary firing over the specified ambient conditions.

The steam turbine shall be designed so that the expected life expenditure of the main components (casing and rotor) shall not exceed 75% of the expected lives of the components at the end of the specified service hours when it will operate on specified conditions.

The steam turbine shall be provided with the necessary number of bore scope ports for easy inspection of the operating conditions of the blades and rotor at periodical intervals, if applicable.

6.4.8 Fuel Supply System

The new plant shall be operated on the specified natural gas from Pande gas field. The GT shall be designed to operate on the specified natural gas. The typical specifications are as shown in Table 6.4-7.

The fuel gas supply system shall cover all the equipment required for the start up, shut down and continuous operation of the GT. A booster compressor station, a pre-treatment system, and a gas pressure-regulating device shall also be included in the scope of the Contractor. The planned fuel gas pressure is 25 bar at the tie-in point the near new gas station. If the tie-in point gas pressure changes the CCGT requirements, it may not be necessary to install either a gas compressor or decompress facility, and thereby service power may be reduced. The pre-treatment system shall be facilitated to clean the specified gas to the extent that it will be used for the GT without any difficulties. The specific energy (caloric value) is expressed on the conditions of 20°C of ambient temperature and 101.3kPa of ambient pressure.

Table 6.4-7 Gas Properties

Properties	
Compositions (mol%)	
Methane	90.823
Ethane	3.452
Propane	1.732
Normal Butane	0.535
Isobutane	0.449
Normal Pentane	1.212
Isopentane	0.152
Normal hexane	0.172
Normal heptane	0.066
Normal octane	0.0018
Nonane	0.0002
Oxygen	0.027
Nitrogen	2.454
Carbon Dioxide	0.001
Hydrogen Sulfide	0
Total	100.0
Hydrogen Sulfide (g/ m^3)	0.000
Specific Energy (kJ/kg)	
Gross specific energy	52,735
Net specific energy	47,562
Specific Gravity (kg/m^3N)	0.8056
Temperature (°C)	Min. 9°C Max. 43°C Performance point 28°C
Pressure at Tie-in point (bar)	25

(Source: EDM)

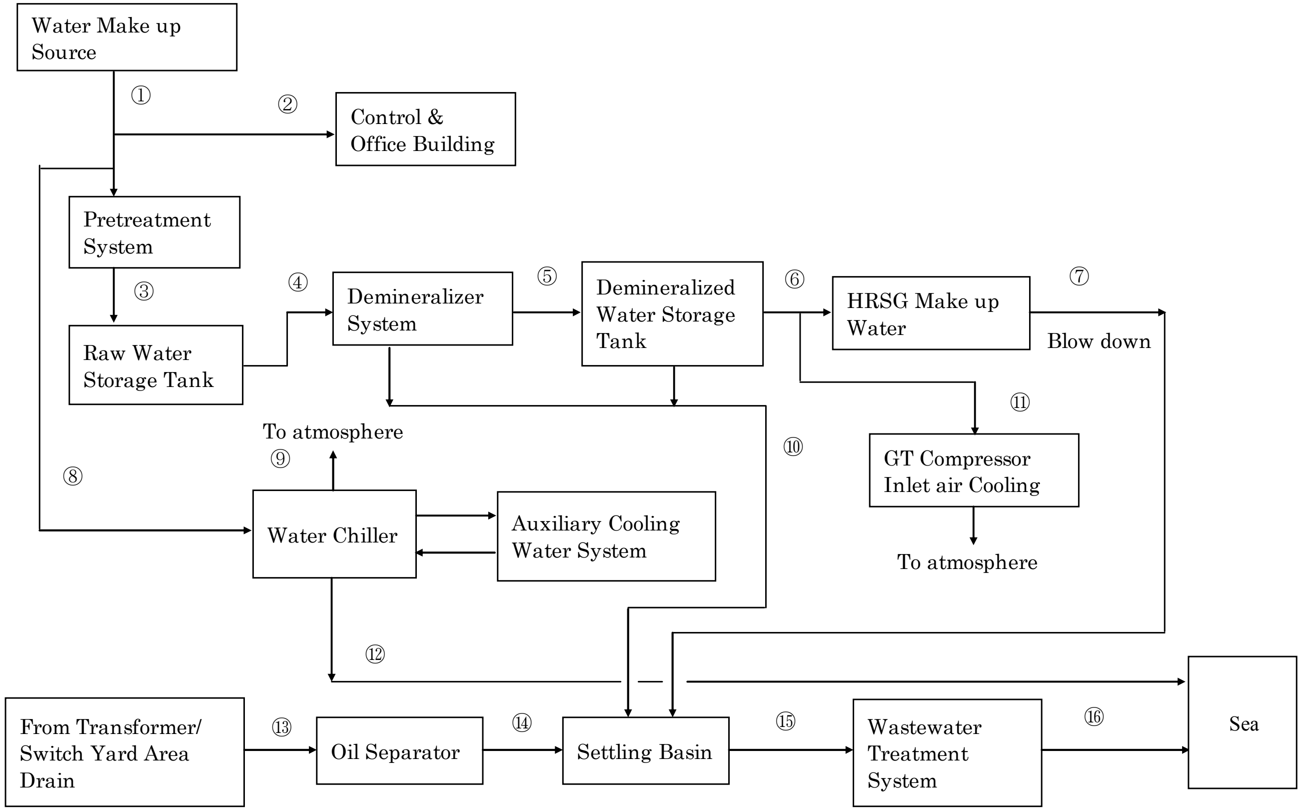
6.4.9 Water Treatment System

Processed water such as demineralized water, drinking water, clean water, water for fire-fighting, and water for miscellaneous use, will be split from the water piping at the entrance of the CTM Power Plant and produced, if necessary, by use of a pretreatment system.

The demineralized water will be used for supplying make-up water to the HRSGs, cooling of the GT intake air, cooling of the auxiliary machinery, and water supply for chemical injection.

The EPC Contractor shall confirm the quality of the produced demineralized water and whether it is acceptable to the HRSG. The pre-treatment system will consist of coagulators and filters, etc. The demineralizer system will consist of chemical storage and regeneration equipment, etc. The necessity and specification of the pre-treatment system will be decided based on the quality of the ground water. The EPC Contractor shall take appropriate countermeasures if required. The conceptual flow diagram is shown in Figure 6.4-4 “Water Mass Balance Diagram”.

Stream No.	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
Flow (m³/h)	30	2	10	10	9	9	1	18	13	1	8	5	3	3	5	5



(Source: JICA Study Team)

Figure 6.4-4 Water Treatment Flow (Water Balance)

6.4.10 Wastewater System

Wastewater shall consist of neutralized regeneration waste from HRSG blow down, floor drains from the GT and steam turbine buildings, and contaminated yard drains from the transformer area. Sewage and sanitary wastewater shall be treated in the purifying facility. Floor drains from the GT and steam turbine buildings and contaminated yard drains from the transformer area shall be treated in the oil/ water separators. After treatment, these clean wastewater streams shall be discharged through the main drainage pipe into Maputo bay.

6.4.11 Fire Fighting System

(1) Fire safety philosophy

The CTM CCGT will be designed and built with the provision of a safe operating environment and safe working personnel. This will be achieved by separation and segregation of equipment with sufficient distance between and by the selection of suitable equipment and materials.

Hazardous areas will be designated and suitable equipment will be selected for use in these areas. Different fire fighting systems will be installed depending on the operational characteristics of the equipment, area and buildings to be protected. The fire fighting capacity of the CTM CCGT must be able to withstand a of two hour fire according to NFPA 850 with a minimum 300 m^3 and pressure of approximately 10 bar.

The CTM CCGT will have its own fire water fighting system with pump house, and
fire water will be provided from the raw water tanks.

The new pumps will consist of:
One 100% electric jockey pump
One 100% electric driven main pump
One 100% diesel engine driven main pump

The water demand and required pressure for the worst case scenario will be ensured by the electrically driven main pump, a second duty diesel engine driven pump shall be on stand-by in the case of main supply failure. The engine driven pump will be of the same capacity as the electric driven main pump.

Table 6.4-8 List of protected areas and fire fighting and detection systems types

Item	Building or Area	Fire Fighting System
1	Gas turbine	CO_2 extinguishing system
2	Steam turbine lube oil package, lube oil piping	Spray water dry type
3	Steam turbine bearings	Spray water dry type
4	Steam turbine building indoors	Wet stand pipe house system
5	Generator unit, auxiliary and start	Spray water dry type

Item	Building or Area	Fire Fighting System
	up transformer	
6	Oil tanks	Form system, dike protection
7	Control room	Cable basement: Sprinkler system Control room: Argonite or similar
8	Electrical/ switchgear	Sprinkler system if required and portable fire extinguishers
9	Yard	Hydrants
10	Common areas	Protective signaling for fire and gas detection systems with main panel in the control room

(Source: JICA Study Team)

(2) Fire fighting system description

The fire fighting system of the CTM CCGT will be provided for the plant as described as follows. In general, the fire fighting system will follow the applicable stipulations of NFPA codes. Extinguishers will be sized, rated and spaced in accordance with NFPA 10. Local buildings fire alarms, automatic fire detectors and the fire signaling panel will be in accordance with NFPA 72.

A dedicated two hour fire water supply will be assured to cover the system design flow rate for the facility in accordance with NFPA. A main firewater pipeline will be provided to serve strategically placed yard hydrants and supply water to the sprinkler and spray system. The firewater distribution system will incorporate sectionalizing valves so that a failure in any part of the system can be isolated while allowing the remainder of the system to function properly. Fuel oil tanks will be furnished with foam fire fighting systems.

6.5 General Specification of Electrical and Control System

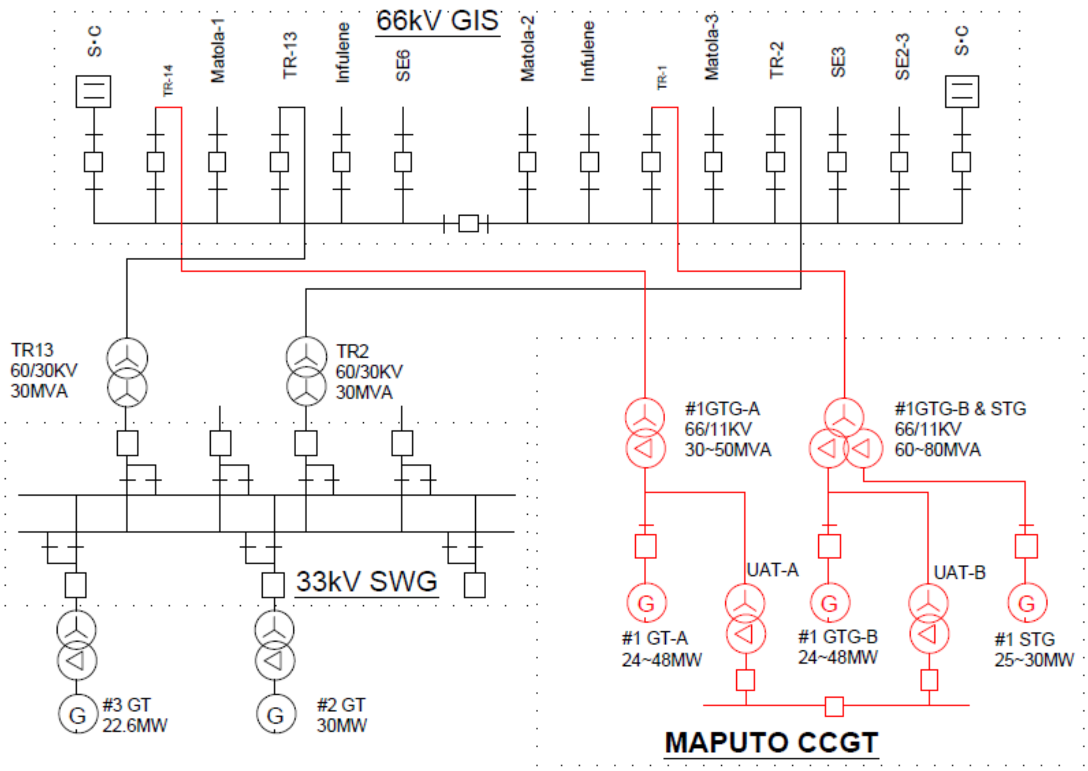
6.5.1 Electrical Facility

Outline of electrical system

GT generator-A will be connected via a single generator step-up transformer to the 66 kV substation. And GT generator-B and the steam turbine generator will be connected via a three-winding transformer to the 66 kV substation. Because of above methods can decrease the requirement only one transformer, these methods are more economical than using both a generator and a transformer.

In addition, for connection to the system, only two sets of switchgears are used at the 66 kV substation. As the existing 66 kV GIS substation to be used has a two-section, single-bus configuration, all the transmission lines connected to the bus must be shut down in order to add a breaker. Currently, however, two switchgear bays are empty as two transformers have been removed to be connected to the 35 kV substation. Therefore, there are plans to connect the two generator step-up transformers to these switchgear bays. Thus no shut down of the 66 kV transmission line will occur.

For connection of the ordinary generators to the system, generator main circuit breakers (“GMCBs”) will be used. The GIS in the 66 kV substation will be used for re-parallelization to the system after auxiliary load operation. An outline of the electrical system is shown in Figure 6.5-1.



(Source: JICA Study Team)

Figure 6.5-1 Outline of electrical system

(1) GT and steam turbine generators

a. Generator specifications

The generator standards shall be as listed below:

Table 6.5-1 Generator specifications

	GT generator (2 units)	Steam Turbine generator (1 unit)
Generator type	Three-phase AC synchronous generator	Three-phase AC synchronous generator
No. of poles	2	2
Phases	3	3
Capacity	24 MW to 48 MW	2 0 MW to 30 MW
Frequency	50 Hz	50 Hz
Speed of rotation	3,000rpm	3,000rpm
Terminal voltage	11 kV	11 kV
Power factor	0.85 (lagging) operation lag 0.85 to lead 0.95	0.85 (lagging) operation lag 0.85 to lead 0.95
Short-circuit ratio	Not less than 0.45	Not less than 0.45
Insulation class	Stator: Class F; Rotor: Class F	Stator: Class F; Rotor: Class F

(Source: JICA Study Team)

The rated output values of the generators shall correspond to the maximum output values of the GT and the steam turbine. The above generation capacities show approximate ranges with regard to the CCGT that is expected to be used. In addition, the rated voltage values are those generally used for 20-40 MW-class generators. Finally, the design voltage of the generator manufacturer will be applied.

The rated power factor shall be a delay of 0.85. The normal operation power factor shall be a range from a lag of 0.85 to a lead of 0.95.

From the viewpoint of system stability, a larger short-circuit ratio is advantageous. However, the short-circuit ratios have been reduced due to downsizing of machines and speeding up of the automatic voltage regulators (“AVRs”). For the Maputo CCGT, the specification shall be for a minimum value of 0.45. This value is also acceptable from the viewpoint of system stability calculation. (Recommended value by IEC 60034-3: When rated output does not exceed 80 MVA in the case of air cooling: 0.45 or higher)

b. Generator cooling facility

The cooling for the GT and steam turbine generators shall be an air cooling type. Whether to use an open air cooling method or a water-cooler shall depend on the generator manufacturer’s recommendation.

c. Excitation system

Each generator is supplied with the field current by a static thyristor exciting arrangement or a rotary rectifier exciting arrangement (brushless exciter). The excitation system includes necessary components such as an excitation transformer, a field circuit breaker, and an initial excitation device. For the stationary thyristor exciting arrangement, the excitation transformer shall be split from the generator main circuit and thus supply from any other power source shall not be allowed.

d. AVRs

AVRs shall be of an immediate response excitation type. For the AVR, a dual system of a microprocessor type shall be used. AVR devices should be installed in air-conditioned rooms. The AVR functions shall include:

- Automatic voltage regulator (90R)
- Field voltage regulator (70R)
- Over excitation limiter (“OEL”)
- Under excitation limiter (“UEL”)
- Power system stabilizer (“PSS”)
- Automatic reactive power regulator (“AQR”)
- Automatic power factor regulator (“APFR”)
- Other necessary functions

e. GT start up method

The GT start up method shall use a motor-driven torque converter, a hydraulic pump or a thyristor, depending on the contractor’s recommendation.

(2) Generator main circuit

a. Current transformer (“CT”)

A CT shall be installed on the bushing of the generator main terminal. The CT shall be installed to be used for metering including generator ratio differential relay, transformer ratio differential relay, other protective relays and the watt-hour meter. The CT for metering shall be of accuracy class of 0.2. The current rating on the secondary side shall be one A.

b. Voltage transformer (“VT”) and surge arrestor (“SA”)

Instrument VT, SA and generator grounding device will be installed between the generator and the generator main circuit breaker (“GMCB”). They will be installed in an independent cubicle or on the GMCB board. The VT used for metering, including the watt-hour meter, shall be of accuracy class of 0.2. The surge condenser capacity shall be as recommended by the manufacturer.

c. Neutral grounding device

The neutral point of the generator shall be grounded via a resistor or the secondary-side single-phase transformer with a resistor. The transformer shall be a dry-type transformer. The resistor shall be a metal grid, non-inductive resistor. A single-core cross-linked polyethelene (“XLPE”) cable shall be used between the generator main terminal and the neutral grounding device.

d. Generator main circuit breaker

A GMCB will be installed between the generator and the generator step-up transformer for generator synchronizing on and off. The continuous rated current of the circuit breaker shall be selected so that it corresponds to the maximum load of the generator. Short-circuit current capacity of the GMCB shall be selected on the condition that a short-circuit current of 25 kA at maximum flows into the bus line of the 66 kV substation. For synchronous detection, a VT shall be installed on the step-up transformer side of the GMCB.

In addition, a grounding device shall be installed on each side of the GMCB for safety work..

e. Main circuit connection

XLPE cables that correspond to the individual voltage classes shall be used between the generator and the GMCB, between the GMCB and the generator step-up transformer, and between the generator step-up transformer and the 66 kV substation. The cables shall be single-core, wire-armored cables.

(3) Major transformers

The connection conditions of the GT transformers, the steam turbine transformers and the auxiliary transformers are shown in Fig. 6.5-1 “Key single line diagram” A one step-up transformer is connected to GT generator-A. GT generator-B and the steam turbine generator are connected to one three-winding transformer for power transmission to the 66 kV substation. The two auxiliary transformers are respectively split from the circuits of GT generator-A and GT generator-B.

a. Generator step-up transformer

The generator step-up transformer boosts the generator voltage (11 kV class) to the transmission voltage (66 kV). The transformer shall be an oil-insulation, outdoor-type, three-phase transformer with an off-load tap changer. The transformer winding type of GT generator-A shall be a two-winding type, Y-Δ (YNd11). The transformer winding type of GT generator-B/ steam turbine generator shall be a three winding type, Y-Δ-Δ (YNd11d11). As the transformer cooling method, Oil Natural Air Natural/ Oil Natural Air Forced ("ONAN"/ "ONAF") shall be used. The neutral point on the high voltage side shall be direct grounding. The rated capacity on the name plate shall be based on calculation and discussion.

b. Auxiliary transformer

The unit auxiliary transformer ("UAT") reduces the GT generator voltage (11 kV) to the auxiliary power voltage (6.6 kV). The UAT shall be an oil-insulation, outdoor-type, three-phase transformer with an on-load tap changer, and the cooling method shall be ONAN. The transformer winding type shall be Δ-Y (Dyn1). The neutral point on the 6.6 kV side shall be resistant grounding (5 ohms). Two UATs with the same capacity shall be installed. Ordinarily, the two transformers shall both be in service but they shall have the capacity to cover the entire load even if one of them breaks down.

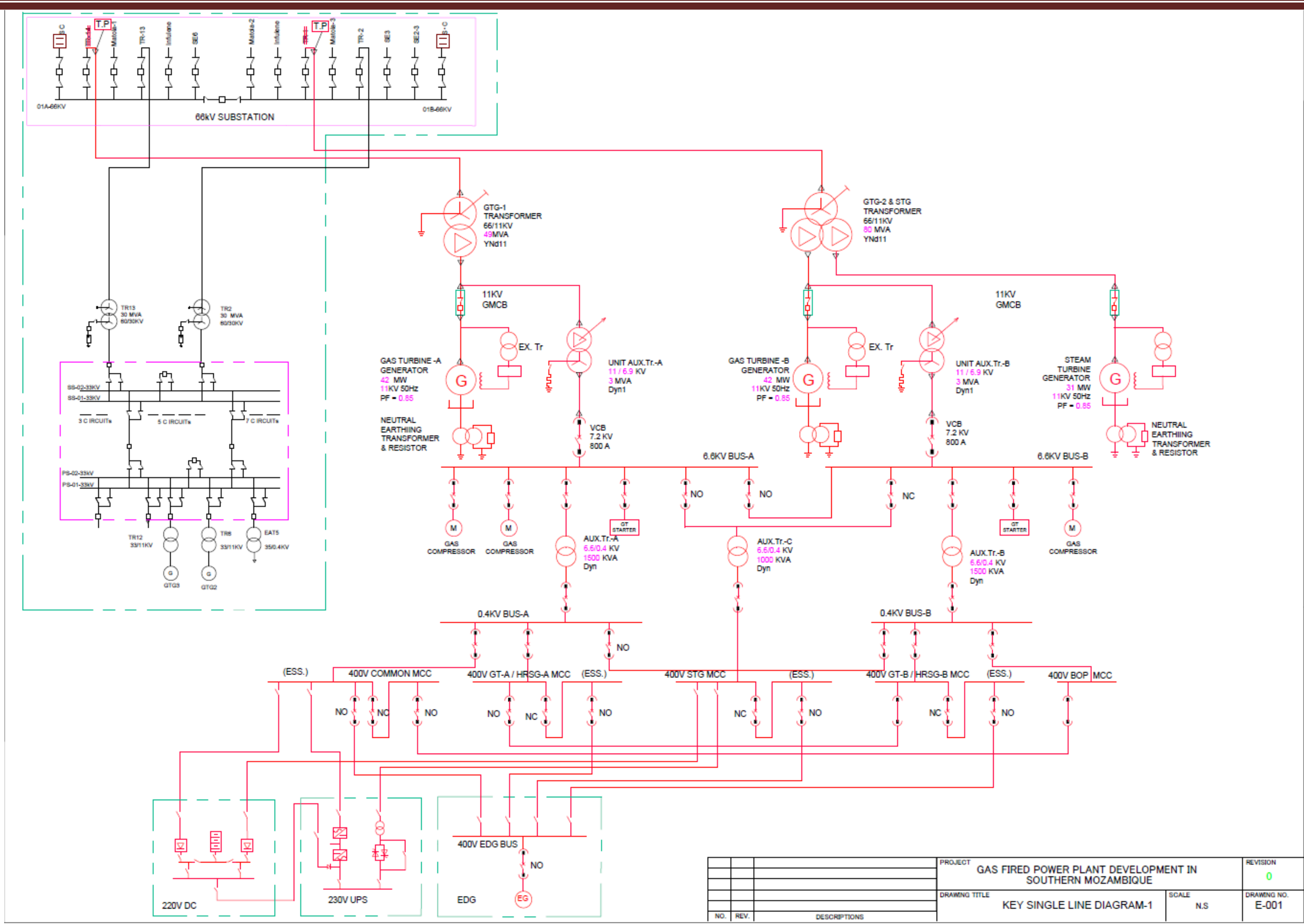
The JICA Study Team has temporarily assumed the transformer capacity to be 3 MVA but the final capacity shall be based on the auxiliary power design by the contractor. The plan is based on a 6.6 kV load, and the gas compressor and GT starting equipment are assumed to have a 6.6 kV load. If a bidder provides a design that is not a 6.6 kV load, the secondary transformer voltage will be set to 400V. In this case, a transformer neutral point shall be directly grounding.

Table 6.5-2 Transformer specifications

Item		GT Generator-A Transformer	GT Generator-B/ Steam Turbine Transformer	Auxiliary Transformer (2 sets)
Rated voltage	Primary	66 kV	66 kV	11.0kV
	Secondary-1	11 kV	11 kV	6.6kV
	Secondary-2	---------	11kV	---------
Rated current	Primary	411A	717A	158A
	Secondary-1	2467A	2467A	263A
	Secondary-2	---------	1638A	---------
Rated capacity	Primary	47MVA	82MVA	3 MVA
	Secondary-1	47MVA	47MVA	3 MVA
	Secondary-2	---------	35MVA	---------
Winding		YNd1	YNd1d1	Dyn11
Cooling method		ONAF	ONAF	ONAN

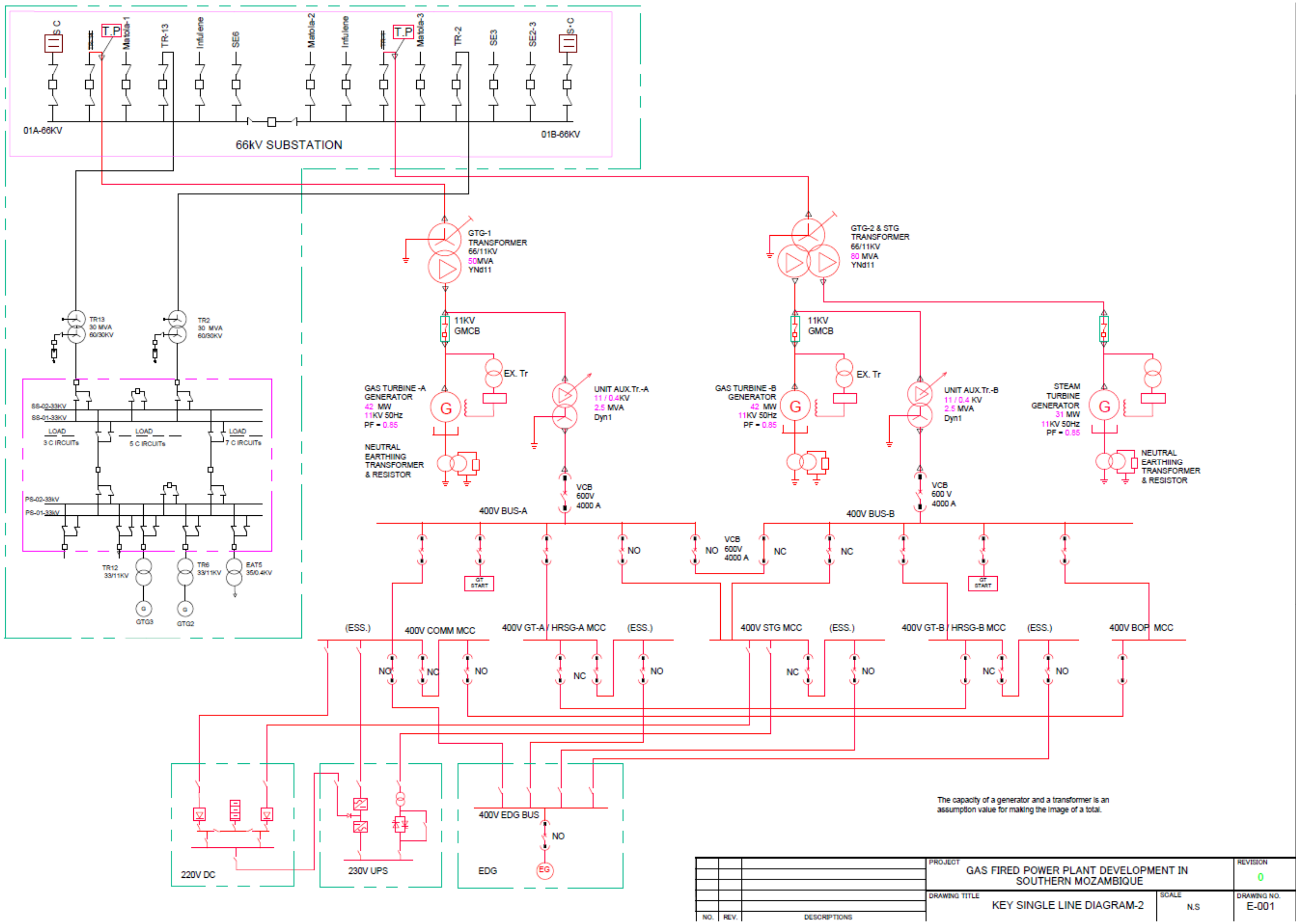
(Source: JICA Study Team)

The above list shows an example of using a GT with an output of 40 MW and an steam turbine with an output of 30 MW. Note that the maximum output of the GT is based on an atmospheric temperature of 10°C and therefore differs from the actual rating described on the plate of the generator step-up transformer.



(Source: JICA Study Team)

Figure 6.5-2 Key Single Line Diagram - 1



(Source: JICA Study Team)

Figure 6.5-3 Key Single Line Diagram – 2

(4) Auxiliary power supply

The auxiliary power supply system consists of two UATs. Including common facilities (water treatment, sewage treatment and other facilities), the facilities used in the Maputo CCGT will be supplied with power from the UATs.

In addition, the Maputo CCGT will be equipped with a 3-phase diesel generator for emergency power supply so as to protect and maintain the power supply in the case where there is a total power station blackout.

a. 6.6 kV medium voltage switchboard (if 6.6 kV load is required)

The 6.6 kV medium voltage switchboard will supply the auxiliary equipment driving power that is required for power generation facility operation and common operation power. The 6.6 kV auxiliary bus lines consist of lines A and B. The bus lines are of a 3-phase, 3-wire type. Each 6.6 kV auxiliary bus will be supplied with power from the auxiliary transformer split from the main circuit of each GT generator. The 6.6 kV medium voltage switchboard will supply power to the 6.6 kV facilities and the 400 V auxiliary bus.

The 6.6 kV bus lines, A and B, will be connected via a bus connection breaker. The bus connection breaker will normally be open. The 6.6 kV medium voltage switchboard shall be equipped with an automatic high-speed bus switcher. At the time of start up and shut down, and even during operation, the whole Maputo CCGT load can be supplied with power by switching the bus connection breaker on in the case where one of the UATs is suspended.

The power panel shall be of a metal clad type and the breaker shall be either a vacuum circuit breaker (“VCB”) or a gas circuit breaker (SF6CB). (Refer to “Key Single Line Diagram –1.)

b. 400 V switchboard

The 400 V switchboard shall supply power to the middle-capacity electric motors and the motor control center (“MCC”). The power will be supplied from the 6.6 kV bus via a 6.6/ 0.4 kV dry-type transformer. The neutral point of the transformer shall be directly grounded. The bus lines shall be of a 3-phase, 4-wire type. Buses are formed with the line bus (“L1”, “L2”, and “L3”) and neutral bus (“N”).

In composition without a 6.6 kV medium voltage switch board, the electricity will be supplied from a 11/0.4kV unit axially transformer. Please refer to “Key Single Line Diagram – 2.”

c. MCC

The MCC shall supply power to the small electric motors and 400 V or 230 V power to the plant. The bus lines are of a 3-phase, 4-wire type. Buses are formed with the line bus (i.e., L1, L2, and L3) and neutral bus (N). The 230 V single-phase loads are supplied from power between the neutral line and phase lines. The switchgear shall be of a drawer type.

d. Emergency AC power facility

One set of diesel generator facilities shall be installed. Emergency power shall be sent from the diesel generator to the 400 V emergency bus line in the case of blackout. The objective of the diesel generator is the safe shut down of the plant in the case of a blackout. It shall not be used for black start of the plant.

The generator capacity shall be sufficiently tolerant for the safe shut down of the plant. The major loads will include the AC bearing oil pumps, AC control oil pumps, gas turbine ventilation fans, battery chargers, uninterrupted power supply ("UPS") units, and emergency AC lighting, etc.

e. Uninterrupted power supply (UPS)

UPS units shall be installed to supply the plant control power or AC 230 V power to important loads for which power loss is unacceptable. The UPS units shall be designed as 230 volts alternating current ("VAC"), single-phase, 2-wire and 50-Hz.

The UPS unit shall consist of an AC-to-DC converter, DC-to-AC inverter, static switch with a voltage regulator for switching to the AC bypass power, and a maintenance bypass transformer. The UPS units shall be supplied with DC power from the 220 volts direct current ("VDC") power supply facility for CCGT.

f. 220 VDC power supply facility

The 220 VDC power supply facility shall consist of two 100%-capacity battery chargers and a group of 100%-capacity batteries. The batteries shall be able to assure safe shut down of the power generation facility in the case there is a blackout of the Maputo CCGT.

(5) Protection and measurement of generators and transformers

For protection of the generators and the generator step-up transformers, there shall be a dual system of a microprocessor type. The DC and AC control power supplies will also be duplex. In addition, the breaker tripping signal shall be duplex via two lockout relay systems (86). The table below shows the basic configuration of relays to be used for protection of the generators, generator step-up transformers and other main circuits.

a. Generator protection

Table 6.5-3 Generator protection relays

Name	Element
Generator Differential protection	87G
Generator Negative Sequence protection	46G
Generator Loss of Excitation protection	40
Generator Reverse Power protection	32R
Rotor Earth Fault Protection	64R
Out-of-Step Protection	78
Generator Stator Earth Fault protection	59NG
Generator Over Current protection	51G
Generator Stator Overload protection	49G
Generator Backup Impedance protection	21G

Name	Element
Generator Over Voltage protection	59G
Generator Under and Over Frequency protection	81
Generator Under Voltage protection	27G
Over Excitation protection U/f	U/F24G
Protection of other exciters	

(Source: JICA Study Team)

b. Generator step-up transformer protection

Table 6.5-4 Generator step-up transformer protection relays

Name (Electrical Protection)	Element
Differential protection	87T
Phase Over Current protection	51
Differential Earth Fault Current protection	87N
Thermal Overload protection	49
Negative Sequence protection	46
Name (Mechanical Protection)	Element
Buchholz relay	96P1
Sudden pressure response devices	96P2
Transformer oil temperature relay	26 Oil
HV winding temperature relay	26WH
LV winding temperature relay (GT, GT/ ST)	26WL
LV winding temperature relay (GT/ ST)	26WL

(Source: JICA Study Team)

c. Auxiliary transformers protection

Table 6.5-5 Auxiliary transformer protection relays

Name (Electrical Protection)	Element
Differential protection	87T
Phase Over Current protection	51
Earth Fault Over Current Protection	51N
Thermal Overload protection	49
Negative Sequence protection	46
Name (Mechanical Protection)	Element
Buchholz relay	96P1
Sudden pressure response devices	96P2
Transformer oil temperature relay	26Oil
HV winding temperature relay	26WH
HV winding temperature relay	26WL
Protection of the tap changer	63OLTC

(Source: JICA Study Team)

d. Electrical control measurement

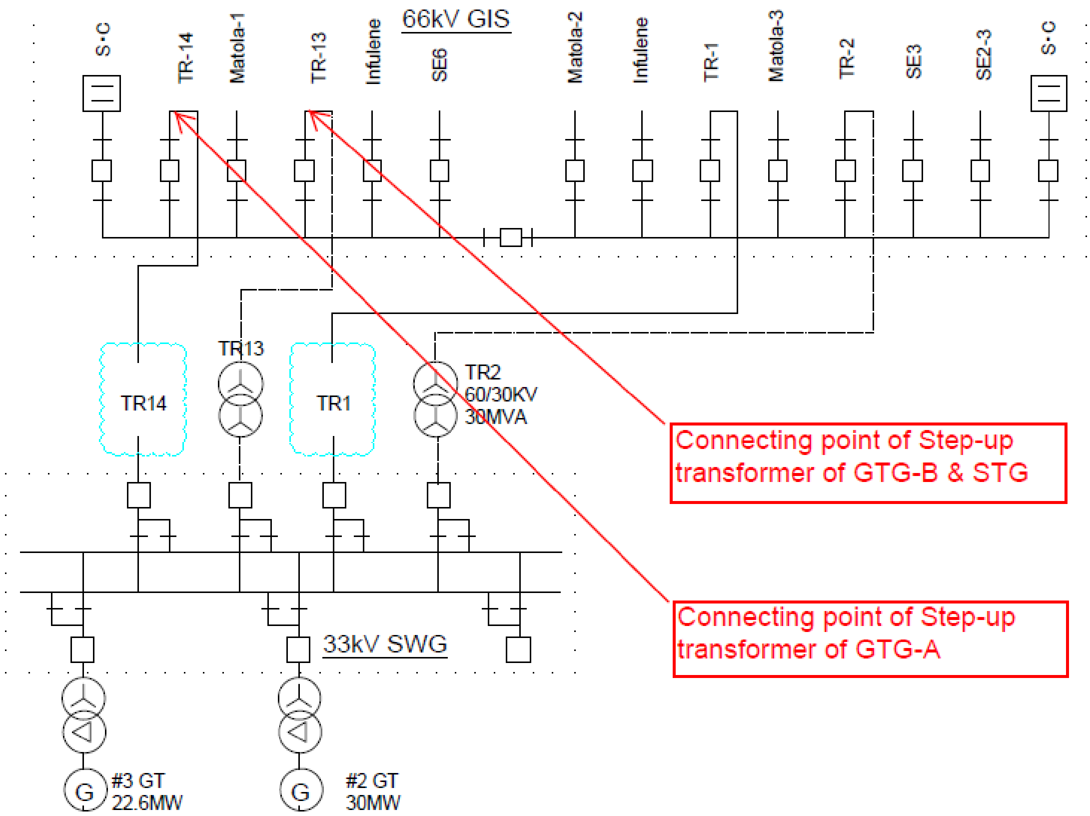
Generator parallelization on and off signals shall be transmitted from the DCS via the generator controller or the protection relay to the GMCB or the 66 kV substation by use of hard wires.

Also by use of hard wires, the current and voltage signals shall be connected from the CT and the VT to the generator control panel or the protection relay.
Devices with accuracies of 0.2 or higher shall be used for measuring instrumentation with regard to the watt-hour meters and the performance tests. Gauges for on-site operation monitoring shall be of class 1.5 or higher.

(6) Substation and power lines

As described in the inception report, the JICA Study Team plans to use the existing power transmission facility without enhancement of the power lines. Based on this assumption, transmission methods of power generated by the CCGT via the CTM Maputo 66 kV substation shall be planned. Three circuits of 66 kV transmission line and one 30 MVA transformer for 33 kV substation connection shall be connected to 1A Bus of CTM Maputo 66 kV substation. Moreover, five circuits of 66 kV transmission line and one 30 MVA transformer for 33 kV substation connection shall be connected to 1B Bus. There were once four transformers but two have been removed and now there are bus lines 1A and 2A, respectively, with one empty switchgear bay. This is suitable as the plan to connect two generator step-up transformers for CCGT.

The connection location of the step up transformer and the current composition of 66 kV GIS are shown in Figure 6.5-4.



(Source: JICA Study Team)

Figure 6.5-4 GIS layout and connection point

6.5.2 Control and Monitor System

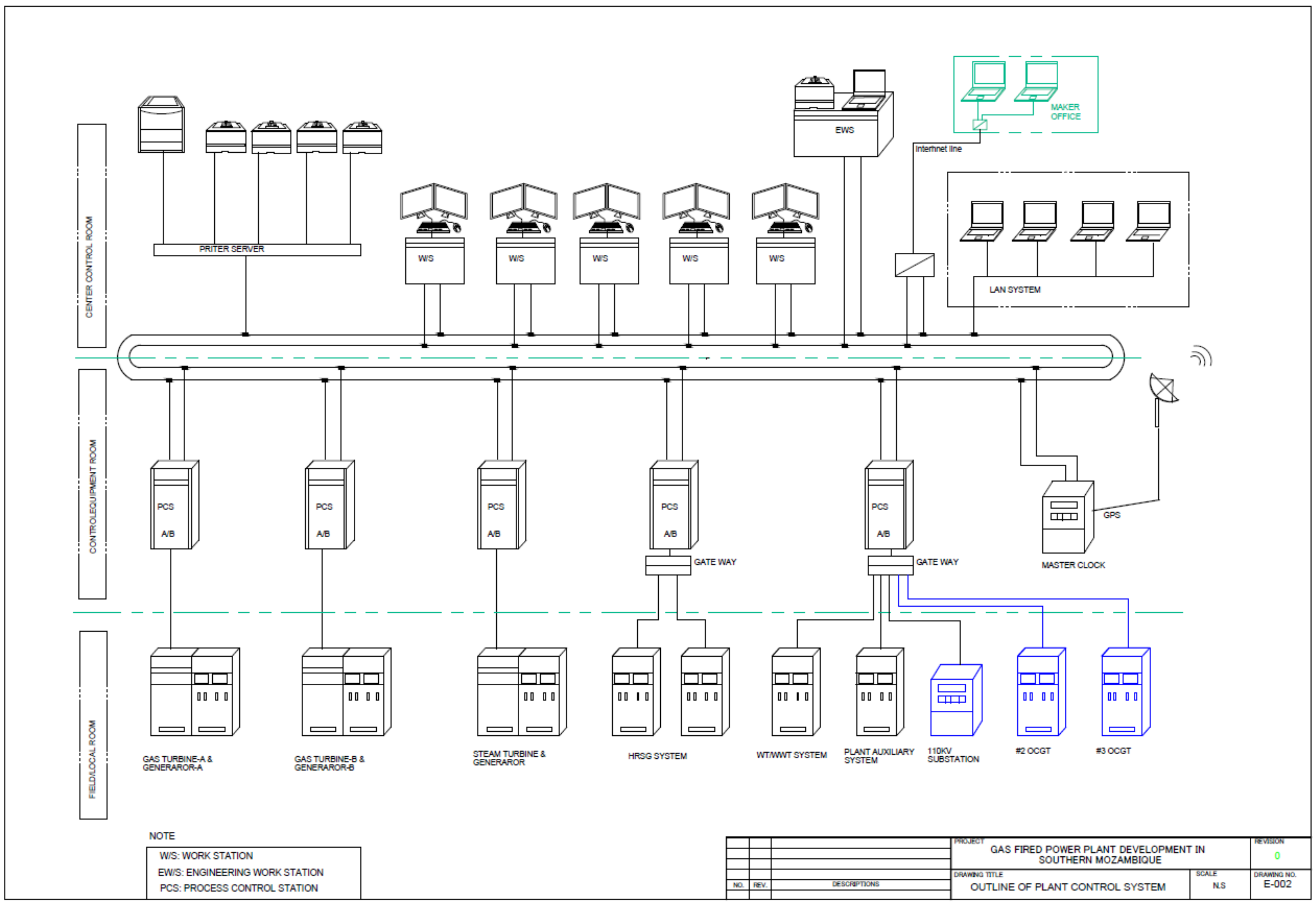
(1) System outline

All the designs of the control and monitoring system shall be provided to maintain the maximum safety of the CTM CCGT employees and equipment and, on the other hand, the system shall have the highest usability as far as can be expected so that it can be operated in a safe and efficient manner in all conditions. The control and monitoring system that will realize all-automatic operation of the generator facility will be configured as a DCS that takes technology and costs into consideration. The DCS facility will make it possible to control and monitor the whole generator facility, including control and monitoring of common facilities.

In addition, the existing CTM CCGTs No. 2 and No. 3 shall be controllable from the newly-built central control room as well as from the CTM CCGT. The system outline is shown in Figure 6.5-5 “Outline of Plant Control.”

The basic design of the DCS facility is as follows:

- Operation and power circuits shall be duplicated.
- Input/ output circuits will be of a single type. However, important circuits will be doubled.
- The power supply will be duplexed by AC and DC (butted method).
- The trunk network will be doubled.
- In principle, operation should be carried out by use of a computer mouse.



(Source: JICA Study Team)

Figure 6.5-5 Outline of Plant Control

(2) Configuration of power plant control and monitoring system

The control and monitoring equipment for the power plant will consist of a DCS facility, an information management system, a maintenance management system, a network system and related equipment.

The DCS facility will consist of an operator console, a turbine control system, a data logging system, a sequence control system, a process input/ output (“I/O”) system and related peripheral machinery, which will be connected via a network.

The standard performance of the instrumentation and transducer are as follows:

- On-site monitoring instrumentation: Accuracy class 2.0 or higher
- Transducer: Accuracy class 0.25 or higher
- Transducer related to performance: Accuracy class 0.2 or higher

(3) DCS function of the power plant

In the design of the CTM CCGT control and monitoring system, there will be the integration of a combination of a GT and a GT generator, a combination of an steam turbine and a steam turbine generator, a combination of an HRSG and a BOP (auxiliary machine), and exclusive control equipment with an air compression facility, etc., using a data logging system and a DCS of the latest technology.

The operator console installed in the CCR shall consist of a keyboard, a computer mouse and a dual display (two liquid crystal displays (“LCDs”)). The GT control system, the steam turbine control system, and the HRSG and local control system shall be connected to the DCS via redundant communications links and by use of hard wiring signals. The signals from such systems as the air compressor control system and the auxiliary steam supply control system shall be sent to the DCS I/O cabinet either directly or via remote I/O units. The LCD graphics will provide the operators information on the control and monitoring of instrument and process conditions, records and alarms.

The detection system for protection control of the GT, steam turbine and the HRSG shall be redundancy/ triple configuration (2 out of 3) to improve the reliability of the generator facility. The control system shall be designed so that the generator facility can be operated and controlled automatically and the operators can be informed of the power plant status, start up/shut down status, troubleshooting status and normal operation status.

The configuration of the control logic and graphic display of the control system shall be designed so that maintenance staff can carry out on-site corrections and modifications easily and without making mistakes.

DCS shall have the following functions:

a. Turbine control and monitoring functions

- GT control and monitoring and GT protection circuit

- HRSG control and monitoring and HRSG protection circuit
- Steam turbine control and monitoring and steam turbine protection circuit
- Condenser control
- Control of control system
- Control of bearing oil system
- Control of synchronization
- Generator protection, excitation control, and voltage control
- Auxiliary and BOP control and monitoring

b. Information collection/ control functions

- Scanning and alerting
- Process calculations (including performance calculations)
- Data log functions and data display
- Functions to control and monitor common facilities
- Fuel gas facility
- Water treatment system
- Wastewater treatment system, etc.

These systems will have independent monitoring and control. In the event of any defect in the equipment, the impact on the power station will be large. For this reason, the calculation system and power supply system, etc., are multiplexed in order to contribute to the reliable operation of the system.

c. Maintenance functions

Maintenance tools (an Engineering Work Station) for the maintenance of DCS shall be installed and these tools shall have the following functions:

- Control circuit setting/ changing functions
- System diagram displaying/ changing functions

When specified under the treaty of LTSA, remote monitoring from the office of the maker of the gas turbine equipment will be possible.

d. Functions for connection with SCADA

In order to monitor the intelligence on substations connected to the generator of CCGT, there shall be a communication system between SCADA and the power plant. In order for the communication system to match that of SCADA's, DCS shall make preparations for such system. DCS will send data and signals that are requested by the dispatch center section.

.

(4) Communications system

A communication system will be established for the management, supervision and correspondence of the power plant.

a. Telephone facility

Cordless telephones shall be prepared for plant yard connection. Private branch exchange ("PBX") shall be installed and used for connection to the public telephone network and internal calls. The facility will include a main distributing frame ("MDF"), PBX, extension terminal box, wireless transmitters, and terminal handsets.

b. Walkie-talkie system

A walkie-talkie system of a frequency and output recognized by the Mozambique government shall be used. Using multiple frequency bands and extension handsets, the master station of the wireless installation, which will be installed in the CCR, will allow broadcast calls and calls between extension handsets set to the same band

c. Clock device

Clock equipment with a global positioning system ("GPS") shall be installed. The DCS and major control equipment shall be synchronized with the clock equipment. Synchronization with the SCADA system shall also be taken into consideration.

d. LAN system

A local area network ("LAN") system will be established plus the internet/intranet system to be used in the CCR, general offices and conference room, etc.

e. CCTV system

Closed-circuit television ("CCTV") equipment will be installed for remote monitoring of the device operation conditions and for yard security monitoring. The equipment shall use color cameras and offer the following functions: nighttime monitoring, zoom functions, tilt functions, and automatic and manual focus adjustment functions. The monitoring screens shall be installed in the CCR and security office.

6.6 Civil and Architectural Works

6.6.1 Major Components of Civil and Architectural Works

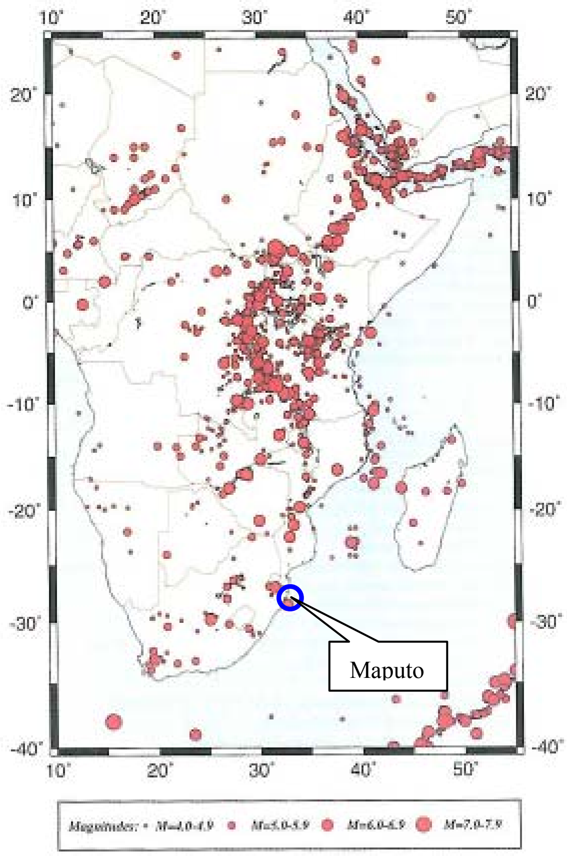
Major components of civil and architectural works include the following:

- Foundation works (including removal of the existing oil tanks and relocating the power cable of the existing No. 3 Gas Turbine)
- Steam turbine building
- Control building
- Other buildings (i.e., warehouse, workshop, etc.)
- Storm drainage system
- Road work

6.6.2 Earthquakes

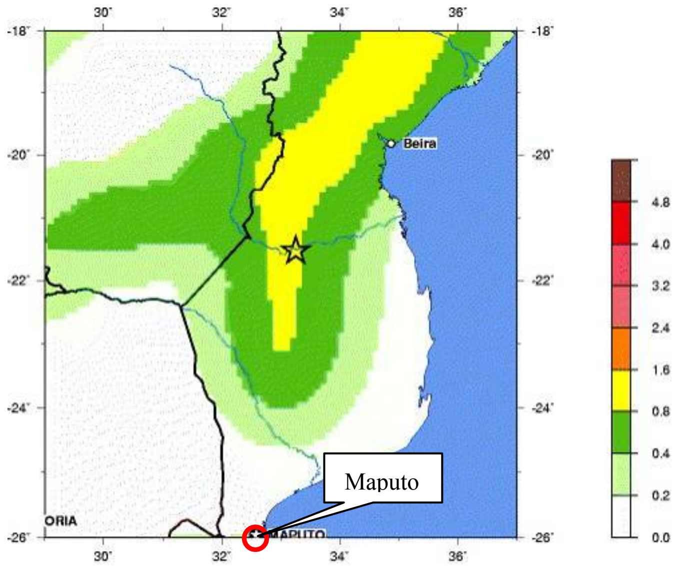
Figure 6.6-1 shows the distribution of earthquake epicenters in the Eastern and Southern African regions for the period 627–1994 for earthquakes with a magnitude stronger than 4.0. This figure reveals that major earthquakes have not occurred within a radius of around 200 km and only earthquakes with a mid-class magnitude (<7.0) have occurred within the radius of 300 km.

Furthermore, Figure 6.6-2 shows the distribution of the expected peak horizontal ground acceleration due to earthquakes, which have a 10% probability of occurring within the next 50 years in Mozambique. From this figure, it is obvious that Maputo city is situated in an area with a low risk of earthquakes and a peak horizontal ground acceleration of less than 0.2 g (200 gal).



(Source: Seismic hazard assessment in Eastern and Southern Africa, 1999)

Figure 6.6-1 Seismicity of Eastern and Southern African Regions



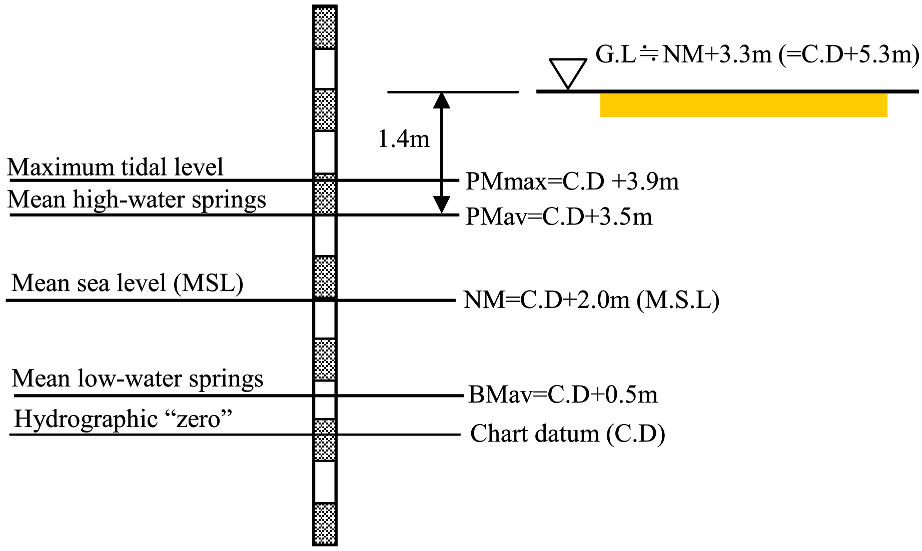
(Source: USGS)

Figure 6.6-2 Distribution of the expected peak horizontal ground acceleration (possibility of 10% within 50 years)

6.6.3 Design Conditions

(1) Ground Level

The average ground level of the site is approximately 3.3m above mean sea level ("M.S.L.") of Port Maputo. Figure 6.7-3 shows the relationship between tidal levels and the ground level of the site.



(Source: Prepared by JICA Study Team based on information obtained from INAHINA)

Figure 6.6-3 Relationship between tidal levels and ground level of the site

The maximum tidal level (PM_{max}) in the above is defined as "the maximum astronomical tide level that can be observed in normal weather conditions" and it does not mean the highest recorded tidal level. According to INAHINA, PM_{max} is usually observed in April.

Since the ground level is the elevation above MSL, the ground level of CTM has an allowance height of 1.4 meters above the maximum tidal level[2]. In general, a local decrease in surface air pressure over the ocean produces an increase in the sea surface of 1 cm per hPa. If a perfect coincidence of PM_{max} and extreme low pressure (i.e., brunt of a tropical storm) occurs, the expected rise in the sea surface is approximately 1.0 meters, which is still 0.4 meters lower than the ground level of CTM. Accordingly, it is not likely that CTM will be affected by storm surges.[3] Thus, it is not necessary to raise the ground level of the CTM site against storm surges.

[2] According to INAHINA, for planning and design of the facilities in port of Maputo, the planned ground plane is set at PM_{max}+0.5 m.
[3] According to INAHINA, the recorded maximum tidal level at Port Maputo is not more than C.D+5.0 m.

(2) Design Wind

Mozambique does not have its own building design code and usually follows the Portuguese design code or other international codes and standards for design of important structures and buildings.

The design wind speed for the Project shall be determined based on the past maximum wind speed records during tropical storms.

(3) Design Seismic Coefficient

As previously mentioned, Mozambique does not have its own building design code. According to the Uniform Building Code (1997), the seismic zone of Maputo city is categorized as "2A." Assuming the soil type of the site as "C_D (stiff soil profile)," the horizontal design seismic coefficient is estimated at 0.071, which corresponds to a horizontal acceleration of 71 gals. This concurs with the seismic hazard of 10% within 50 years for the site (less than 200 gal) as previously mentioned in Section 6.1-2.

(4) Design Rainfall Intensity

The National Directorate of Water (DNA) in the Ministry of Public Works and Housing stipulates the design standards of the storm water drainage system and sewerage. The following formula is provided to calculate the design rainfall intensity of Maputo city. This formula can be applied to the design of the storm water drainage system for the Project.

$I(mm/h) = a \times t\ (min)^b$

Where,

T: return period

I: rainfall intensity (mm/h)

a, b: constants (see the table below)

t: duration of rainfall (mm)

Table 6.6-1 Rainfall intensity for various return periods

T (year)	2	5	10	20	25	50
a	534.0468	694.504	797.3841	896.5751	930.8815	1026.694
b	-0.5075	-0.59383	-0.5869	-0.58197	-0.58119	-0.57749

(Source: Regulation of public systems for water supply and wastewater drainage (Decree 30/2003, 1. July; DNA, 2003))

In the above formula, assuming a return period of 50 years and a rainfall duration of 1,440 minutes (i.e., 24 hours), the rainfall intensity is estimated at 13.6 mm for a period of 24 hours, which corresponds to the total daily rainfall of 326 mm. It was found that this figure coincides with the recorded maximum daily rainfall observed on February 6, 2000. Accordingly, the return period of 50 years shall be adopted for design of the storm water drainage system of the Project.

6.6.4 Design of Foundations

(1) Selection of Foundation Type

Since foundation settlement should be avoided for the major equipment and structures, a pile foundation is basically adopted. In selection of the pile used in this Project, compatibility with soil condition on the site, past experience of construction in the region, market availability, etc. shall be taken into consideration. From the viewpoint of market availability, cast-in-place piles could be the most appropriate for this Project. Spread foundations could be used for pipe racks; however, the larger footing of spread foundations may cause interference with the other structures. Thus, the pile foundation is also recommended for pipe racks. For other miscellaneous structures and cable trenches, a spread foundation will be adopted.

Since the existing oil tanks and oil containment dykes interfere with the foundation of gas turbines, stacks, HRSGs, and pipe racks, they must be totally demolished and removed from the site before the foundation work starts. It is appropriate that the existing piles, which support the oil tanks, be buried after removal of oil tanks. Accordingly, the location of existing piles shall be surveyed before being buried and plotted on the drawings in order to avoid interference with piles for foundations of the equipment and structures.

(Source: EDM)

Figure 6.6-4 A photo showing installation of the existing oil tanks (in 1970s)

(2) Preliminary Study of Foundation Design

(a) Design conditions

Major design conditions are summarized in the following table.

Table 6.6-2 Design conditions

Item	Description
Design process and evaluation	1) The sectional design of the foundation is based on the allowable stress method. 2) A vibration analysis is conducted to ensure that the natural frequency of the foundation meets the requirements for vibrating machines (e.g., GTG, STG, etc.)
Soil conditions	Soil constants are estimated by using empirical formulas for cohesive soil based on N-values obtained from the soil investigation.
Loading conditions	The following loads are considered for design of foundations. 1) Machine load 2) Dead load (i.e., weight of concrete with a unit weight of 24 kN/m^3) 3) Seismic load
Allowable bearing capacity of pile	The allowable bearing capacity of cast-in-place pile is estimated by using the following empirical formula. - Long-term allowable bearing capacity: $R_a = 1/3 \cdot R_p + 1/3 \cdot R_f$ - Short-tem allowable bearing capacity: $R_a = 2/3 \cdot R_p + 2/3 \cdot R_f$ - Ultimate end bearing capacity: $R_p = 150 \cdot N \cdot A_p$ - Ultimate skin friction resistance: $R_f = 10/3 \cdot N_s \cdot L_s \cdot \varphi + 1/2\ q_u \cdot L_c \cdot \varphi$ Where, A_p: Effective sectional area at the tip of pile (m^2) N: Average N-value at the tip of pile Ns: Average N-value of sandy soil Ls: Contact length of pile with sandy soil (m) Φ: Peripheral length of pile (m) q_u: Unconfined compression strength of cohesive soil (kN/m^2), which is estimated by using the empirical formula, qu=12.5 N (<200 kN/m^2)[4]. L_c: Contact length of pile with cohesive soil (m)

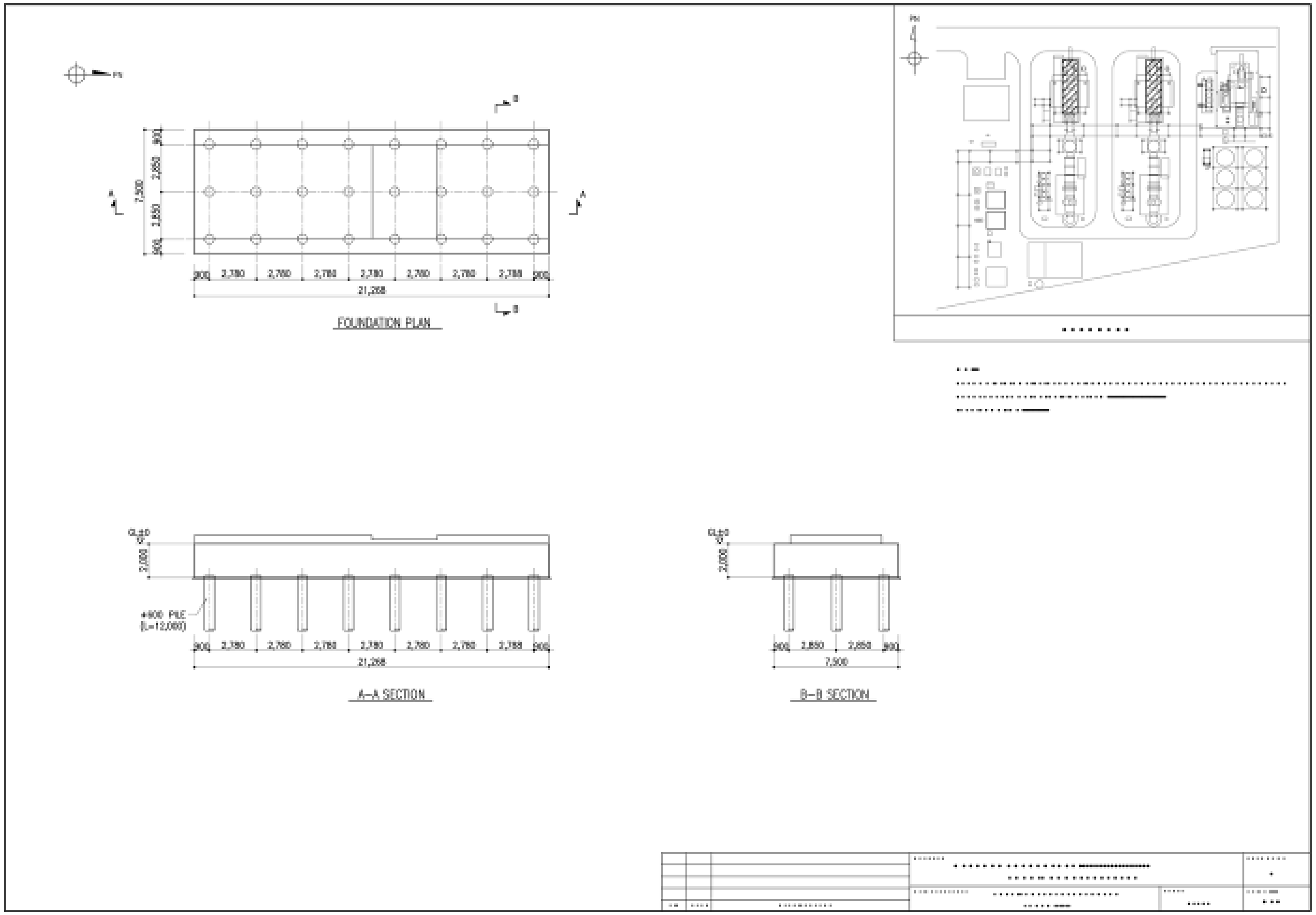
(Source: JICA Study Team)

(b) Results of study

For design of the vibrating machines (gas turbines and a steam turbine), the cross-sectional area of the foundation is determined based on the required dead weight of foundation against sympathetic vibration with equipment, as determined in the vibration analysis. For instance, the thickness of the mat foundation of a gas turbine is estimated at 2.0 meters, which is much bigger than the required foundation depth based on the static stress analysis and results in minimum reinforcement.

Figure 6.7-5 shows an outline drawing for the foundation of a gas turbine. The structural calculation sheet for the gas turbine foundation is contained in the Appendix of this report.

[4] Guideline for Structural Design of Foundations, Yokohama City.



(Source: JICA Study Team)

Figure 6.6-5 Outline drawing for foundation of gas turbine

6.6.5 Architectural Works

The specifications required for the major buildings for the Project are summarized in Table 6.1-2.

Table 6.6-3 Specifications of major buildings for the Project (draft)

Name of building	Specification
Steam turbine building	• The building is a steel frame structure equipped with overhead travelling crane(s) • Side walls are constructed with corrugated plates and steel plates and roof structures are constructed with steel truss • Windows and louvers provided for ventilation purposes • Structures to be designed for a lifetime of 20 to 30 years
Control building	• The building is a reinforced concrete structure • The walls are constructed with bricks with holes, cement blocks or concrete • An air conditioning system shall be provided in the majority of rooms
Workshop	• The building is basically of one span and one story • Steel frame structure equipped with a crane
Warehouse	• Specification are the same as the workshop

(Source: JICA Study Team)

6.6.6 Storm Water Drainage System

As explained in Section 5.1.1 of this report, since the embankment of the highway located to the north acts as a topographic divide, rain that falls on the north side of the highway does not flow in the direction of CTM. In addition, since drainage channels with sufficient capacity have been provided on both sides of the railway embankment, there is little chance that storm water will flow into the CTM site from the outside (see the left-hand photos in Figure 6.6-6 and Figure 6.6-7).

On the other hand, there is no appropriate drainage system in CTM. This is considered to be the major cause of the flood damage that occurred in the No.1 GT and No.2 GT buildings when torrential rain hit Maputo city on February 6, 2000.

Since the No.1 GT and No.2 GT buildings are located in a relatively lower area in CTM where rainwater tends to gather, storm drains are provided in this area. However, periodical maintenance of storm drains is seemingly not done and the opening of the storm drain nearest the No.1 GT building was completely clogged with soil (see the right-hand photo in Figure 6.6-6). Furthermore, the drainage pipe (φ300 mm) is not exposed at the end point but is apparently buried in the ground. Thus, it is obvious that storm water in CTM is not properly discharged when heavy rain occurs.

(Source: JICA Study Team)

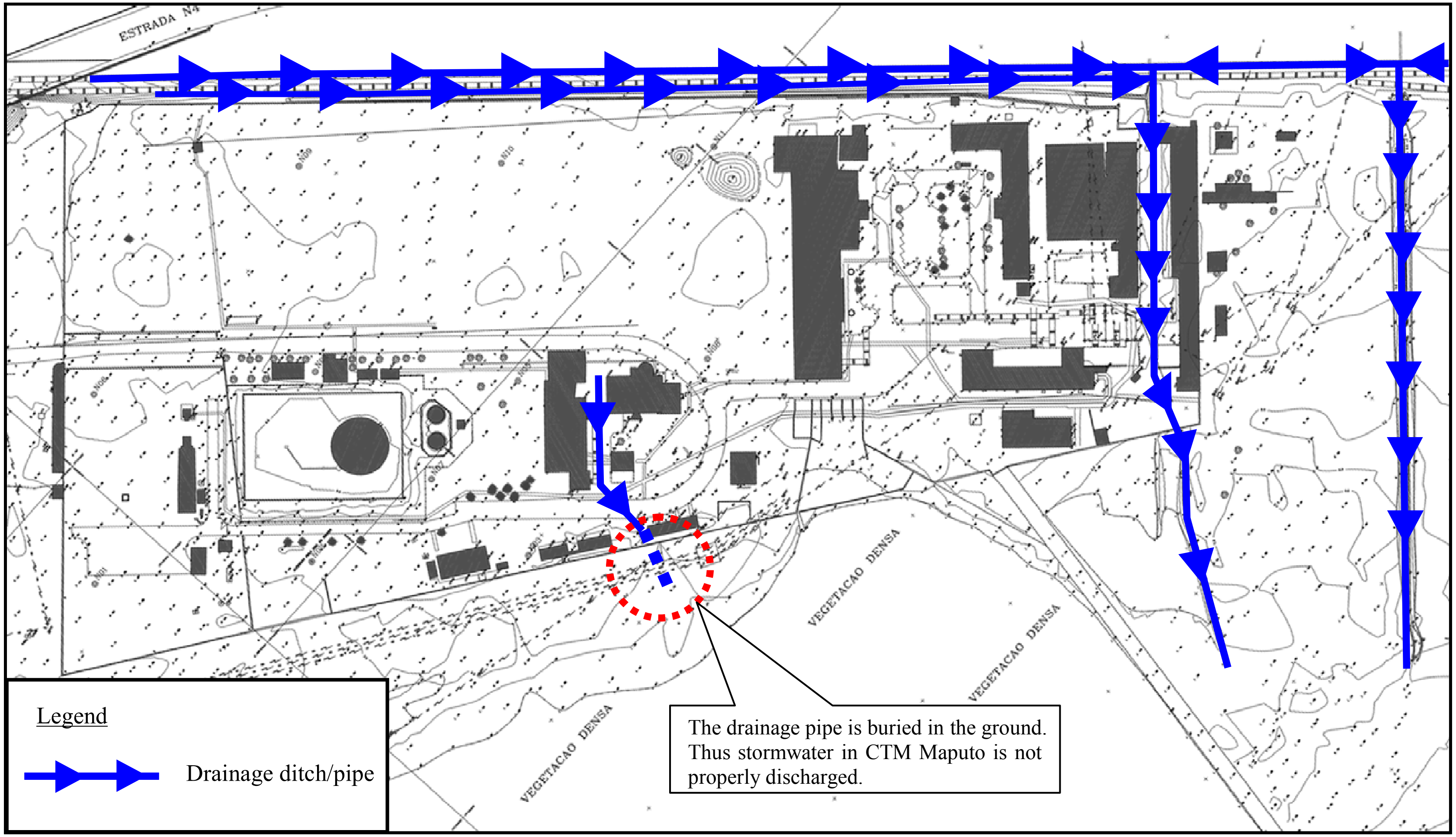
Figure 6.6-6 A drainage channel parallel to railway (70 cm wide) and a storm drain in CTM

The floor level of GT buildings is set at almost the same level as the ground level of the surrounding area; thus, it may contribute to flood damage in GT buildings. In fact, no flood damage occurred in the canteen, which is situated close to GT

buildings but whose floor level is set at approximately 20 cm higher than the ground level of the surrounding area.

In conclusion, a new storm water drainage system with sufficient capacity in accordance with the design rainfall intensity (50-year return period) shall be established in CTM. In planning and design of the storm water drainage system for CTM, the following basic design policy shall be considered:

- The catchment area shall be divided into two by the existing road that runs in the east-west direction.
- Open ditches shall be used as practicably as possible in order to facilitate easier maintenance of the drainage system.
- Inverted siphons shall be used to convey storm water across existing cable trenches. The diameter of the inverted siphon pipes shall be at least 800 mm for easy maintenance.
- An oil separator shall be provided at the end point of each drainage system.



(Source: JICA Study Team)

Figure 6.6-7 Existing drainage system in and around the CTM

Chapter 7

Natural Gas Supply Plan

Chapter 7 Natural Gas Supply Plan

7.1 Overview of Natural Gas in Mozambique

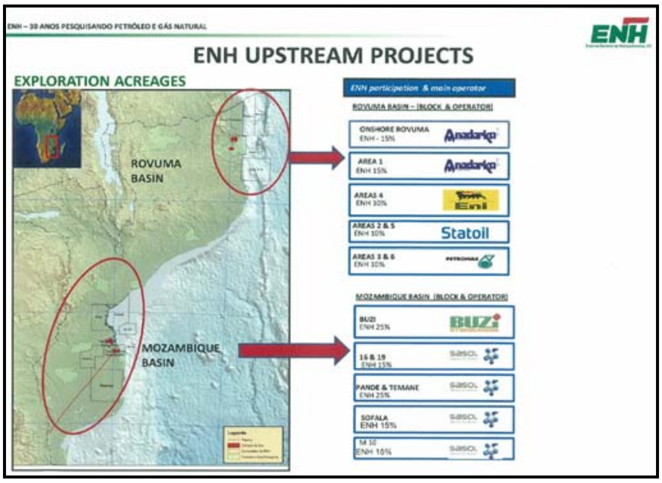
At present, Mozambique has two gas fields: one in the Rovuma Basin of Cabo Delgado province in the north and the other in the Mozambique Basin of Inhambane province in the south. Their locations are illustrated in Figure 7.1-1

In the Mozambique Basin, gas was first found in the Pande area in 1961, then in the Buzi area in 1962, followed by the Temane area in 1967. After that, natural gas development has been sluggish since the 1970s due to the absence of demand and political instability in Mozambique. In 2003, gas was found in the Inhassoro area, and natural gas development was promoted by the enactment of the Petroleum Law (3/81) and establishment of the Mozambican National Hydrocarbon Company ("ENH") since the 1990s. Since the mid-1990s, Production Sharing Agreements ("PSA") and Engineering, Procurement and Construction (contracts) ("EPC") have been signed with international oil developers (Arco in 1997, BP in 1998, and Sasol, Petronas, Hydro and DNO in 2000 and onward). Thus, natural gas development has been promoted, including the construction of gas pipelines going to South Africa by Sasol.

In the Rovuma Basin, tenders for development licensing have been invited since 2005. As a result, development and licensing agreements were signed with global developers such as Anadarko (U.S.A.), ENI (Italy), Petronas (Malaysia) and Artumas (Canada). Since then, natural gas development has been promoted.

In the Pande and Temane areas in the Mozambique Basin, natural gas sources have been developed and natural gas has been produced under a Petroleum Production Agreement ("PPA") between Sasol Petroleum Temane and ENH.

In 2004, the first commercial production was initiated in the Temane area. In 2009, production started in the Pande area.



(Source: ENH)

Figure 7.1-1 Gas Fields in Mozambique

The following table lists the development and production areas with developers and producers in the Rovuma Basin and Mozambique Basin.

Table 7.1-1 Development and Production Areas in the Rovuma Basin and Mozambique Basin

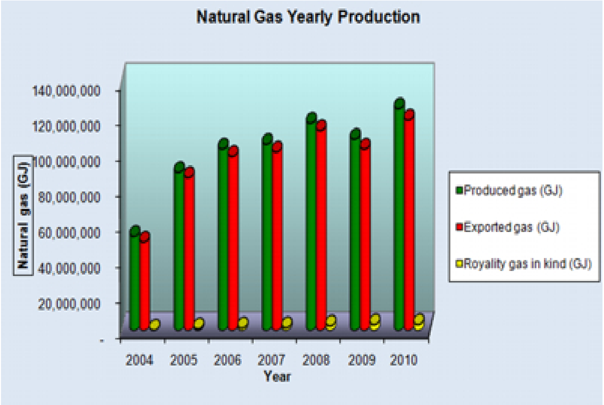
Rovuma Basin	
Block	**Partners**
Onshore Rovuma	Anadarko (35.7%), Wentworth (15.3%), Maurel & Prom (24%), ENH (15%), Cove Energy (10%)
Area 1	Anadarko (36.5%), Mitsui (20%) ENH (15%), Bharat Petroleum Corporation (10%), Videocon Energy Resources (10%), Cove Energy (8.5%)
Area 4	Eni (70%), ENH (10%), Galp (10%), Kogas (10%)
Area 2 & 5	Statoil (90%), ENH (10%)
Area 3 & 6	Petronas (90%), ENH (10%)
Mozambique Basin	
Block	**Partners**
Pande - Temane	Sasol (70%), ENH (25%), IFC (5%)
16 & 19	Sasol (50%), Petronas (35%), ENH (15%)
Sofala	Sasol (85%), ENH (15%)
M10	Sasol (42.5%), Petronas (42.5%), ENH (15%)
Buzi	Buzi Hydrocarbons (75%), ENH (25%)
Area A	Sasol (90%), ENH (10%)

(Source: ENH)

According to available data, reserves of natural gas in Mozambique are 4.8 to 8.8 trillion cubic feet (“TCF”) in the Mozambique Basin and 52.5 to 110 TCF in the Rovuma Basin. There are several sources of data showing recoverable reserves, which lie in the range of 5.504 to about 10 TCF, 7% of which have already been found. The area-wise recoverable reserves in the Mozambique Basin are 2.321 to 2.7 TCF in the Pande area, 0.618 to 1.0 TCF in the Temane area and 14 billion cubic feet (“BCF”) in the Buzi area.

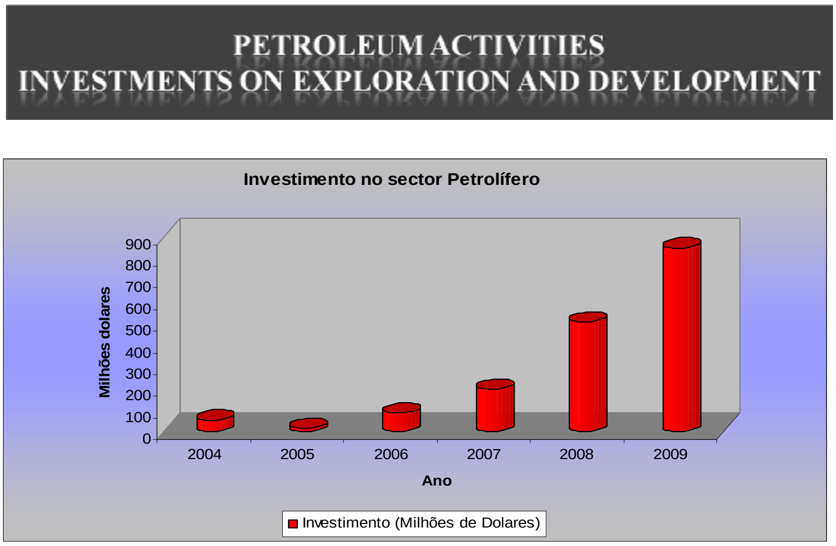
Current production volume in Mozambique is approximately 130 million gigajoules (“MGJ”) per annum from the Pande and Temane areas of the Mozambique Basin. More than 95% of the gas produced is sent through the 865 km-long pipeline to South Africa, and is consumed in a Sasol factory. Approximately 3 MGJ is consumed in Mozambique per year (i.e., approximately 3 MGJ per annum in the Matola area (by Mozal and others) and 0.3 MGJ each year in the Vilankulo and Inhassoro areas close to a gas field (80% of which is for EDM power generation).

Figure 7.1-2 shows yearly gas production in Mozambique and Figure 7.1-3 shows investment in the oil and gas sector.



(Source: Instituto Nacional de Petroleos ("INP", in English – National Petroleum Institute)

Figure 7.1-2 Yearly Gas Production in Mozambique



(Source: Ministry of Mineral Resources ("MMR"))

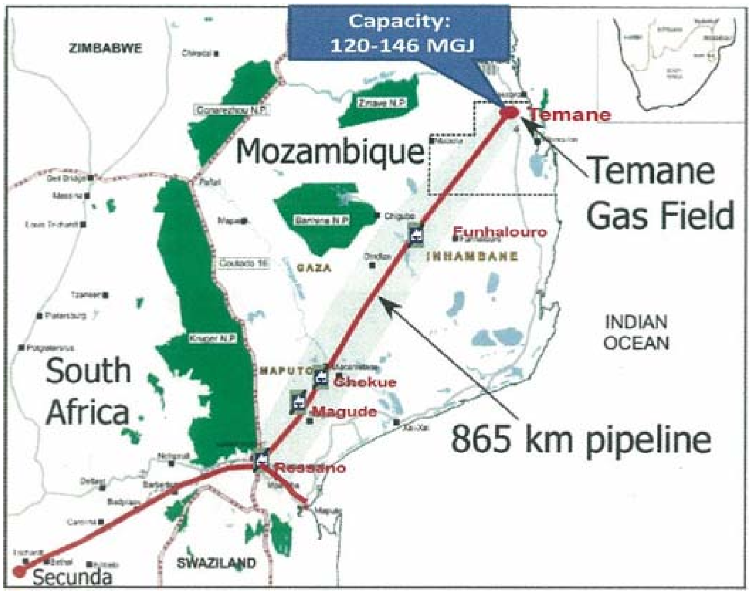
Figure 7.1-3 Investment in the Oil and Gas Sector

7.2 Gas Supply in the South

7.2.1 Gas Production Volume and Route

In 2004, a gas pipeline leading from the Pande and Temane gas fields of Mozambique to Secunda of South Africa (ROMPCO pipeline, where a 50% interest is owned by the Government of Mozambique (ENH) and the Government of South Africa (iGas), and the remaining 50% interest by Sasol of South Africa) was constructed and was put into commercial operation (refer to Figure 7.2-1). This pipeline has a total length of 865 km with a diameter of 660 mm. The current gas feed capacity is approximately 150 MGJ per annum, which can be increased to 240 MGJ per annum by installation of additional compressor stations. The production volume in the Pande and Temane gas fields for fiscal 2011 (July 2010 to June 2011) was approximately 130 MGJ per annum. According to the MMR report of January 2012, the production volume for 2012 is anticipated to reach the level of 149 MGJ per annum. The pipeline from the Pande and Temane gas fields to Secunda is provided with five takeoff points (also called tap-off points) in Mozambique; however, only the Ressano Garcia takeoff point of Maputo province was working as of 2011, and in the current stage, a detailed usage plan of the Chokwa takeoff point is being developed.

In 2006, construction of a pipeline was completed from the takeoff point of Ressano Garcia close to the national boundary with South Africa to Matola city. This pipeline is currently in commercial service. This pipeline is run by the Matola Gas Company ("MGC"), established as a joint venture between ENH and private capital. The current gas demand in Matola city comes mainly from the Mozal aluminum smelter plant and Ciementos de Mozambique (cement plant), and amounts to approximately 3 MGJ per annum. This demand is expected to grow due to a firm increase in the future demand for switching from petroleum over to gas in the Industrial Park in the suburbs of Maputo city (Vidreira (glass industry) and CDM (beverage manufacturer)), and due to the gas demand for household (residential) use and for power generation.



(Source: ENH)

Figure 7.2-1 Temane–Secunda Gas Pipeline Route

7.2.2 Gas Supply Volume

Extension work of the central processing facility ("CPF") at the Pande and Temane gas fields has already been completed in 2012 and the gas supply volume of the ROMPCO gas pipeline has also been increased from 120 MGJ/year to 183 MGJ/year.

The maximum gas supply volume of the ROMPCO gas pipeline is 240 MGJ/year. The pipeline still has a surplus capacity of 57 MGJ/year since the expansion work was completed. However, further expansion work is not planned.

<u>Gas Sales Agreement One ("GSA 1")</u>

1) 120 MGJ per annum (for South Africa)

<u>Gas Sales Agreement Two ("GSA 2")</u>

2) 27 MGJ per annum (for South Africa)
3) 27 MGJ per annum (for domestic power generation and other consumers (residential, commercial, industrial and natural gas vehicle ("NGV"))

<u>Royalty paid to the Government of Mozambique</u>

4) Approx. 9 MGJ per annum (= 120 x 5% + (27 + 27) x 6%)

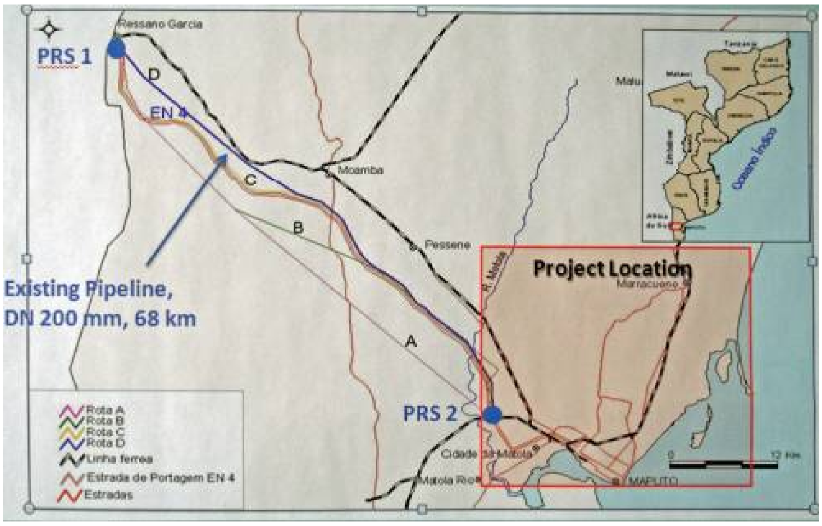
Total: 183 MGJ per annum

The Government of Mozambique retains the right to receive approximately 9 MGJ per annum as royalties in 2014 and onward; the volume currently received (amount of gas consumed domestically) amounts to 3 to 4 MGJ per annum (with the remainder received in cash). In the National Strategy for the Development of the Natural Gas Market in Mozambique (Resolution No. 64/2009) published in 2009, the Government of Mozambique expressed a plan to supply, on a priority basis, royalty gas to the projects that would contribute to economic development in Mozambique and whose profitability cannot easily be ensured on a purely commercial basis.

The gas volume for domestic power generation described in 3) above is broken down into: (1) 6 MGJ per annum for power generation for EDM and other consumers (residential, commercial, industrial) and NGV, (2) 11 MGJ per annum for power generation for an IPP at Ressano Garcia (by Gigawatt-Mozambique), and (3) 10 MGJ per annum for another IPP at Ressano Garcia (by Sasol New Energy and EDM). At present, there are ongoing negotiations between ENH and EDM on the agreement for the supply of the above-mentioned 6 MGJ per annum.

7.2.3 Gas Supply Route in the South

Gas is branched off at the Pressure Reducing Station ("PRS 1") at Ressano Garcia, where the gas pressure is reduced from 100 to 40 bars, and is fed to the Pressure Reducing Station ("PRS 2") located in Matola city, where the pressure is further reduced to 10 bar. After that, gas is supplied to users in Matola city. Figure 7.2-2 illustrates the existing pipeline route.



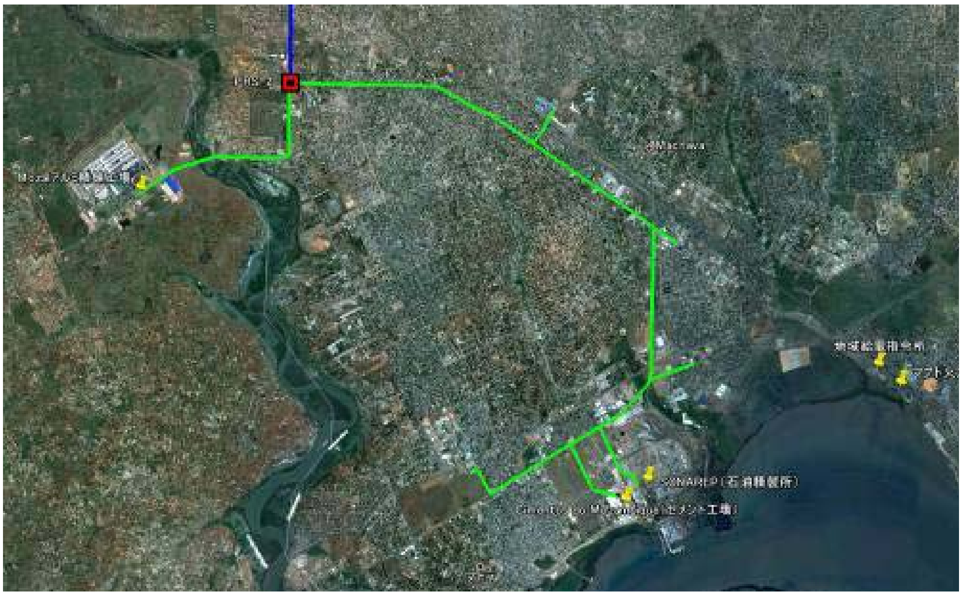
(Source: ENH)

Figure 7.2-2 MGC Gas Pipeline Route

The following are the basic specifications of the pipeline from Ressano Garcia to the PRS 2.

1) Pipe diameter: 8" (200 mm)
2) Total length: Approx. 68 km
3) Gas feed capacity: 40,000 m^3/h at 25°C, 1 atm (currently in operation at 12,000 m^3/h)
4) Maximum allowable gas pressure: 70 bar (currently in operation at 40 bar)

At present, 10-bar gas is supplied from the PRS 2 of Matola city to gas users through a 22 km-long piping network. Most (92%) of the gas supplied is consumed by the Mozal aluminum smelter plant and Ciementos de Mozambique (cement plant). Figure 7.2-3 illustrates the existing gas pipeline network in Matola city.



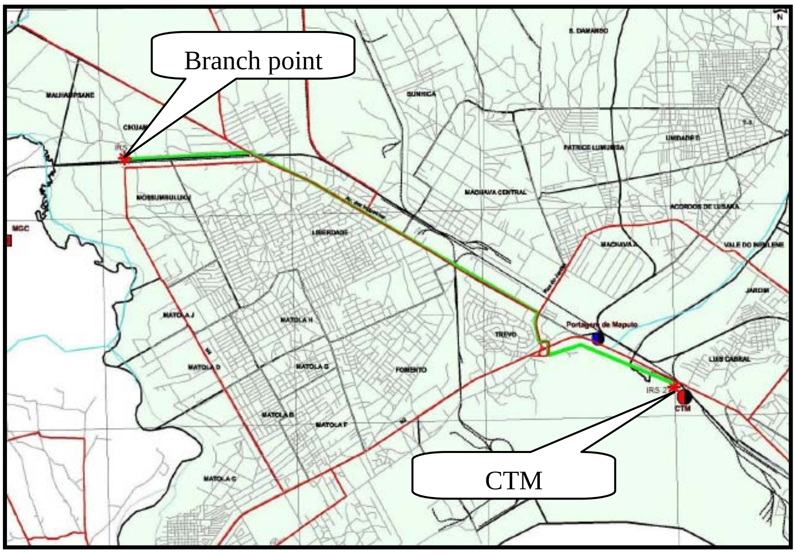
(Source: Prepared by the JICA Study Team based on ENH data)

Figure 7.2-3 Existing Gas Pipeline Network (green) in Matola City

It has been decided that ENH and KOGAS will jointly implement the natural gas pipeline project in the Matola area. The preparation work for the project has already started (see Figure 7.2-4). Gas pipeline work will begin from March 2013 and will be completed by January 2014. Since EDM has confirmed that this project includes pipeline work to CTM site, it is not necessary to include the pipeline work to the new Maputo power plant in the Japanese ODA project. In this case, gas pressure in the MGC pipeline upstream will be decreased from 40 to 25 bars to meet the increase in gas demand by laying new pipeline. Figure 7.2-4 illustrates the new pipeline route (from the branch point situated 1.8 km upstream of the existing PRS-2 to CTM site) and Figure 7.2-5 illustrates the gas pipeline route near the CTM site and the location of a new pressure reducing station in CTM site.

(Source: EDM)

Figure 7.2-4 Preparation Work of New Pipeline Linking MGC Pipeline and CTM (ENH/KOGAS)



(Source: ENH)

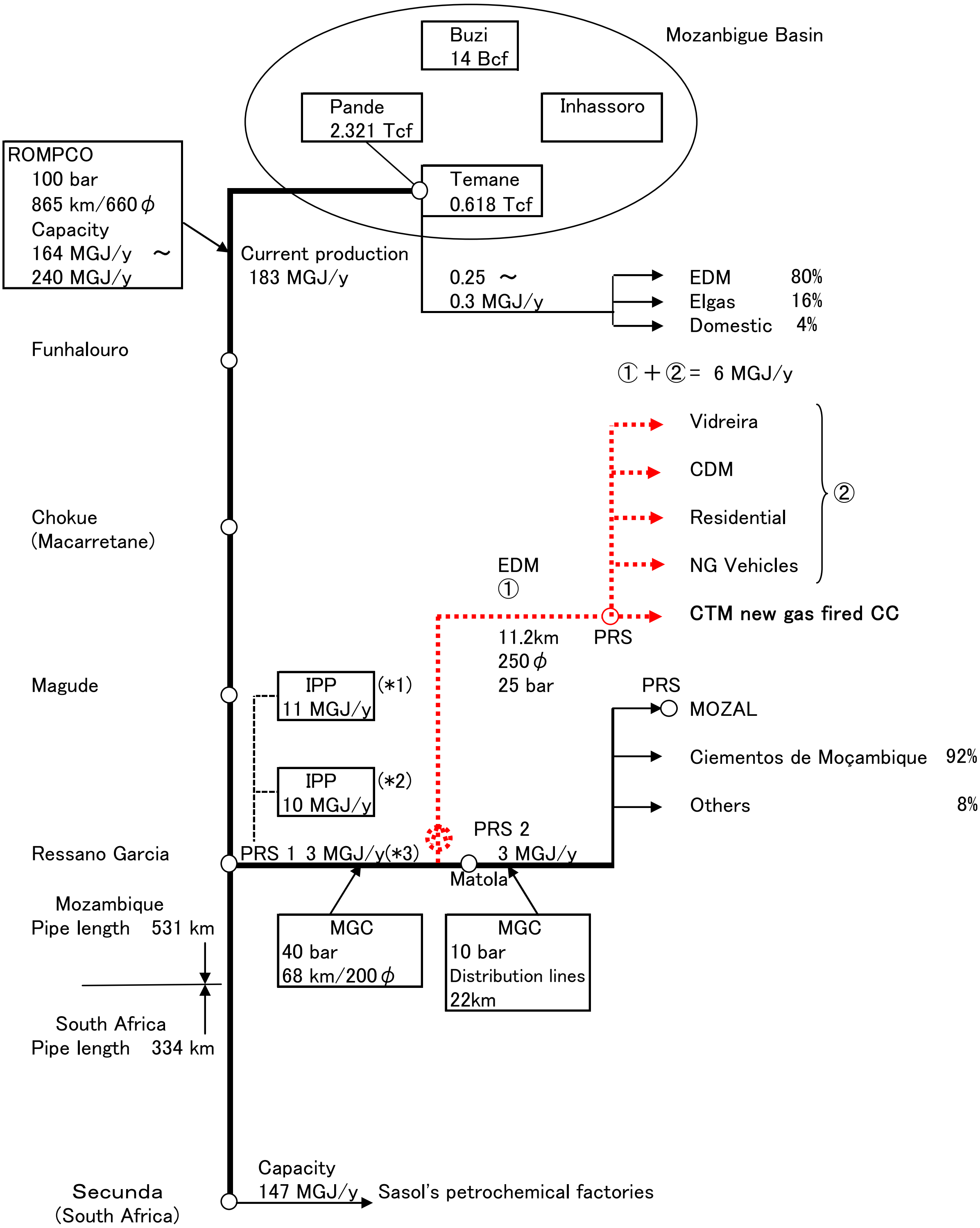
Figure 7.2-5 Route of New Pipeline Linking MGC Pipeline and CTM (ENH/KOGAS)

(Source: ENH)

Figure 7.2-6 Pipeline Route near CTM and Location of Pressure Reducing Station in CTM

7.2.4 Gas Supply Volume to the Gas-fired Thermal Power Plant in the Southern Region

Gas for the new gas pipeline mentioned above is planned to supply gas to the power plants owned by EDM and customers in Maputo city. It is expected that the available gas volume would be 6.0 MGJ/year (2.8MGJ/y for CTM and 3.2MGJ/y for Beluluane) However, it is confirmed that gas of 5.8 MGJ/y will be supplied to EDM in contract agreement. Figure 7.2-7 shows the overall gas flow schematic in the Southern region. The broken line indicates the pipeline to be installed in the future. The values enclosed in parentheses indicate the future gas volumes.

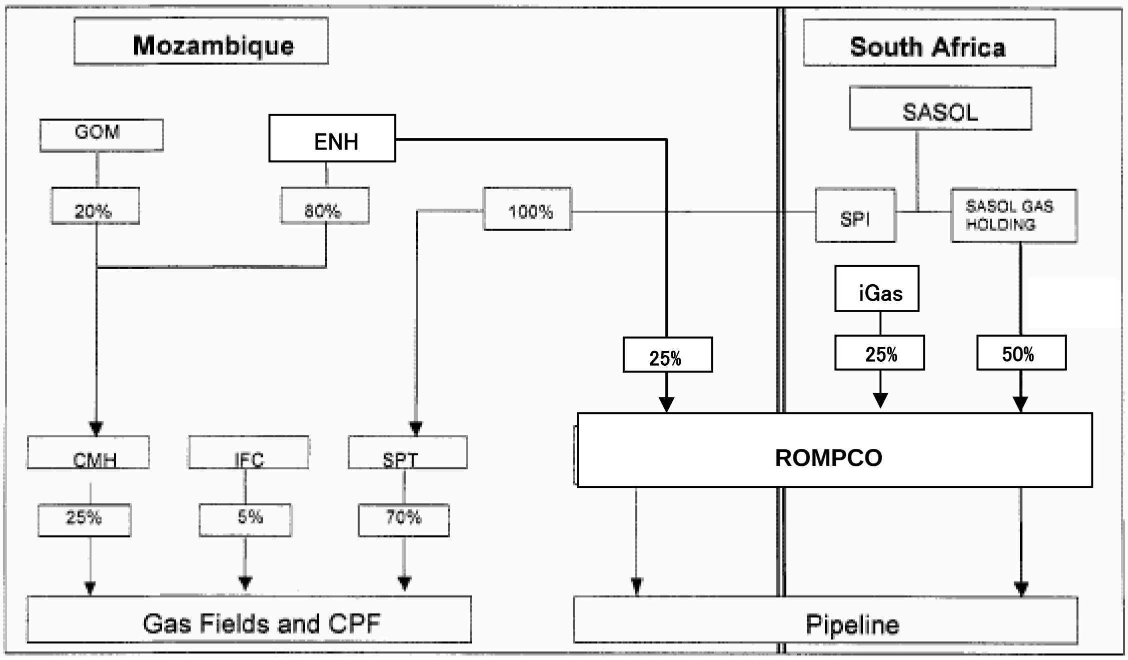


(*1) IPP at Ressano Garcia by GigaWatt-Mozambique
(*2) IPP at Ressano Garcia by Sasol New Energy and EDM
(*3) Current consumption rate
(*4) Refer to 4.3.3 (2)

(Source: Prepared by the JICA Study Team based on information and data obtained from ENH)

Figure 7.2-7 Overall Gas Flow Schematic in the Southern Region

Figure 7.2-8 shows the organization structure for gas production and pipeline operations of Pande-Temane Gas Fields.



(Source: World Bank)

Figure 7.2-8 Organization Structure for Gas Production and Pipeline Operations of Pande-Temane Gas Fields

7.3 Gas Price

EDM is now negotiating with Maputo Gas Company ("MGC") about a gas supply agreement and with ENH about a gas transportation agreement. It seems that both contracts will be made by March 2013.

Gas price is assumed to be 5.6 USD/MGJ for CTM and 5.2 USD/MGJ for Beluluane. The difference of gas prices between CTM and Beluluane is the length of the gas pipeline.

Gas prices are calculated based on the below table.

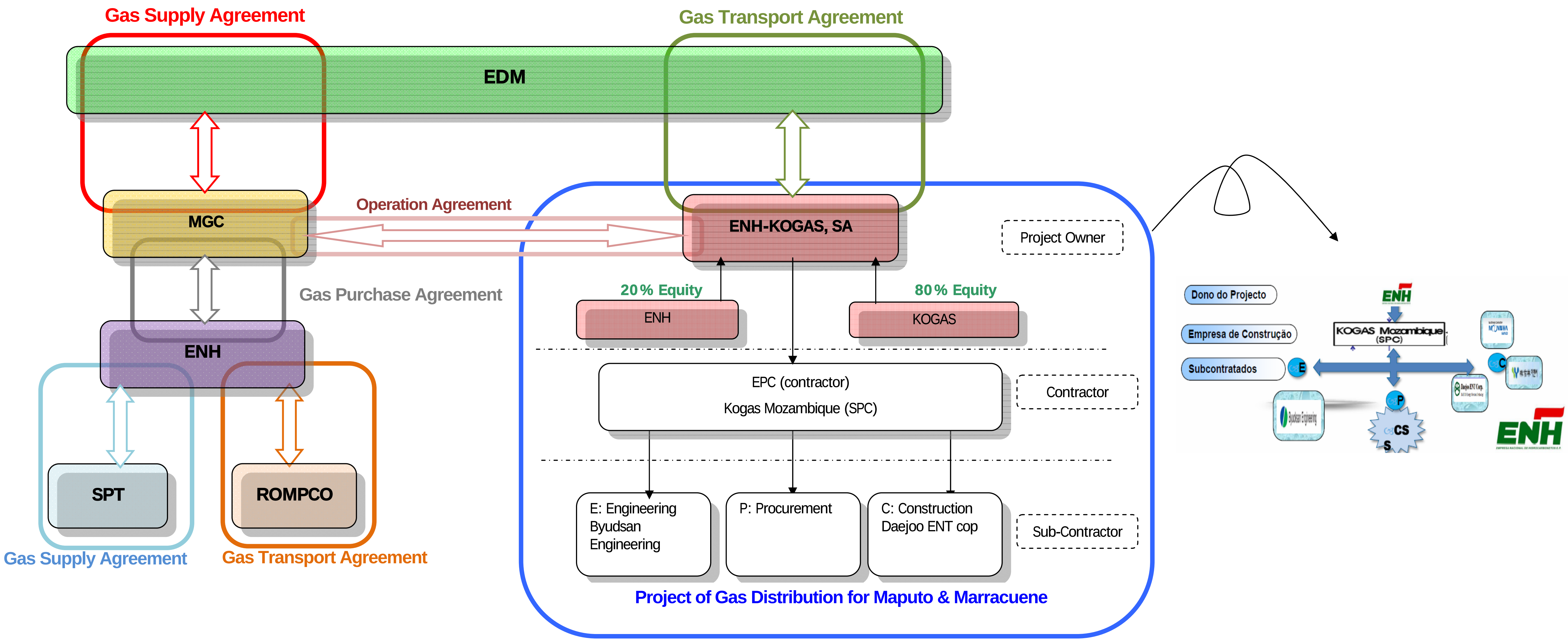
Table 7.3-1 Gas Price Structure

Preço Base do Gás Natural em Maputo, 2012/ Base price for natural gast in Maputo, 2012	
	USD/GJ
Preço à Boca do Poço/ Price straight from the pit	1,60
Tarifa de Processamento CPF/Processing tariff CPF	0,89
Tarifa de transporte ROMPCO/Transportation Tariff ROMPCO	1,25
Sub total, (em Ressano Garcia)/Sub total (at Ressano Garcia)	3,74
Tarifa Transporte MGC/Transportation tariff MGC	0,90
Tarifa de Transporte Novo Gasoduto ENH/Transportation tariff new gas pipeline	0,96
Preço Base (em Maputo) /base price (at Maputo)	5,60

(Source: EDM)

7.4 Relationship of Relevant Organization related to Gas Supply and Transport Agreements

Figure 7.4-1 shows the relationship of the relevant organizations related to the gas supply and transport agreements.



Note:

ENH-KOGAS, SA (new company 30% ENH + 70% KOGAS from Korea): It will transport 5.8 MGJ/y of gas from Matola to Maputo & Marracuene via CTM and will tap the existing MGC pipeline in Matola

Empresa National de Hidrocarbonetos, EP (ENH) – Public company and arm of the government in the petroleum sector which has the allocation of 6 MGJ/y for EDM Power Generation at CTM and for Maputo and Marracuene

Korea Gas Corporation ("KOGAS") – One of the world's largest LNG importers, executing with ENH a new project for the construction of a gas pipeline and operating facility to supply gas to Maputo and Marracuene using the build-operate-transfer ("BOT") method

Kogas Mozambique: New Mozambican company and KOGAS have majority equity and acting as an EPC company for the construction of the new ENH-KOGAS, SA pipeline from Matola to Maputo and Marracuene

Matola Gas Company, SA ("MGC"): . Private company, has the pipeline from Ressano Garcia to Matola, and provides around 3 MGJ/y to the industrial area at Beluluane and Matola area and will supply 5.8 MGJ/y to EDM

Sasol Petroleum Temane Limitada ("SPT"): Responsible for production activities from the Pande and Temane field reservoirs

Rompco: Has the pipeline property from Temane to Secunda in South Africa and provides five take-off points in Mozambique and only Ressano Garcia Take-off point working at the moment

(Source：EDM)

Figure 7.4-1 Gas Supply & Transport Concept to EDM

7.5 Scope of Gas Pipeline Work and Tie-in Point

As mentioned in the previous item, the gas pipeline works and pressure reducing stations ("PRSs") are the scope of supply of ENH/KOGAS. The tie-in point at PRS in CTM between EDM and ENH/KOGAS is an outlet valve of PRS in CTM.

Currently, the gas pressure at PRS of CTM is approximately 25 bar. In this case, it is not necessary to treat gas for GT through PRS because the required gas pressure at the GT nozzle inlet is 40 bar for LM6000 and 26 bar for H25, respectively. After PRS, a gas compressor should be installed to boost gas to the required gas pressure. In the meantime, if gas will be tapped before PRS2 and gas with more than 60 bar gas pressure is obtained, it is not necessary to install a gas compressor after PRS in order to reduce gas pressure.