6. Improvement of Distribution System

Western Area network has a lot of weak points because of not only old facilities but also insufficient planning, rehabilitation and maintenance.

Considering present situation of the system, this master plan shall be divided into three terms, i.e. the short, medium and long terms.

Especially, in the short term, the aim is the urgent rehabilitation of existing facilities and the main objectives are to secure the power supply to consumers and to improve old facilities.

① Current Situation of Distribution System (6.1)
STEP-1：Study of Current Situation
■ Data collection (specification of distribution facility, quantity, faulty condition, etc.)
■ Operation and maintenance conditions (fault and repair information of the system)
■ Demand on major distribution station (load current, voltage, power factor, etc.)
STEP-2：Preparation of Preliminary Database for Distribution Network
■ Facility Register (11/ 33 kV lines, transformer, Ring Main Unit (RMU))
■ Related documents (single line diagram of the system and S/S, location and route map)
STEP-3：Preliminary System Analysis to the end of 2008
■ Demand study at major distribution stations
■ Preparation of system diagram
■ System analysis (Voltage drop and energy losses)
■ Obstruction of weak points and countermeasures
② Basic Policy (6.2)
■ Development plan in Western Area (infrastructural, industrial, housing, etc.)
■ Consideration of countermeasure to the current system
■ Improvement of distribution system
➢ Securing of a safe and economical system
➢ Promotion of rural electrification
➢ Establishment of optimal distribution system
③ Demand Forecast and Distribution Network (6.3)
■ Demand forecast at major distribution stations
■ Preparation of preliminary system diagram and route map for 2015/2020/2025
④ System Analysis (6.4)
■ Outline of analysis and preparation of data
■ System analysis on year 2015/2020/2025
■ Results and Conclusion
⑤ Optimal Distribution System (6.5)
■ Recommendations for the system in 2015/2020/2025
■ Projects for rehabilitation, reinforcement and expansion of distribution network
■ Project cost for rehabilitation, reinforcement and expansion of distribution network
⑥ Recommendations (6.6)
■ Recommendations for planning and O&M of distribution network
■ Recommendations for transmission and distribution system (10.2.2)

[Source] JICA Study Team

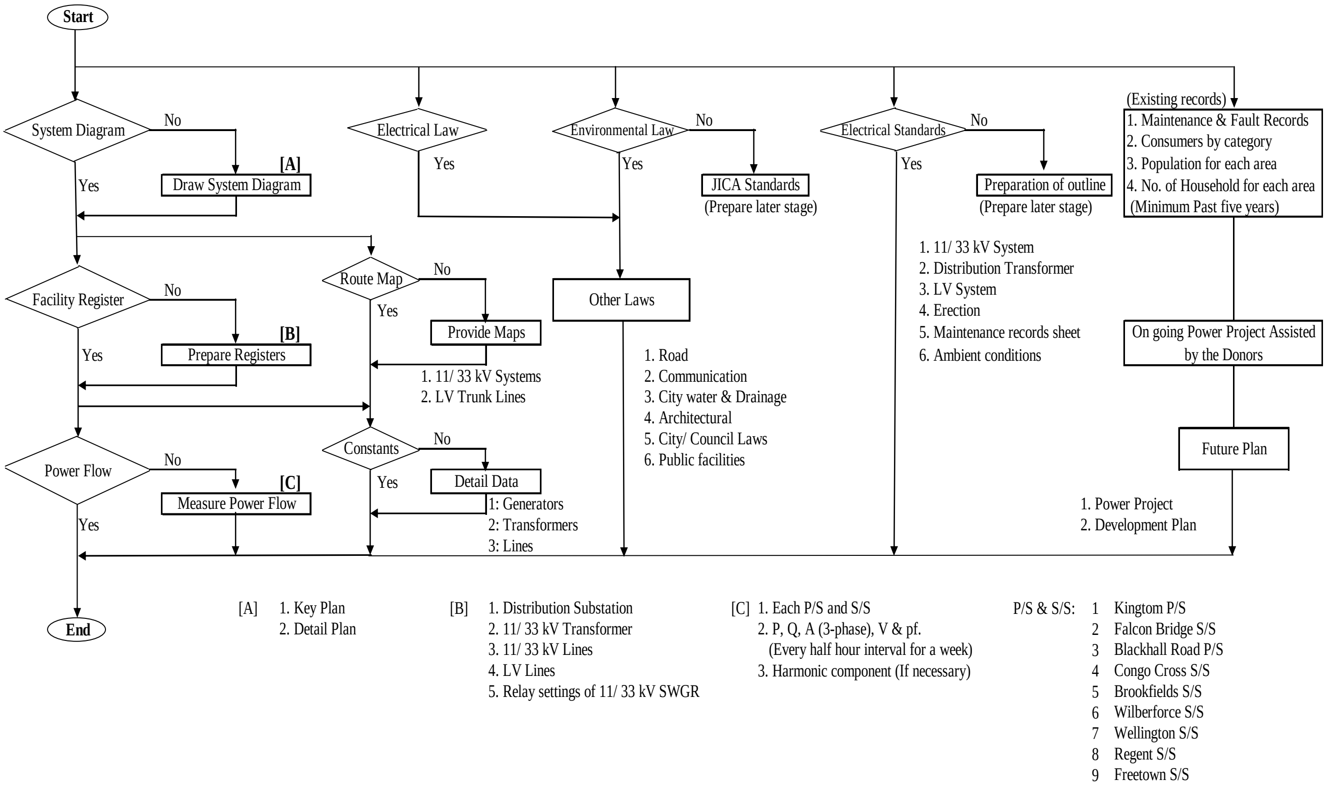
6.1 Collection of Data

(1) Current Status of Distribution Facilities

Since there are not enough existing data, data on existing facilities such as generators, transformers and lines are collected based on the detailed work flow shown in Fig. 6.1-1. These facility data are summarized as the preliminary facility registers shown in Chapter-2 of Supplemental Volume-1.

Location of facilities and 11 kV line route shall be provided considering existing data and latest information shown in item-3 of the Appendices in this volume.

Regarding constants for generators, transformers and lines which are necessary to conduct system analysis, these are also investigated and shown in item 6.7 with some assumptions, and the constants of future facilities are adopted as ordinary values.



[Source] JICA Study Team

Fig. 6.1-1 Work Flow of Data Collection

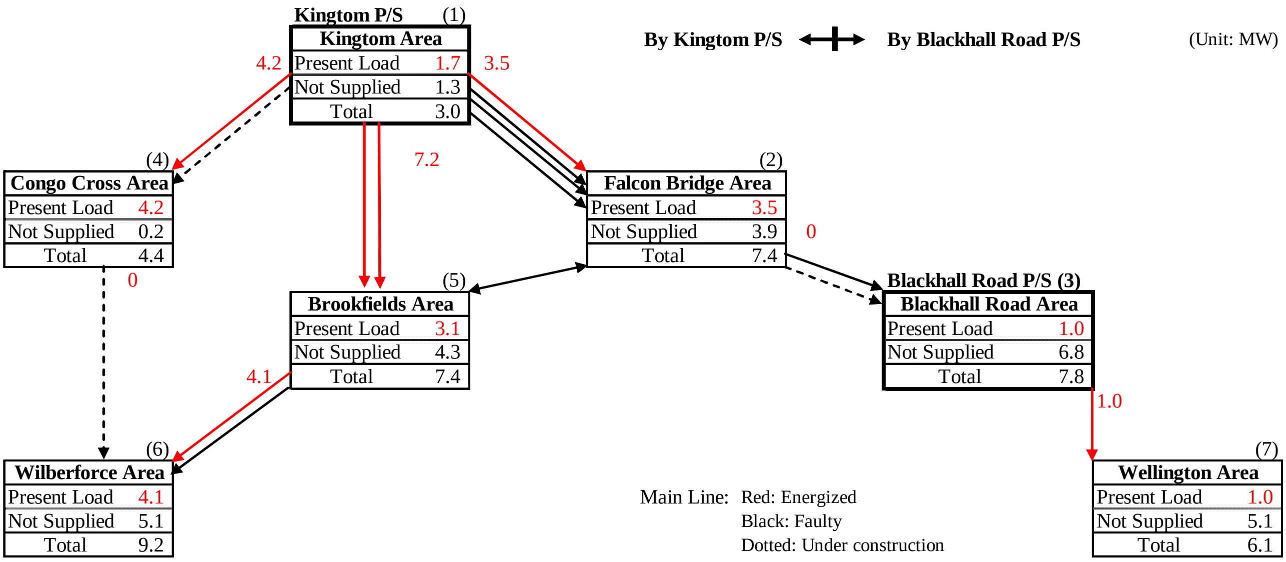
(2) Demand at the End of 2008

The 11 kV power supply system in Western Area can be divided into seven (7) major power distribution stations. Power flow on 11 kV network as of the end of 2008 is estimated considering; (i) actual measurement of current at major substations, (ii) capacity of transformers connected to each feeder, and (iii) records of peak load on each feeder.

The peak demand is adopted as residential because the peak demand was recorded at night time.

There are two independent power supply sources in Western Area: One is Kingtom P/S and the other is Blackhall Road P/S but these are not synchronized.

The estimated maximum power demand is 45.3 MW at the end of 2008 and flow, assuming power factor to be 0.9, is shown in Fig. 6.1-2.



Remarks:
1) Estimated Power Factor: 0.9
2) Not Supply: **26.7** [MW]
3) Total Load: **45.3** [MW]
4) Arrow shows power flow and No. of 11 kV main line which capacity is about 5 MW.
5) Red numerical values are present peak load on each area. Therefore, time difference shall be considered for the study of actual system demand.
6) Black numerical value shows the power which can not supply because of load sharing.

[Source] JICA Study Team

Fig. 6.1-2 Power Flow on 11 kV Network in 2008

(3) Analysis of Existing System

The existing distribution system at the end of 2008 is operated with emergency conditions far from the normal system, i.e. shortage of power supply and temporary power supply route because of line faults. However, to find out existing weak points and abstraction of policy, it is necessary to conduct preliminary study.

Considering Fig. 6.1-2, Falcon Bridge is an important station which distributes power to the centre of Freetown and also to major commercial areas and there are four weak points for voltage drop located at the end of 11 kV radial systems. Preliminary system analysis is applied to the following five points which are shown by red letters in Fig. 6.1-3.

① Falcon Bridge S/S,
② Lakka No. 2,
③ Cape Sierra,
④ Guma pumping station, and
⑤ Waterloo.

1) Assumptions and conditions

Assumptions and conditions to be used for the preliminary system analysis are as follows;

① Assume the load by connected transformer capacity on each line based on the field investigation and information by NPA,
② The peak demand is assumed to occur during night time when residential electricity consumption is dominant based on the daily load curve in 2002 when all DEG units at Kingtom P/S were available,
③ Power factor is selected considering actual measurements at Kingtom and Blackhall Road

P/S as 0.9 and 0.8 respectively and sending voltage as 11 kV,

④ It is assumed that each area peak occurs at the same time for the simple study.

⑤ Short circuit analysis is neglected because the power system is small at 20 MW, and

⑥ Protection coordination analysis is omitted.

2) Result of Analysis:

Based on the above assumptions and conditions, preliminary analysis was conducted at the end of 2008 and highlighted as follows;

① Voltage drop at Lakka No. 2 area is beyond permissible voltage range, and

② Energy losses are high.

The result of voltage drop analysis is shown in Table 6.1-1, and Fig. 6.1-3 shows voltage at each point.

Table 6.1-1 Voltage Drop in Western Area (2008)

No.	From	Voltage [kV]			Remarks	No.	From	Voltage [kV]			Remarks
		Bus bar	Drop	[%]				Bus bar	Drop	[%]	
A:	**Kingtom System (pf=0.9)**										
1	**To Lakka No. 2 line**					**2**	**To Pumping Station line**				
	1) Kingtom	11.00					1) Kingtom	11.00			
	2) Brookfield	10.88	0.12	1.1			2) Brookfield	10.88	0.12	1.1	
	3) Wilberforce	10.75	0.25	2.3			3) River Side Drive	10.83	0.17	1.6	
	4) Lumley	10.62	0.38	3.5			4) Hill Station	10.73	0.27	2.5	
	5) Peninsular	10.41	0.59	5.6			5) Pumping Station	10.69	0.31	2.9	
	6) Lakka No. 2	10.39	0.61	5.9							
	Power losses on the above lines				**173 kW**						**112 kW**
3	**To Cape Sierra line**					**4**	**To Falcon Bridge line**				
	1) Kingtom	11.00					1) Kingtom	11.00			
	2) Congo Cross	10.83	0.17	1.5			2) Falcon Bridge	10.81	0.19	1.7	
	3) Cape Sierra	10.61	0.39	3.6							
	Power losses on the above lines				**97 kW**						**56 kW**
B:	**Blackhall Road System (pf=0.8)**						**Total Power Losses:**	**471** [kW]			
1	To Waterloo line										
	1) Blackhall Road	11.00									
	2) Wellington	10.88	0.12	1.1							
	3) FTC	10.83	0.17	1.6							
	4) Waterloo	10.73	0.27	2.5							
	Power losses on the above lines				**33 kW**						

Remarks: Power factor at Blackhall Road P/S was considered actual record.

[Source] JICA Study Team

3) Countermeasures:

As preliminary steps to counter weak points, the following countermeasures shall be taken urgently;

① Increase sending voltage to 11.5 kV at power stations,

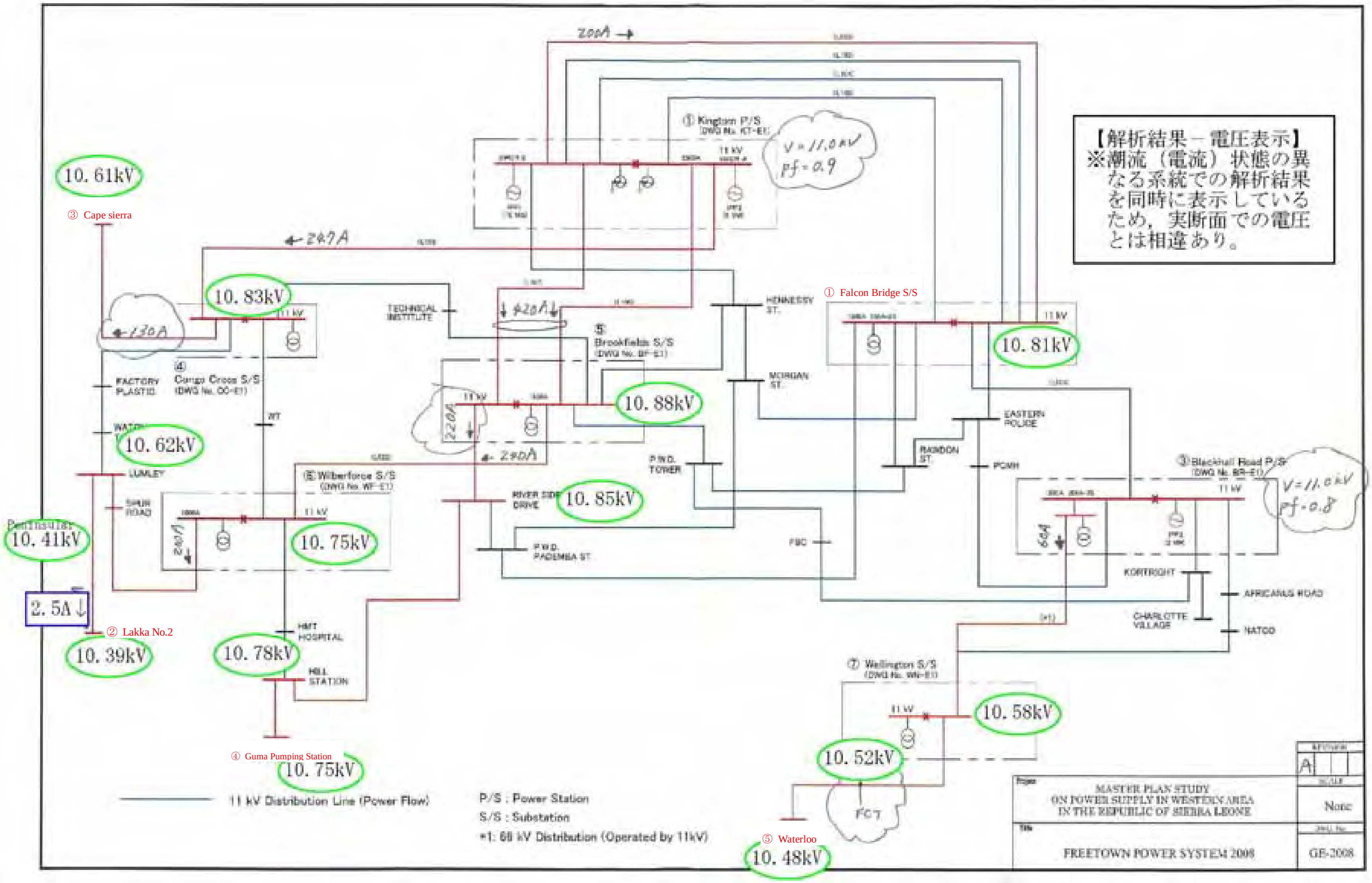
② Power factor shall be more than 0.9 (0.95 is preferable),

③ Select adequate tap for distribution transformers in voltage problem areas,

④ Add new trunk lines to reduce line impedance,

⑤ Select adequate power flow to reduce power losses, and

⑥ Consider reactive power supplier.



[Source] JICA Study Team

Fig. 6.1-3 Voltage Analysis in Western Area (2008)

6.2 Basic Strategy and Policy

Optimal distribution system to be studied up to 2025 shall be conducted in three phases considering i) current situation of the distribution system, ii) future plans, iii) new technology and establishment of high reliability and quality from emergency rehabilitation implemented as first priority.

Basic strategy is divided into three phases as follows;

- Short Term (2010 ~ 2015 year): Emergency Program,
- Medium Term (2016 ~ 2020 year): Improvement and Rural Electrification, and
- Long Term (2021 ~ 2025 year): Secure Reliability and Quality.

The contents of basic policy are selected considering clear-off of the present weak points on power supply network and upgrading of living standards.

＊ Secure stable distribution System
＊ Promote Rural Electrification
＊ Establish Optimal Distribution System

Detailed items to be taken into considerations in formulating the plans that accord with the above mentioned policies are as follows.

1) Secure Stable Distribution System

① Secure main power supply line
② Ensure back-up power supply line
③ Preparation of design and installation standards

2) Promote Rural Electrification

① Establish 33 kV distribution network
② Secure safety power supply
③ Consider load density

3) Establish Optimal Distribution System

① Capacity building for distribution system including 33 kV system
② No excessively over loaded facilities
③ Provide adequate protection system
④ Secure quality of supplied power
⑤ Standardization of design, operation and maintenance
⑥ Establish Central Dispatching Centre and economical operation

Based on site investigation and considering energy strategy of the MEWR and the NPA, the key index to be set in order to approach the goal is shown in Table 6.2-1.

Table 6.2-1 Key Index to each Phase (Year 2015/2020/2025)

Index	Unit	2008	2015	2020	2025
Energy Losses	[%]	42.0	30>	20>	10>
Power Outage	[Hours]	>5,000	500>	50>	1>
No. of Fault	[Times]	981	600>	300>	100>
Electrification Rate	[%]	22.9	>40	>60	>95
New Consumers	[Houses]	3,664	>56,000	>88,000	>136,000

[Remarks]
1. Above key index applied Western Area only.
2. Energy losses are only for distribution network. Not including transmission line including 161 kV S/S.
3. Energy losses are including technical and non-technical losses.

[Source] JICA Study Team

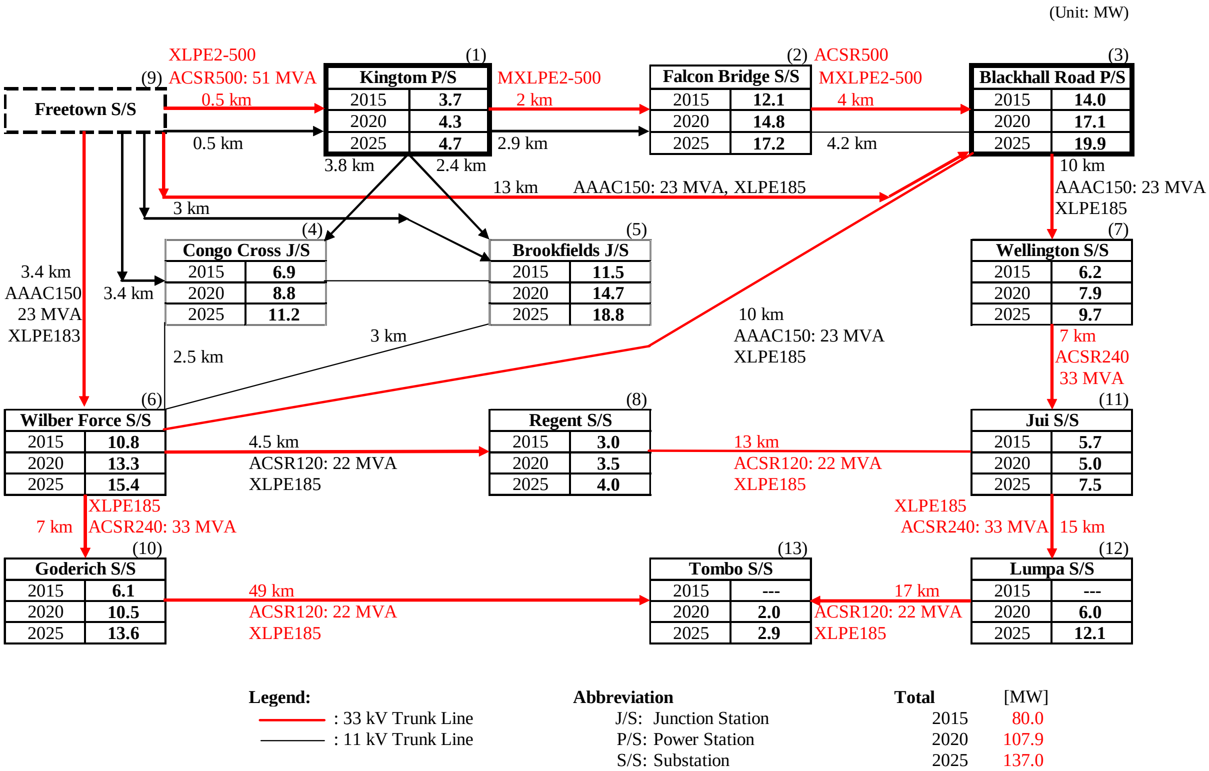
6.3 Demand Forecast and Distribution System

6.3.1 Demand Forecast

Demand forecast as a basis for this study in Western Area is assumes based on area demand as shown in item 6.1 and taking into consideration energy strategy and future development plans in Western Area.
The peak demand in major distribution stations depends on the load conditions, for example, daytime demand is high in commercial areas, whereas nighttime demand is high in residential areas which are also affected by weekends. That is, the total of peak demand for distribution stations is different to the overall Western Area demand.
For example, area peak demand mentioned in section 4 in 2015 is 67.4 MW. However, the total of distribution stations is 80 MW as shown in Fig. 6.3-1 which is always larger than area peak demand.

Peak demand to be used for system analysis shall be peak demand in each major distribution station which is based on data in 2008 as mentioned in Fig. 6.1-2 and also considering energy strategy of power sector, future development plans such as rural electrification, housing plans, availability of land and average annual rate of increase rate of the demand in each area.

Considering above conditions and peak demand of each distribution station in 2015/2020/2025, preliminary power flow is shown in Fig. 6.3-1.



[Source] JICA Study Team

Fig. 6.3-1 Peak Demand Forecast in each Area (2015/2020/2025)

6.3.2 Distribution Network

Rehabilitation, reinforcement and expansion plan of the distribution network shall have close relation ship to generation and transmission planning. Generation plan shall be applied to the Hydro Dominant Scenario shown in Table 5.3-8 and 161 kV, single circuit from Bumbuna P/S shall be considered as transmission line.

The optimal distribution system shall be planned taking into consideration the basic policy mentioned in item 6.2, considering clear-off of the weak points on existing system and minimization of the modification of the existing facilities, and also considering future requirements to the system.

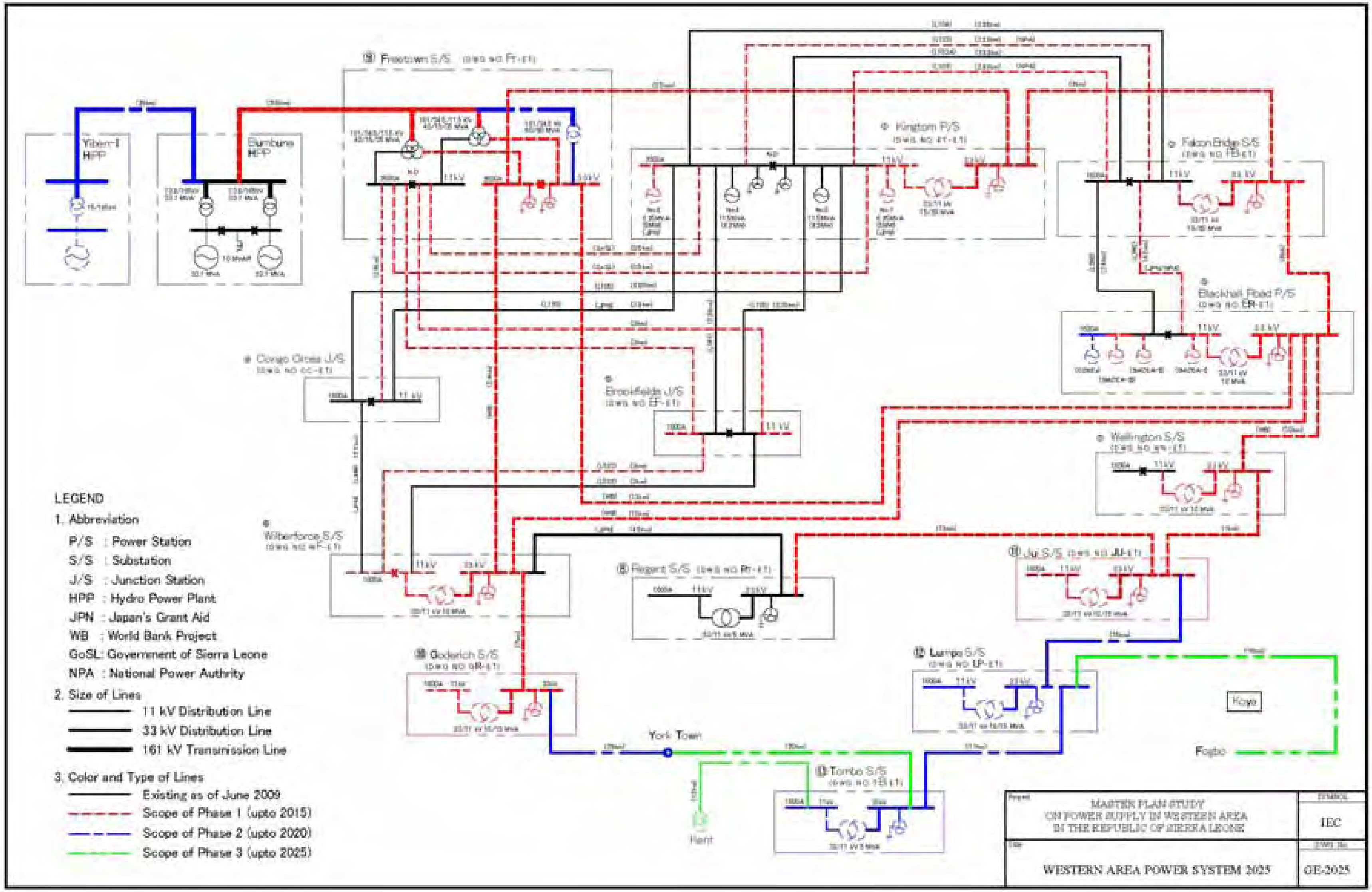
The conceptual plan shall be provided considering the following points:

a) New facilities shall be used until year 2025.
b) Location of new substations shall be determined considering load density and coverage area.
c) Loop system shall be adapted to 33 kV system.
d) Reduce energy losses on the distribution network.
e) Consider environmental aspect to facility planning.
f) Promote rural electrification.
g) Consider ongoing project by the WB.
h) Power from international line comes from Bumbuna 161 kV, 1-circuit line

Preliminary distribution system to be used for the system analysis shall be provided considering rehabilitation of the 11 kV system, reinforcement of distribution system to adopt the 33 kV system and expansion of distribution network.

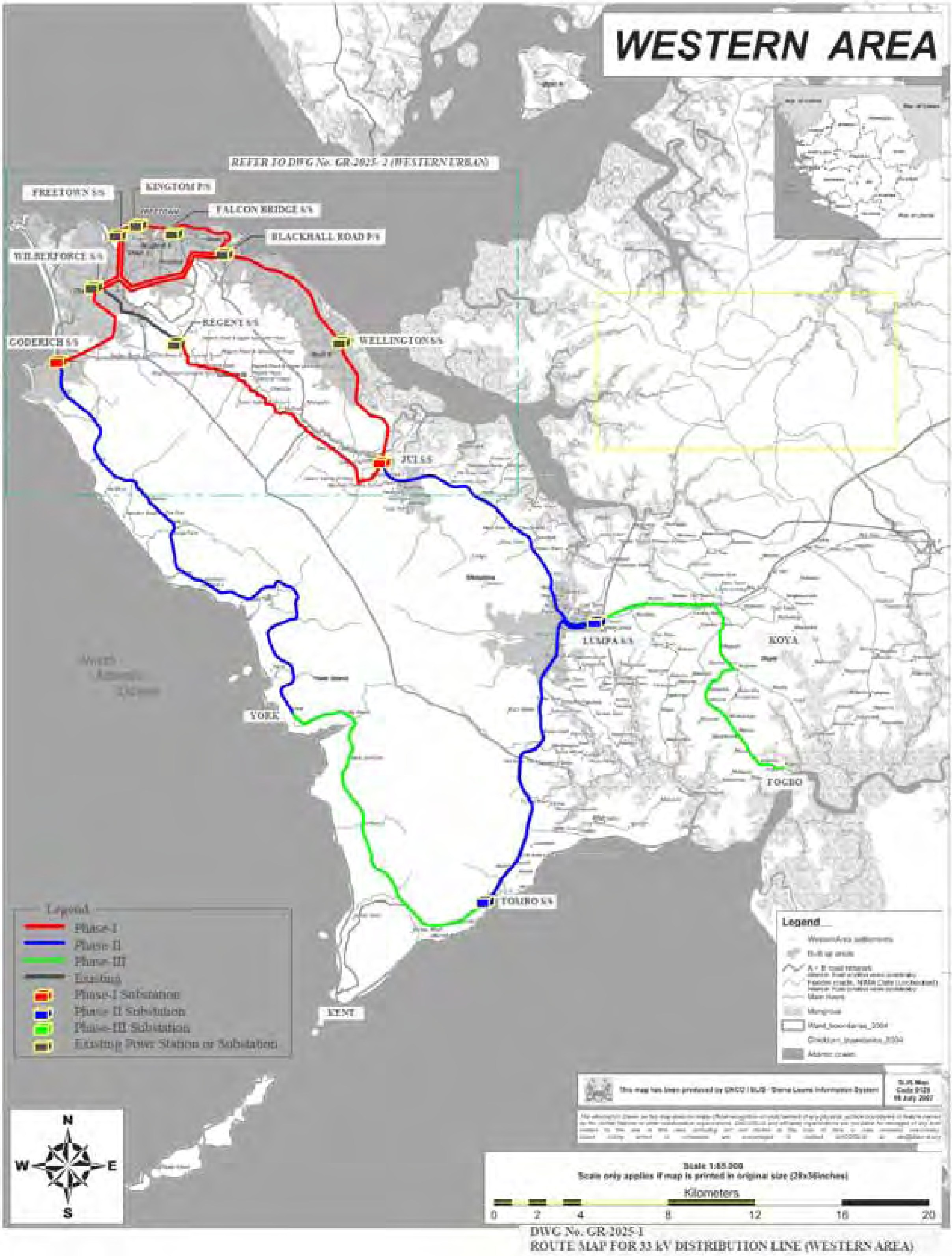
Considering the above requirements, preliminary power system up to 2025 is shown in Fig. 6.3-2 and location of new substation and line route is shown in Fig. 6.3-3 and Fig. 6.3-4 respectively.

Location of Goderich S/S with new 33 kV line shall be planned considering environmental aspects. Preliminary new 33 kV line route is shown in Fig. RM-D05 and also 11 kV and 33 kV SWGR systems are shown in item 3 of Appendices.



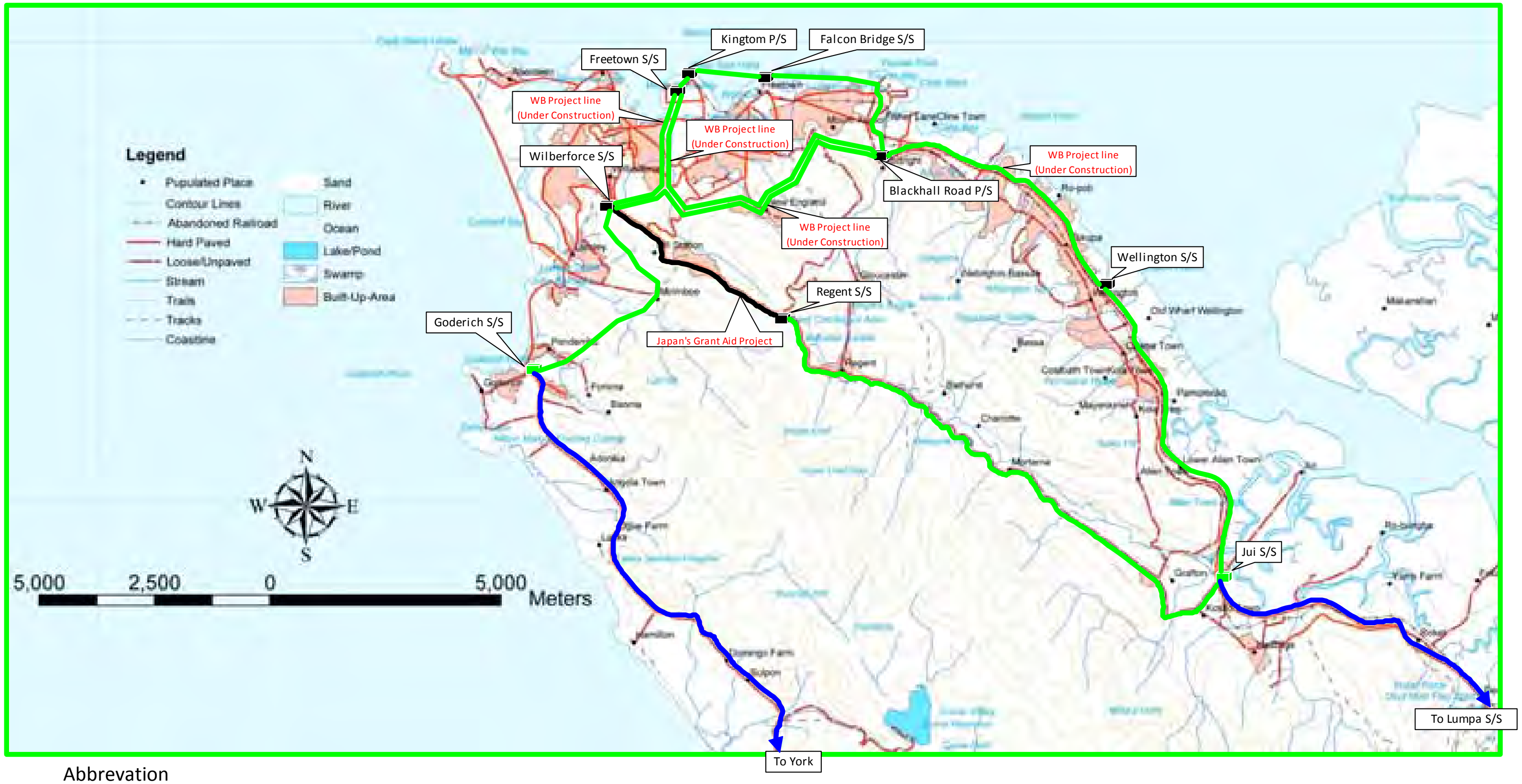
[Source] JICA Study Team

Fig. 6.3-2 Western Area Power System 2025



[Source] JICA Study Team

Fig. 6.3-3 Route Map for 33 kV Line (Western Area: 2025)



Abbrevation

P/S : Power Station

S/S : Substation

DWG No. GR-2025-2
ROUTE MAP FOR 33 kV DISTRIBUTION LINE (WESTERN URBAN)

Symbol

: Existing Power Station or Substatioı

: Substation for phase-1

: Substation for phase-2

: Existing 33 kV Line

: 33kV Phase-1 Line

: 33 kV Phase-2 Line

[Source] JICA Study Team

Fig. 6.3-4 Route Map for 33 kV Line (Urban Area: 2015/ 2020)

6.4 System Analysis

System analysis shall be conducted based on the demand forecast in each area and system configuration described in item 6.3. Major components of the analysis are: (1) Outline of analysis, (2) Preparation of analysis data, (3) Result of the analysis, and (4) Conclusion which is as follows.

(1) Outline of Analysis

Outline of the analysis consists of five items, namely 1) Scope of analysis, 2) Analyzing year, 3) Contents of analysis, 4) Prerequisite and 5) Methodology of analysis, and is as follows.

1) Scope of Analysis

The scope is Above 11 kV system connected to Western Area network except radial system.

2) Analyzed Year

Peak demand in each year 2015, 2020 and 2025 (Refer to Fig. 6.3-1).

3) Contents of Analysis

The following six items shall be analyzed using software of Japanese institute as follows.

a) Calculation of Power Flow
b) Calculation of Short Circuit Capacity
c) Calculation of Power Flow at N-1 system Fault
d) Analysis of Voltage Stability
e) Calculation of Frequency
f) Analysis of Stability

4) Prerequisite

a) Generator output shall be according to Table 5.3-8,
b) Peak demand in each area shall be as per Fig. 6.3-1 and load on Bus [A] and [B] of 11 kV and 33 kV SWGR shall be divided equally,
c) Generator voltage shall be rated voltage of generator which shall be 1 power unit (p.u.),
d) Power factor shall be 0.9,
e) 11 kV bus-tie CB shall be open in Freetown S/S and Kingtom P/S and others are close conditions,
f) System losses shall be calculated according to balancing method of generator output (Refer to Appendix 6.4-1). Minimum output of DEG shall be 1.0 MW,
g) When voltage adjustment is required for power flow, first, transformer tap shall be adjusted and if it is not enough then reactive power suppliers shall be considered. Voltage adjustment range shall be within 1.00 p.u. +/- 0.05 p.u.,
h) 11 kV radial systems are not included in this analysis, and
i) Study of optimal system is only for 2015.

5) Methodology

① Power flow in Base case (Transformer tap is 1.00 p.u. and without phase regulator)
② Power flow after adjustment of transformer tap changing
③ Power flow after installation of preliminary phase regulator
④ Re-calculation of power flow with proposed SC to 2015
⑤ Calculation of short circuit capacity
⑥ Confirmation of countermeasure to excessive short circuit capacity
Changing the system configuration and reconfirmation of above item ① ~ ⑤

⑦ Power flow on N-1 system fault condition
Apply one circuit fault on double circuits on loop system and identify the faulty points in the power flow

⑧ Analysis of voltage stability
Confirm P-V curve on 11 kV SWGR at Kingtom P/S

⑨ Calculation of frequency
Confirmation of frequency at Kingtom P/S when Bumbuna 161 kV line fault and advice load shedding.

⑩ Analysis of stability
Confirmation of stability of generators at Kingtom P/S when load shedding is applied to the above item ⑨.

(2) Preparation of Analytical Data

It is necessary to provide technical data for transmission/ distribution lines, transformer and generator which were collected during site survey. Similar technical data and conditions of standard line arrangement in Japan shall be applied if electrical facilities, line specifications and arrangement of lines are unclear.

1) Transmission and distribution line data

Facility resister of lines, Western Area power system 2025 (DWG No. GE-2025) and Fig. 6.3-1 shall be used for impedance and admittance calculation (Refer to Table 6.4-1 of section 6.7).

2) Transformer data

Facility resister of transformer shall be used to determine the reactance (Refer to Table 6.4-2 of section 6.7).

3) Generator data

Using existing generator data and some data were assumed (Refer to Table 6.4-3 of section 6.7).

(3) Analysis and Result

System analysis based on Fig. 6.3-1 consists of 1) Power flow calculation, 2) Re-calculation of power flow with proposed SC, 3) Calculation of short circuit capacity, 4) Power flow calculation at N-1 fault, 5) Voltage stability analysis, 6) Frequency calculation, and 7) Stability analysis.
Detail calculation results are as follows.

1) Calculation of power flow

There are three steps to the analysis: First, step ① is to calculate without any voltage adjustment and if bus bar voltage is not within 0.95 to 1.05 p.u., then step ② shall be applied which is apply tap changing of transformer, and if voltage is still not within permissible range, then step ③ shall be applied as a last solution which is considered static condenser.

Following points as a basis shall be considered for the voltage adjustment;

a) Voltage adjustment range of transformer shall be considered margin in which highest and lowest tap shall not be used,
b) SC shall be installed on 11 kV systems and unit capacity shall be 2 MVA as three phase capacity. The capacity of SC shall be selected as about 1/3 of installed transformer capacity, and
c) Assume reactive power of generator shall be within rated power factor of generator.

Table 6.4-4 Calculation Result of Power Flow in 2015

Name of Station	Bus Voltage [kV]	Power flow① (Base)	Power flow② Tap Adjustment		Power flow③ Installation of SC		
		V [p.u.]	Tap	V [p.u.]	Tap	Capacity [MVA]	V [p.u.]
Kingtom	33	0.98	▲3	1.02	—		1.00
	11 (A)	0.98		0.99			1.00
	11 (B)	1.00		1.00			1.00
Falcon Bridge	33	0.98	▲3	1.02	—		1.00
	11	0.98		0.98		+6	0.99
Blackhall Road	33	0.97	▲7	1.02	—		1.00
	11	1.00		1.00			1.00
Congo Cross	11	0.98		0.98		+6	0.99
Brookfields	11	0.97		0.98		+8	0.99
Wilberforce	33	0.97	—	1.00	—		0.99
	11	0.95		0.96		+6	0.98
Wellington	33	0.94	+3	0.99	—		0.98
	11	0.90		0.98		+4	0.98
Regent	33	0.96	+2	1.00	—		0.99
	11	0.92		0.99		+2	0.99
Freetown	161	0.98	—	1.01	—		1.00
	33	0.98		1.02			1.00
	11 (A)	1.00		1.00			1.00
	11 (B)	0.98		0.99			1.00
Goderich	33	0.95	+1	0.99	—		0.98
	11	0.93		0.99		+2	0.97
Jui	33	0.94	+1	0.98	—		0.97
	11	0.91		0.98		+2	0.96
Lumpa	33						
	11						
Tombo	33						
	11						
Bumbuna	161	1.01	▲1	1.05	▲1		1.04
	13.8	1.00		1.00			1.00
Loss of active power		3 MW	3 MW		2 MW		
Loss of reactive power		▲2 MVar*[1]	▲3 MVar*[1]		▲5 MVar*[1]		
Kingtom	Active	4.4 MW	4.4 MW		4.4 MW		
	Reactive	37.4 MVar	29.7 MVar		2.2 MVar		
	Power factor	Lead 0.12	Lag 0.15		Lag 0.89		
Blackhall Road	Active	17.4 MW	17.1 MW		16.6 MW		
	Reactive	14.5 MVar	19.9 MVar		8.4 MVar		
	Power factor	Lead 0.77	Lag 0.65		Lag 0.89		
Bumbuna	Active	50 MW	50 MW		50 MW		
	Reactive	▲3.3 MVar	▲1.6 MVar		0.1 MVar		
	Power factor	Lead 1.00	Lead 1.00		Lag 1.00		
YIBEN-I	Active						
	Reactive						
	Power factor						
Reference Drawings		Fig. 6.4-1	Fig. 6.4-2		Fig. 6.4-3		

(* Red letters means out of adjustable range of voltage and power factor of generator)

(* Output of P/S is the total value at generator terminal in each P/S)

(*1 : ▲ means minus reactive power because of charging current to line is too large rather than losses)

[Source] JICA Study Team

Table 6.4-5 Calculation Result of Power Flow in 2020

Name of Station	Bus Voltage [kV]	Power flow① (Base)	Power flow② Tap Adjustment		Power flow③ Installation of SC		
		V [p.u.]	Tap	V [p.u.]	Tap	Capacity [MVA]	V [p.u.]
Kingtom	33	0.95	▲3	0.99	—		0.99
	11 (A)	0.97		0.98			1.00
	11 (B)	1.00		1.00			1.00
Falcon Bridge	33	0.95	▲3	0.99	—		0.99
	11	0.97		0.97		＋10	0.99
Blackhall Road	33	0.94	▲7	0.99	—		0.99
	11	1.00		1.00			1.00
Congo Cross	11	0.96		0.97		＋12	0.99
Brookfields	11	0.95		0.96		＋12	0.99
Wilberforce	33	0.93	—	0.97	—		0.98
	11	0.93		0.94		＋10	0.98
Wellington	33	0.88	＋4	0.93	—		0.97
	11	0.82		0.93		＋6	0.97
Regent	33	0.91	＋2	0.95	—		0.98
	11	0.87		0.94		＋2	0.97
Freetown	161	0.95	—	0.99	—		0.99
	33	0.95		0.99			0.99
	11 (A)	0.99		1.00			1.00
	11 (B)	0.97		0.98			1.00
Goderich	33	0.90	＋2	0.94	—		0.98
	11	0.85		0.94		＋8	0.98
Jui	33	0.87	＋2	0.91	—		0.97
	11	0.84		0.93		＋4	0.97
Lumpa	33	0.82	＋2	0.87	—		0.96
	11	0.79		0.88		＋6	0.97
Tombo	33	0.81	＋2	0.85	—		0.96
	11	0.77		0.84		＋2	0.97
Bumbuna	161	1.00	▲1	1.04	▲1		1.04
	13.8	1.00		1.00			1.00
YIBEN-I	161	1.00	▲1	1.04	▲1		1.04
	15	1.00		1.00			1.00
Loss of active power		9 MW	8 MW		6 MW		
Loss of reactive power		25MVar	21MVar		13 MVar		
Kingtom	Active	4.3 MW	4.3 MW		4.3 MW		
	Reactive	68.1 MVar	58.9 MVar		0.6 MVar		
	Power factor	Lag 0.06	Lag 0.07		Lag 0.99		
Blackhall Road	Active	20.6 MW	19.7 MW		17.8 MW		
	Reactive	23.9 MVar	29.5 MVar		12.5 MVar		
	Power factor	Lag 0.65	Lag 0.55		Lag 0.82		
Bumbuna	Active	36.8 MW	36.8 MW		36.8 MW		
	Reactive	2.9 MVar	3.2 MVar		2.6 MVar		
	Power factor	Lag 1.00	Lag 1.00		Lag 1.00		
YIBEN-I	Active	45.3 MW	45.3 MW		45.3 MW		
	Reactive	1.2 MVar	1.7 MVar		1.0 MVar		
	Power factor	Lag 1.00	Lag 1.00		Lag 1.00		
Reference Drawings		Fig. 6.4-4	Fig. 6.4-5		Fig. 6.4-6		

(* Red letters means out of adjustable range of voltage and power factor of generator)

(* Output of P/S is the total value at generator terminal in each P/S)

[Source] JICA Study Team

Table 6.4-6 Calculation Result of Power Flow in 2025

Name of Station	Bus Voltage [kV]	Power flow① (Base)	Power flow② Tap Adjustment		Power flow③ Installation of SC		
		V [p.u.]	Tap	V [p.u.]	Tap	Capacity [MVA]	V [p.u.]
Kingtom	33	0.93	▲3	0.96	—		0.99
	11 (A)	1.00		0.96			0.99
	11 (B)	1.00		1.00			1.00
Falcon Bridge	33	0.93	▲3	0.96	—		0.99
	11	0.98		0.96		+12	0.99
Blackhall Road	33	0.92	▲7	0.95	—		0.99
	11	1.00		1.00			1.00
Congo Cross	11	0.96		0.95		+18	0.99
Brookfields	11	0.96		0.94		+18	0.99
Wilberforce	33	0.90	—	0.92	—		0.98
	11	0.93		0.91		+18	0.98
Wellington	33	0.82	+7	0.86	—		0.96
	11	0.74		0.86		+8	0.97
Regent	33	0.87	+3	0.90	—		0.98
	11	0.82		0.89		+4	1.00
Freetown	161	0.94	—	0.95	—		0.98
	33	0.93		0.96			0.99
	11 (A)	0.99		0.99			1.00
	11 (B)	0.99		0.96			1.00
Goderich	33	0.85	+3	0.88	—		0.98
	11	0.77		0.98		+12	0.99
Jui	33	0.79	+3	0.83	—		0.96
	11	0.75		0.85		+8	0.98
Lumpa	33	0.71	+3	0.75	▲1		0.95
	11	0.62		0.74		+12	0.98
Tombo	33	0.72	+3	0.76	▲2		0.96
	11	0.66		0.74		+4	1.00
Bumbuna	161	0.99	▲1	1.03	▲1		1.03
	13.8	1.00		1.00			1.00
YIBEN-I	161	1.00	▲1	1.02	▲1		1.04
	15	1.00		1.00			1.00
Loss of active power		18 MW	17 MW		12 MW		
Loss of reactive power		64 MVar	59 MVar		40 MVar		
Kingtom	Active	5.2 MW	4.2 MW		4.2 MW		
	Reactive	125.9 MVar	102.6 MVar		1.7 MVar		
	Power factor	Lag 0.04	Lag 0.04		Lag 0.93		
Blackhall Road	Active	47.1 MW	47.5 MW		41.7 MW		
	Reactive	8.5 MVar	22.9 MVar		1.3 MVar		
	Power factor	Lag 0.98	Lag 0.90		Lag 1.00		
Bumbuna	Active	50 MW	50 MW		50 MW		
	Reactive	8.0 MVar	10.0 MVar		6.3 MVar		
	Power factor	Lag 0.99	Lag 0.98		Lag 0.99		
YIBEN-I	Active	54.6 MW	54.6 MW		54.6 MW		
	Reactive	5.7 MVar	8.0 MVar		4.2 MVar		
	Power factor	Lag 0.99	Lag 0.99		Lag 1.00		
Reference Drawings		Fig. 6.4-7	Fig. 6.4-8		Fig. 6.4-9		

(* Red letters means out of adjustable range of voltage and power factor of generator)
(* Output of P/S is the total value at generator terminal in each P/S)
[Source] JICA Study Team

As a result of calculation of power flow, the system shall not be able to operate within the voltage adjustment range and permissible power factor range of generator which are shown in Tables 6.4-4, 6.4-5 and 6.4-6.

However, it is possible to maintain the system voltage within the permissible range, if the adequate static condenser (SC) shall be installed considering power flow and demands on each substation. Then the voltage on the 11 kV and 33 kV systems can be maintained within permissible range.

2) Re-calculation of power flow

Power flow calculation at year 2015 on item 1), Table 6.4-4 shows calculation result considering with estimated SC after adjustment of voltage taps of transformer. Considering this estimated SC capacity and calculation result, and also taking into consideration of future system improvement plan, installation space of SC in the substation and easy operation and maintenance, proposed SC is shown on Table 6.4-7.

Table 6.4-7 Proposed installation Plan of SC by year 2015

Name of station	Capacity of SC [MVA]	Target of installation
Falcon Bridge	6	By 2015
Brookfields	6	By 2015
Congo Cross	6	By 2015
Wilberforce	4	By 2015
Wellington	4	By 2015
Goderich	6	Including plan
Jui	6	Including plan

[Source] JICA Study Team

Based on the above proposed plan and re-calculation of power flow, 11 kV and 33 kV SWGR at each power station and substation can maintain the voltage within adjustable range and also generator can be operated by adjustable range of power factor. Re-calculation results are shown in Table 6.4-8 and system diagram in Fig. 6.4-10.

The number of static condensers in each station shall be more than two (2) banks considering load conditions, maintainability and operability.

New substations such as Goderich and Jui S/S should be taken into consideration of these SC from the planning stage.

Regarding re-calculation of power flow to 2020 and 2025, it shall be omitted because of a lot of unknown factors concerning distribution system, specification of lines and generators and also international transmission lines. Therefore, reference SC capacity is as shown in Table 6.4-5 and Table 6.4-6.

It is recommendable that the new substations such as Lumpa S/S and Tombo S/S shall be considered to have adequate SC capacity from the planning stage.

Table 6.4-8 Re-calculation Result of Power Flow with Proposed SC by 2015

Name of Station	Bus Voltage [kV]	Power flow ③ Installation of SC (Preliminary)			Re-calculation of Power flow with proposed SC		
		Tap	SC [MVA]	V [p.u]	Tap	SC [MVA]	V [p.u]
Kingtom	33	–		1.00	–		1.00
	11 (A)			1.00			1.00
	11 (B)			1.00			1.00
Falcon Bridge	33	–		1.00	–		1.00
	11		+6	0.99		+6	0.99
Blackhall Road	33	–		1.00	–		1.00
	11			1.00			1.00
Congo Cross	11		+6	0.99		+6	0.99
Brookfields	11		+8	0.99		+6	0.99
Wilberforce	33	–		0.99	–		0.99
	11		+6	0.98		+4	0.98
Wellington	33	–		0.98	–		0.99
	11		+4	0.98		+4	0.99
Regent	33	–		0.99	–		0.99
	11		+2	0.99		–	0.96
Freetown	161	–		1.00	–		1.01
	33			1.00			1.00
	11 (A)			1.00			1.00
	11 (B)			1.00			1.00
Goderich	33	–		0.98	–		0.99
	11		+2	0.97		+6	0.99
Jui	33	–		0.97	–		0.99
	11		+2	0.96		+6	1.00
Lumpa	33						
	11						
Tombo	33						
	11						
Bumbuna	161	▲1		1.04	▲1		1.04
	13.8			1.00			1.00
YIBEN-I	161						
	15						
Loss of active power		2 MW			2 MW		
Loss of reactive power		▲5 MVar*1			▲5 MVar*1		
Kingtom	Active	4.4 MW			4.4 MW		
	Reactive	2.2 MVar			2.5 MVar		
	Power factor	Lag 0.89			Lag 0.87		
Blackhall Road	Active	16.6 MW			16.6 MW		
	Reactive	8.4 MVar			7.9 MVar		
	Power factor	Lag 0.89			Lag 0.90		
Bumbuna	Active	50 MW			50 MW		
	Reactive	0.1 MVar			▲0.2 MVar		
	Power factor	Lag 1.00			Lead 1.00		
Reference Drawings		Fig. 6.4-3			Fig. 6.4-10		

(* Output of P/S is the total value at generator terminal in each P/S)

(*1 : ▲ means minus reactive power because of charging current to line is too large rather than losses)

[Source] JICA Study Team

3) Calculation of short circuit capacity

Based on the above power flow calculation, short circuit capacity shall be calculated and it shall be confirmed that the permissible current of lines and short circuit current of circuit breaker are not beyond the rating of facilities (Methodology ⑤) .

If the result is abnormal, then the following countermeasures shall be considered (Methodology ⑥);

a) Open the abnormal circuits in which short circuit current is more than the permissible one. Replace the circuit breaker if the rated short circuit current of CB for transformer feeder is less than the calculated one.
b) Conduct power flow calculation based on revised system configuration and confirm the system condition. Recheck the transformer taps and additional SC considering Methodology ① ~ ④.

【2015】

＜Base system configuration (Methodology ⑤)＞

Table 6.4-9 Confirmation of short circuit capacity of base system (Refer to Fig. 6.4-11)

No.	Facility below short circuit current of the system		Short circuit current [kA]		
			Line spec.	CB	Analysis
1	11 kV line: L203	Falcon Bridge	11.0	20.0	13.6
		Blackhall Road		20.0	14.8
2	11 kV line: L120	Kingtom	11.0	25.0	14.6
		Congo Cross		20.0	9.0

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜System configuration after open circuits (Methodology ⑥)＞

Table 6.4-10 Confirmation of short circuit capacity after open circuit (Refer to Fig. 6.4-12)

No.	Facility below short circuit current of the system		Short circuit current [kA]		
			Line spec.	CB	Analysis
1	11 kV line: L203		Open circuit		
2	11 kV line: L120		Open circuit		

Table 6.4-11 Confirmation of voltage after open circuit (after adjustment)

Name of station after adjustment of Tap and add SC		Bus voltage [kV]	Tap	SC
Non adjustment				
Total losses: Active/ Reactive power		2 MW／▲5 MVar*[1]		
Kingtom	Active/ Reactive power	4.4 MW／2.9 MVar		
	Power factor	Lag 0.83		
Blackhall Road	Active/ Reactive power	16.6 MW／7.8 MVar		
	Power factor	Lag 0.90		
Bumbuna	Active/ Reactive power	50 MW／0.1 MVar		
	Power factor	Lag 1.00		
Reference Drawings		Fig. 6.4-13		

(*1 : ▲ means minus reactive power because of charging current to line is too large rather than losses)

Table 6.4-12 Confirmation of power flow with modified system configuration

Facility below required thermal capacity to the distribution lines	Continuous current of line	Rated short circuit current of CB	Power flow
No thermal capacity problems			

＜**Facilities after consideration of countermeasure to short circuit capacity**＞

・No facility

【2020】

＜**Base system configuration (Methodology ⑤)**＞

Table 6.4-13 Confirmation of short circuit capacity of base system (Refer to Fig. 6.4-14)

No.	Facility below short circuit current of the system		Short circuit current [kA]		
			Line spec.	CB	Analysis
1	11kV line: L203	Falcon Bridge	11.0	20.0	17.7
		Blackhall Road		20.0	22.6
2	11kV line: L120	Kingtom	11.0	25.0	18.7
		Congo Cross		20.0	10.6
3	11kV line: L450	Congo Cross	22.3	20.0	10.2
		Freetown		16.0	18.3
4	11kV line: L550	Brookfields	22.3	20.0	14.1
		Freetown		16.0	18.0
5	11kV line: L551	Brookfields	22.3	20.0	14.1
		Freetown		16.0	18.1
6	11kV line: L202	Falcon Bridge	26.6	20.0	14.8
		Blackhall Road		20.0	20.6
7	Blackhall Road 33/11kV Transformer	33kV		25.0	5.0
		11kV		20.0	22.3

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜**System configuration after open circuits (Methodology ⑥)**＞

Table 6.4-14 Confirmation of short circuit capacity after open circuit (Refer to Fig. 6.4-15)

No.	Facility below short circuit current of the system		Short circuit current [kA]		
			Line spec.	CB	Analysis
1	11kV line: L203		Open circuit		
2	11kV line: L120		Open circuit		
3	11kV line: L450		Open circuit		
4	11kV line: L550		Open circuit		
5	11kV lineL551		Open circuit		
6	11kV line: L202	Falcon Bridge	26.6	20.0	12.3
		Blackhall Road		20.0	19.0
7	Blackhall Road 33/11kV Transformer	33kV		25.0	4.7
		11kV		20.0	21.3

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

Table 6.4-15 Confirmation of voltage after open circuit (after adjustment)

<table>
<tr><th colspan="2">Name of station after adjustment of Tap and add SC</th><th>Bus voltage [kV]</th><th>Tap</th><th>SC</th></tr>
<tr><td colspan="2">Non adjustment</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Total losses: Active/ Reactive power</td><td colspan="2">6 MW／14 MVar</td></tr>
<tr><td rowspan="2">Kingtom</td><td colspan="2">Active/ Reactive power</td><td colspan="2">4.3 MW／1.2 MVar</td></tr>
<tr><td colspan="2">Power factor</td><td colspan="2">Lag 0.90</td></tr>
<tr><td rowspan="2">Blackhall Road</td><td colspan="2">Active/ Reactive power</td><td colspan="2">18.2 MW／11.8 MVar</td></tr>
<tr><td colspan="2">Power factor</td><td colspan="2">Lag 0.84</td></tr>
<tr><td rowspan="2">Bumbuna</td><td colspan="2">Active/ Reactive power</td><td colspan="2">36.8 MW／2.6 MVar</td></tr>
<tr><td colspan="2">Power factor</td><td colspan="2">Lag 1.00</td></tr>
<tr><td rowspan="2">YIBEN-I</td><td colspan="2">Active/ Reactive power</td><td colspan="2">45.3 MW／1.0 MVar</td></tr>
<tr><td colspan="2">Power factor</td><td colspan="2">Lag 1.00</td></tr>
<tr><td colspan="3">Reference Drawings</td><td colspan="2">Fig. 6.4-16</td></tr>
</table>

Table 6.4-16 Confirmation of power flow with modified system configuration

<table>
<tr><th colspan="2">Facility below required thermal capacity to the distribution lines</th><th>Continuous current of line</th><th>Rated short circuit current of CB</th><th>Power flow</th></tr>
<tr><td rowspan="2">11kV line: L105</td><td>Kingtom</td><td rowspan="2">355A</td><td>1,250A</td><td rowspan="2">542A (9.2MW)</td></tr>
<tr><td>Congo Cross</td><td>1,250A</td></tr>
<tr><td rowspan="2">11kV line: L107</td><td>Kingtom</td><td rowspan="2">355A</td><td>1,250A</td><td rowspan="2">550A
(10.1MW)</td></tr>
<tr><td>Brookfields</td><td>1,250A</td></tr>
<tr><td rowspan="2">11kV line: L106</td><td>Kingtom</td><td rowspan="2">355A</td><td>1,250A</td><td rowspan="2">558A
(10.6MW)</td></tr>
<tr><td>Brookfields</td><td>1,250A</td></tr>
</table>

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Facilities after consideration of countermeasure to short circuit capacity＞

a) Lack of short circuit current of 11 kV CB for transformer feeder at Blackhall Road (Required short circuit current is more than 21.3 kA).
b) Lack of continuous rated current of 11 kV line: L105 (require more than 542 A)
c) Lack of continuous rated current of 11 kV line: L106 (require more than 558 A)
d) Lack of continuous rated current of 11 kV line: L107 (require more than 550 A)

【2025】

＜**Base system configuration (Methodology ⑤)**＞

Table 6.4-17 Confirmation of short circuit capacity of base system (Refer to Fig. 6.4-17)

No.	Facility below short circuit current of the system		Short circuit current [kA]		
			Line spec.	CB	Analysis
1	11kV line: L203	Falcon Bridge	11.0	20.0	17.7
		Blackhall Road		20.0	22.6
2	11kV line: L120	Kingtom	11.0	25.0	18.7
		Congo Cross		20.0	10.6
3	11kV line: L450	Congo Cross	22.3	20.0	10.2
		Freetown		16.0	18.3
4	11kV line: L550	Brookfields	22.3	20.0	14.1
		Freetown		16.0	18.0
5	11kV line: L551	Brookfields	22.3	20.0	14.1
		Freetown		16.0	18.1
6	11kV line: L202	Falcon Bridge	26.6	20.0	14.8
		Blackhall Road		20.0	20.6
7	Blackhall Road 33/11 kV Transformer	33 kV		25.0	5.0
		11 kV		20.0	22.3

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜**System configuration after open circuits (Methodology ⑥)**＞

Table 6.4-18 Confirmation of short circuit capacity after open circuit (Refer to Fig. 6.4-18)

No.	Facility below short circuit capacity of the system		Short circuit current [kA]		
			Line spec.	CB	Analysis
1	11kV line: 203		Open circuit		
2	11kV line: L120		Open circuit		
3	11kV line: L450		Open circuit		
4	11kV line: L550		Open circuit		
5	11kV line: L551		Open circuit		
6	11kV line: L202	Falcon Bridge	26.6	20.0	12.3
		Blackhall Road		20.0	19.0
7	Blackhall Road 33/11kV Transformer	33kV		25.0	4.7
		11kV		20.0	21.3

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

Table 6.4-19 Confirmation of voltage after open circuit (after adjustment)

Name of station after adjustment of Tap and add SC		Bus voltage [kV]	Tap	SC
Brookfields		33	–	
		11		＋20 （＋2）
Total losses: Active/ Reactive power			13 MW/ 41 MVar	
Kingtom	Active/ Reactive power		4.2MW/ 2.5 MVar	
	Power factor		Lag 0.86	
Blackhall Road	Active/ Reactive power		43.3MW/ 0.9 MVar	
	Power factor		Lag 1.00	
Bumbuna	Active/ Reactive power		50MW/ 6.5 MVar	
	Power factor		Lag 0.99	
YIBEN-I	Active/ Reactive power		54.6MW/ 4.4 MVar	
	Power factor		Lag 1.00	
Reference Drawings			Fig. 6.4-19	

(*Numerical values in ( ) shows additional capacity of SC calculated by ③ of item-1).

Table 6.4-20 Confirmation of power flow with modified system configuration

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33kV line: L3901	Wilberforce	407A	1,250A	573A(32.2MW)
	Freetown		1,250A	
11kV line: L105	Kingtom	355A	1,250A	854A(13.0MW)
	Congo Cross		1,250A	
11kV line: L107	Kingtom	355A	1,250A	883A(14.1MW)
	Brookfields		1,250A	
11kV line: L106	Kingtom	355A	1,250A	796A(14.2MW)
	Brookfields		1,250A	
11kV line: L202	Falcon Bridge	430A	1,250A	972A(13.3MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Facilities after consideration of countermeasure to short circuit capacity＞

a) Lack of short circuit current of 11 kV CB for transformer feeder at Blackhall Road (Required short circuit current is more than 21.3 kA).
b) Lack of continuous rated current of 11 kV line: L3901 (require more than 573 A)
c) Lack of continuous rated current of 11 kV line: L105 (require more than 854 A)
d) Lack of continuous rated current of 11 kV line: L106 (require more than 796 A)
e) Lack of continuous rated current of 11 kV line: L107 (require more than 883 A)
f) Lack of continuous rated current of 11 kV line: L202 (require more than 972 A)

The problem can be solved taking into consideration “open circuit of some distribution lines“ and “replacement of the 11 kV transformer CB to break the actual short circuit current“ in 2015, 2020 and 2025 as is shown in Table 6.4-10, Table 6.4-14 and Table 6.4-18 respectively.

Regarding requirement of SC in 2015 and 2020, the distribution system can be operated without additional SC judging from Table 6.4-11 and Table 6.4-15 which show the results of voltage confirmation after adjustment.

It is necessary to add additional SC on 11 kV system at Brookfields J/S in 2025 to have adequate voltage adjustment. However, actual capacity and location shall be decided considering total system losses and operability.

Regarding overbalance of thermal capacity of the facilities, it is not faulty in year 2015 as is shown in Table 6.4-12, however, 2020 and 2025 shall have a lack of short circuit current of CB and a lack of thermal capacity on some lines as is shown in Table 6.4-16 and Table 6.4-20.

It is recommendable to re-calculate after re-checking of;

a) Specification of installed generators and number of synchronized generators (to the lack of short circuit current of CB).
b) Actual line specification, especially from Freetown to Congo Cross S/S line (L450) and Freetown to Brookfields J/S (L550 and L551), concerning which size shall be larger than estimated specifications (to solve lack of continuous thermal capacity).

4) Power flow calculation at N-1 fault

As analysis ⑦, this calculation is to confirm that there exists over thermal capability when circuit fault happens on dual lines and/or loop systems on condition that there is no feeder of lack of thermal capacity when short circuit fault happens.
Load shedding shall be applied if voltage drop of bus bar comes to more than 10%. After load shedding, bus voltage is confirmed within adjustable range. Then re-confirmation of overloaded facilities shall be conducted.

【2015】

Table 6.4-21 Assumption of fault in 2015

No.	Facility	Faulty lines (Line No.)	Result and Remarks
1	33 kV line	Kingtom～Falcon Bridge (L3101)	*No thermal capacity problem*
2		Kingtom～Freetown (L3903)	*No thermal capacity problem*
3		Falcon Bridge～Blackhall Road (L3201)	*No thermal capacity problem*
4		Blackhall Road～Wilberforce (L3301)	*No thermal capacity problem*
5		Blackhall Road～Wellington (L3302)	*No thermal capacity problem*
6		Blackhall Road～Freetown (L3902)	*No thermal capacity problem*
7		Wilberforce～Regent (L3601)	*No thermal capacity problem*
8		Wilberforce～Freetown (L3901)	***Faulty (See Table 6.4-22)***
9		Wilberforce～Goderich (L3602)	Radial system
10		Wellington～Jui (L3701)	*No thermal capacity problem*
11		Regent～Jui (L3804･L3604)	*No thermal capacity problem*
12		Goderich～Tombo (L31001)	York～Tombo: not connected
13		Jui～Lumpa (L31101)	Radial system
14		Lumpa～Tombo (L31201)	Radial system
15	11 kV line	Kingtom(A-Bus)～Falcon Bridge (L103)	*No thermal capacity problem*
16		Kingtom(A-Bus)～Falcon Bridge (L104)	*No thermal capacity problem*
17		Kingtom(B-Bus)～Falcon Bridge (L103A)	*No thermal capacity problem*
18		Kingtom(B-Bus)～Falcon Bridge (L102)	*No thermal capacity problem*
19		Kingtom(A-Bus)～Congo Cross (L120)	Open circuit
20		Kingtom(B-Bus)～Congo Cross (L105)	***Faulty (See Table 6.4-23)***
21		Kingtom(A-Bus)～Brookfields (L107)	***Faulty (See Table 6.4-24)***
22		Kingtom(B-Bus)～Brookfields (L106)	***Faulty (See Table 6.4-25)***
23		Kingtom(A-Bus)～Freetown (L150)	*No thermal capacity problem*
24		Kingtom(B-Bus)～Freetown (L151)	*No thermal capacity problem*
25		Falcon Bridge～Blackhall Road (L203)	Open circuit
26		Falcon Bridge～Blackhall Road (L202)	*No thermal capacity problem*
27		Congo Cross～Wilberforce (L440)	*No thermal capacity problem*
28		Congo Cross～Freetown(A-Bus) (L450)	*No thermal capacity problem*
29		Brookfields～Wilberforce (L523)	*No thermal capacity problem*
30		Brookfields～Wilberforce (L522)	*No thermal capacity problem*
31		Brookfields～Freetown(A-Bus) (L550)	***Faulty (See Table 6.4-26)***
32		Brookfields～Freetown(B-Bus) (L551)	***Faulty (See Table 6.4-27)***

[Source] JICA Study Team

＜Fault No. 8（L3901）＞

Table 6.4-22 Neck point on fault No. 8

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L106	Kingtom	355A	1,250A	356 A (6.8 MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 20（L105）＞

Table 6.4-23 Neck point on fault No. 20

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L106	Kingtom	355A	1,250A	364 A (6.9MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 21（L107）＞

Table 6.4-24 Neck point on fault No. 21

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L106	Kingtom	355A	1,250A	425A (8.1 MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 22（L106）＞

Table 6.4-25 Neck point on fault No. 22

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L107	Kingtom	355A	1,250A	417A (7.9 MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 31（L550）＞

Table 6.4-26 Neck point on fault No. 31

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11kV line: L106	Kingtom	355A	1,250A	364A (6.9MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 32（L551）＞

Table 6.4-27 Neck point on fault No. 32

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11kV line: L107	Kingtom	355A	1,250A	367A (6.8MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Normal: Countermeasure to have reliability and capability to short circuit at N-1 fault＞

a) Lack of continuous rated current of 11 kV line: L106 (require more than 425 A)
b) Lack of continuous rated current of 11 kV line: L107 (require more than 417 A)

【2020】

Table 6.4-28 Assumption of fault at year 2020

No.	Facility	Faulty lines (Line No.)	Result and Remarks
1	33 kV line	Kingtom～Falcon Bridge (L3101)	***Faulty (See Table 6.4-29)***
2		Kingtom～Freetown (L3903)	***Faulty (See Table 6.4-30)***
3		Falcon Bridge～Blackhall Road (L3201)	***Faulty (See Table 6.4-31)***
4		Blackhall Road～Wilberforce (L3301)	***Faulty (See Table 6.4-32)***
5		Blackhall Road～Wellington (L3302)	***Faulty (See Table 6.4-33)***
6		Blackhall Road～Freetown (L3902)	*No thermal capacity problem*
7		Wilberforce～Regent (L3601)	***Faulty (See Table 6.4-34)***
8		Wilberforce～Freetown (L3901)	***Faulty (See Table 6.4-35)***
9		Wilberforce～Goderich (L3602)	Radial system
10		Wellington～Jui (L3701)	*No thermal capacity problem*
11		Regent～Jui (L3804･L3604)	***Faulty (See Table 6.4-36)***
12		Goderich～Tombo (L31001)	York～Tombo Not installed
13		Jui～Lumpa (L31101)	Radial system
14		Lumpa～Tombo (L31201)	Radial system
15	11 kV line	Kingtom(A-Bus)～Falcon Bridge (L103)	***Faulty (See Table 6.4-37)***
16		Kingtom(A-Bus)～Falcon Bridge (L104)	***Faulty (See Table 6.4-38)***
17		Kingtom(B-Bus)～Falcon Bridge (L103A)	***Faulty (See Table 6.4-39)***
18		Kingtom(B-Bus)～Falcon Bridge (L102)	***Faulty (See Table 6.4-40)***
19		Kingtom(A-Bus)～Congo Cross (L120)	Open circuit
20		Kingtom(B-Bus)～Congo Cross (L105)	***Faulty (See Table 6.4-41)***
21		Kingtom(A-Bus)～Brookfields (L107)	***Faulty (See Table 6.4-42)***
22		Kingtom(B-Bus)～Brookfields (L106)	***Faulty (See Table 6.4-43)***
23		Kingtom(A-Bus)～Freetown (L150)	***Faulty (See Table 6.4-44)***
24		Kingtom(B-Bus)～Freetown (L151)	***Faulty (See Table 6.4-45)***
25		Falcon Bridge～Blackhall Road (L203)	Open circuit
26		Falcon Bridge～Blackhall Road (L202)	*No thermal capacity problem*
27		Congo Cross～Wilberforce (L440)	***Faulty (See Table 6.4-46)***
28		Congo Cross～Freetown(A-Bus) (L450)	Open circuit
29		Brookfields～Wilberforce (L523)	***Faulty (See Table 6.4-47)***
30		Brookfields～Wilberforce (L522)	***Faulty (See Table 6.4-48)***
31		Brookfields～Freetown(A-Bus) (L550)	Open circuit
32		Brookfields～Freetown(B-Bus) (L551)	Open circuit

[Source] JICA Study Team

＜Fault No. 1（L3101）＞

Table 6.4-29 Neck point on fault No. 1

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33kV line: L3901	Wilberforce	407A	1,250A	493A (28.2MW)
	Freetown		1,250A	
11kV line: L105	Kingtom	355A	1,250A	546A (9.3MW)
	Congo Cross		1,250A	
11kV line: L106	Kingtom	355A	1,250A	577A (10.9MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 2（L3903）＞

Table 6.4-30 Neck point on fault No. 2

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33kV line: L3901	Wilberforce	407A	1,250A	513A (29.2MW)
	Freetown		1,250A	
11kV line: L107	Kingtom	355A	1,250A	573A (10.6MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 3（L3201）＞

Table 6.4-31 Neck point on fault No. 3

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33kV line: L3901	Wilberforce	407A	1,250A	481A (27.5MW)
	Freetown		1,250A	
11kV line: L105	Kingtom	355A	1,250A	547A (9.4MW)
	Congo Cross		1,250A	
11kV line: L107	Kingtom	355A	1,250A	556A (10.3MW)
	Brookfields		1,250A	
11kV line: L106	Kingtom	355A	1,250A	572A (10.8MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 4（L3301）＞

Table 6.4-32 Neck point on fault No. 4

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11kV line: L107	Kingtom	355A	1,250A	553A (10.2MW)
	Brookfields		1,250A	
11kV line: L106	Kingtom	355A	1,250A	563A (10.7MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 5（L3302）＞

33 kV bus voltage will go down to more than 10% at Wellington S/S when line No. L3302 fault makes the open loop of 33 kV network. In order to prevent this voltage drop, 33 kV line No. L3701 shall be immediately opened when L3302 has fault and also load shedding shall be applied.

This solution makes the system voltage within permissible range. However, the following thermal capacity problems shall be considered.

Table 6.4-33 Neck point on fault No. 5

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	422A (24.2MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	543A (9.3MW)
	Congo Cross		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	560A (10.6MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 7（L3601）＞

Table 6.4-34 Neck point on fault No. 7

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3302	Blackhall Road	407A	1,250A	409A (23.2MW)
	Wellington		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 8（L3901）＞

Table 6.4-35 Neck point on fault No. 8

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3302	Blackhall Road	407A	1,250A	409A (23.2MW)
	Wellington		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	573A (10.2MW)
	Congo Cross		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	633A (11.8MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	652A (12.4MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 10（L3701）＞

Table 6.4-36 Neck point on fault No. 10

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33kV line: L3901	Wilberforce	407A	1,250A	425A (24.3MW)
	Freetown		1,250A	
11kV line: L105	Kingtom	355A	1,250A	543A (9.3MW)
	Congo Cross		1,250A	
11kV line: L107	Kingtom	355A	1,250A	553A (10.2MW)
	Brookfields		1,250A	
11kV line: L106	Kingtom	355A	1,250A	568A (10.8MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 15（L103）＞

Table 6.4-37 Neck point on fault No. 15

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L107	Kingtom	355A	1,250A	569A (10.4MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 16（L104）＞

Table 6.4-38 Neck point on fault No. 16

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11kV line: L107	Kingtom	355A	1,250A	571A (10.5MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 17（L103A）＞

Table 6.4-39 Neck point on fault No. 17

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11kV line: L105	Kingtom	355A	1,250A	545A (9.3MW)
	Congo Cross		1,250A	
11kV line: L106	Kingtom	355A	1,250A	573A (10.8MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 18（L102）＞

Table 6.4-40 Neck point on fault No. 18

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L105	Kingtom	355A	1,250A	546A (9.3MW)
	Congo Cross		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	580A (11.0MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 20（L105）＞

Table 6.4-41 Neck point on fault No. 20

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L107	Kingtom	355A	1,250A	700A (12.8MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	845A (15.8MW)
	Brookfields		1,250A	
11 kV line: L440	Congo Cross	351A	1,250A	490A (8.4MW)
	Wilberforce		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 21（L107）＞

Table 6.4-42 Neck point on fault No. 21

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L105	Kingtom	355A	1,250A	604A (10.5MW)
	Congo Cross		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	950A (17.7MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 22（L106）＞

Table 6.4-43 Neck point on fault No. 22

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L105	Kingtom	355A	1,250A	662A (11.7MW)
	Congo Cross		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	911A (17.0MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 23（L150）＞

Table 6.4-44 Neck point on fault No. 23

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L105	Kingtom	355A	1,250A	561A (9.7MW)
	Congo Cross		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	740A (14.0MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 24（L151）＞

Table 6.4-45　Neck point on fault No. 24

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11kV line: L107	Kingtom	355A	1,250A	698A (12.5MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 27（L440）＞

Table 6.4-46　Neck point on fault No. 27

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L107	Kingtom	355A	1,250A	563A (10.5MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	594A (11.3MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 29（L523）＞

Table 6.4-47　Neck point on fault No. 29

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L105	Kingtom	355A	1,250A	576A (9.9MW)
	Congo Cross		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 30（L522）＞

Table 6.4-48　Neck point on fault No. 30

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L105	Kingtom	355A	1,250A	576A (9.9MW)
	Congo Cross		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Neck facilities on normal operation and at N-1 fault after taking into consideration countermeasures to short circuit problems＞

a) Lack of short circuit current of 11 kV CB for transformer feeder at Blackhall Road (Required short circuit current is more than 21.3 kA).
b) Lack of continuous rated current of 11 kV line: L3302 (require more than 409 A)
c) Lack of continuous rated current of 11 kV line: L3901 (require more than 513 A)
d) Lack of continuous rated current of 11 kV line: L105 (require more than 662 A)
e) Lack of continuous rated current of 11 kV line: L106 (require more than 950 A)
f) Lack of continuous rated current of 11 kV line: L107 (require more than 911 A)
g) Lack of continuous rated current of 11 kV line: L440 (require more than 490 A)

【2025】

Table 6.4-49 Assumption of fault at year 2025

No.	Facility	Faulty lines (Line No.)	Result and Remarks
1	33 kV line	Kingtom～Falcon Bridge (L3101)	***Faulty (See Table 6.4-50)***
2		Kingtom～Freetown (L3903)	***Faulty (See Table 6.4-51)***
3		Falcon Bridge～Blackhall Road (L3201)	***Faulty (See Table 6.4-52)***
4		Blackhall Road～Wilberforce (L3301)	***Faulty (See Table 6.4-53)***
5		Blackhall Road～Wellington (L3302)	***Faulty (See Table 6.4-54)***
6		Blackhall Road～Freetown (L3902)	***Faulty (See Table 6.4-55)***
7		Wilberforce～Regent (L3601)	***Faulty (See Table 6.4-56)***
8		Wilberforce～Freetown (L3901)	***Faulty (See Table 6.4-57)***
9		Wilberforce～Goderich (L3602)	***Required load shedding***
10		Wellington～Jui (L3701)	***Faulty (See Table 6.4-58)***
11		Regent～Jui (L3804･L3604)	***Faulty (See Table 6.4-59)***
12		Goderich～Tombo (L31001)	*No thermal capacity problem*
13		Jui～Lumpa (L31101)	***Required load shedding***
14		Lumpa～Tombo (L31201)	*No thermal capacity problem*
15	11 kV line	Kingtom(A-Bus)～Falcon Bridge (L103)	*No thermal capacity problem*
16		Kingtom(A-Bus)～Falcon Bridge (L104)	*No thermal capacity problem*
17		Kingtom(B-Bus)～Falcon Bridge (L103A)	*No thermal capacity problem*
18		Kingtom(B-Bus)～Falcon Bridge (L102)	*No thermal capacity problem*
19		Kingtom(A-Bus)～Congo Cross (L120)	Open circuit
20		Kingtom(B-Bus)～Congo Cross (L105)	***Faulty (See Table 6.4-60)***
21		Kingtom(A-Bus)～Brookfields (L107)	***Faulty (See Table 6.4-61)***
22		Kingtom(B-Bus)～Brookfields (L106)	***Faulty (See Table 6.4-62)***
23		Kingtom(A-Bus)～Freetown (L150)	***Faulty (See Table 6.4-63)***
24		Kingtom(B-Bus)～Freetown (L151)	***Faulty (See Table 6.4-64)***
25		Falcon Bridge～Blackhall Road (L203)	Open circuit
26		Falcon Bridge～Blackhall Road (L202)	*No thermal capacity problem*
27		Congo Cross～Wilberforce (L440)	***Faulty (See Table 6.4-66)***
28		Congo Cross～Freetown(A-Bus) L450	Open circuit
29		Brookfields～Wilberforce (L523)	***Faulty (See Table 6.4-67)***
30		Brookfields～Wilberforce (L522)	***Faulty (See Table 6.4-68)***
31		Brookfields～Freetown(A-Bus) (L550)	Open circuit
32		Brookfields～Freetown(B-Bus) (L551)	Open circuit

[Source] JICA Study Team

＜Fault No. 1（L3101）＞

Table 6.4-50 Neck point on fault No. 1

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33 kV line: L3901	Wilberforce	407A	1,250A	707A (39.6MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	857A (13.1MW)
	Congo Cross		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	815A (14.4MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 2（L3903）＞

Table 6.4-51 Neck point on fault No. 2

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33 kV line: L3901	Wilberforce	407A	1,250A	738A (41.4MW)
	Freetown		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	906A (14.6MW)
	Brookfields		1,250A	
11 kV line: L151	Kingtom	1,210A	1,250A	1,354A (25.2MW)
	Freetown		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 3（L3201）＞

Table 6.4-52 Neck point on fault No. 3

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33 kV line: L3901	Wilberforce	407A	1,250A	707A (39.9MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	858A (13.1MW)
	Congo Cross		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	885A (14.3MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	811A (14.4MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 4（L3301）＞

Table 6.4-53 Neck point on fault No. 4

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33 kV line: L3901	Wilberforce	407A	1,250A	664A (37.5MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	855A (13.1MW)
	Congo Cross		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	889A (14.2MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	805A (14.3MW)
	Brookfields		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	985A (13.5MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 5（L3302）＞

33 kV loop system will be open system because of fault on 33 kV line No. L3302 and end voltage at Wellington S/S will drop to more than 20 %.

In order to prevent this voltage drop, when L3302 was faulty, then L3701 shall be immediately opened and Wellington line disconnected from the network (apply load shedding).

Try to get voltage stability to take above solution. Voltage drop can be kept within 10% to take above action. However, the following thermal capacity problems shall be solved.

Table 6.4-54 Neck point on fault No. 5

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3601	Wilberforce	388A	1,250A	403A (22.8MW)
	Regent		630A	
33 kV line: L3901	Wilberforce	407A	1,250A	683A (38.9MW)
	Freetown		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 6（L3902）＞

Table 6.4-55 Neck point on fault No. 6

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	579A (32.5MW)
	Freetown		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 7（L3601）＞

Table 6.4-56 Neck point on fault No. 7

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3302	Blackhall Road	407A	1,250A	569A (32.5MW)
	Wellington		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	988A (13.9MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 8（L3901）＞

Table 6.4-57 Neck point on fault No. 8

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3301	Blackhall Road	407A	1,250A	462A (26.2MW)
	Wilberforce		1,250A	
33 kV line: L3302	Blackhall Road	407A	1,250A	459A (26.2MW)
	Wellington		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	892A (14.5MW)
	Congo Cross		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	1,000A (16.8MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	929A (17.2MW)
	Brookfields		1,250A	
11 kV line: L151	Kingtom	1,210A	1,250A	1,281A (23.2MW)
	Freetown		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	1,003A (14.0MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 9（L3602）＞

33 kV loop system will be opened because of the fault of 33 kV line No. L3602 and end voltage at Goderich S/S will be down more than 30 % which may cause the voltage collapse.

In order to prevent this fault, 33 kV line No. L31001 shall be immediately opened and Goderich line shall be disconnected from the loop when L3602 has a fault. To take this solution, voltage drop can be kept within 10 % and there are not any thermal capacity problems.

＜Fault No. 10（L3701）＞

Table 6.4-58 Neck point on fault No. 10

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33 kV line: L3601	Wilberforce	388A	1,250A	402A (22.8MW)
	Regent		630A	
33 kV line: L3901	Wilberforce	407A	1,250A	687A (39.1MW)
	Freetown		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	893A (14.2MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	804A (14.5MW)
	Brookfields		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	1,019A (14.1MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 11（L3804･L3604）＞

Table 6.4-59 Neck point on fault No. 11

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33 kV line: L3302	Blackhall Road	407A	1,250A	501A (28.6MW)
	Wellington		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 13（L31101）＞

33 kV loop system will be opened because of the fault on 33 kV line No. L31101 and end voltage at Lumpa S/S will be down more than 30% which may cause the voltage collapse.
In order to prevent this fault, 33 kV line No. L31201 shall be immediately disconnected from the loop when L31101 has a fault.

Voltage drop can be kept within 10% to take above action and there are no thermal capacity problems.

＜Fault No. 20（L105）＞

Table 6.4-60 Neck point on fault No. 20

Facility below required thermal capacity to the distribution lines		**Continuous current of line**	**Rated short circuit current of CB**	**Power flow**
33 kV line: L3901	Wilberforce	407A	1,250A	618A (35.0MW)
	Freetown		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	1,115A (18.1MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	1,245A (21.7MW)
	Brookfields		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	1,060A (14.8MW)
	Blackhall Road		1,250A	
11 kV line: L440	Congo Cross	351A	1,250A	771A (12.4MW)
	Wilberforce		1,250A	
11 kV line: L523	Brookfields	455A	1,250A	632A (9.4MW)
	Wilberforce		1,250A	
11 kV line: L522	Brookfields	455A	1,250A	631A (9.4MW)
	Wilberforce		1,250A	
Wilberforce 33/11 kV Transformer	33kV	10MVA	630A	177A (10.0 MW)
	11kV		630A	532A (10.1 MVA)

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 21（L107）＞

Table 6.4-61 Neck point on fault No. 21

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	615A (34.5MW)
	Freetown		1,250A	
11 kV line: L102	Kingtom	355A	1,250A	531A (2.4MW)
	Falcon Bridge		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	952A (14.7MW)
	Congo Cross		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	1,408A (23.6MW)
	Brookfields		1,250A	
11 kV line: L151	Kingtom	1,210A	1,250A	1,327A (24.4MW)
	Freetown		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 22（L106）＞

Table 6.4-62 Neck point on fault No. 22

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	603A (34.1MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	1,018A (16.3MW)
	Congo Cross		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	1,381A (23.1MW)
	Brookfields		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	991A (14.1MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 23（L150）＞

Table 6.4-63 Neck point on fault No. 23

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	607A (34.2MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	874A (13.5MW)
	Congo Cross		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	1,009A (18.1MW)
	Brookfields		1,250A	
11 kV line: L151	Kingtom	1,210A	1,250A	1,449A (26.3MW)
	Freetown		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	1,042A (15.2MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 24（L151）＞

Table 6.4-64 Neck point on fault No. 24

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	612A (34.4MW)
	Freetown		1,250A	
11 kV line: L102	Kingtom	355A	1,250A	486A (3.7MW)
	Falcon Bridge		1,250A	
11 kV line: L107	Kingtom	355A	1,250A	1,087A (17.2MW)
	Brookfields		1,250A	
11 kV line: L150	Kingtom	1,210A	1,250A	1,300A (23.6MW)
	Freetown		1,250A	
11 kV line: L202	Falcon Bridge	430A	1,250A	1,125A (14.5MW)
	Blackhall Road		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 27（L440）＞

Table 6.4-65 Neck point on fault No. 27

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
11 kV line: L107	Kingtom	355A	1,250A	894A (14.4MW)
	Brookfields		1,250A	
11 kV line: L106	Kingtom	355A	1,250A	829A (14.8MW)
	Brookfields		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No.29（L523）＞

Table 6.4-66 Neck point on fault No. 29

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	588A (33.1MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	906A (13.7MW)
	Congo Cross		1,250A	
11 kV line: L522	Brookfields	455A	1,250A	502A (6.6MW)
	Wilberforce		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Fault No. 30（L522）＞

Table 6.4-67 Neck point on fault No. 30

Facility below required thermal capacity to the distribution lines		Continuous current of line	Rated short circuit current of CB	Power flow
33 kV line: L3901	Wilberforce	407A	1,250A	588A (33.1MW)
	Freetown		1,250A	
11 kV line: L105	Kingtom	355A	1,250A	906A (13.7MW)
	Congo Cross		1,250A	
11 kV line: L523	Brookfields	455A	1,250A	502A (6.6MW)
	Wilberforce		1,250A	

(*Red value shows that the calculated short circuit current is more than the permissible one of facilities)

＜Neck facilities on normal operation and at N-1 fault after taking into consideration countermeasures to short circuit problems＞

a) Lack of short circuit current of 11 kV CB for transformer feeder at Blackhall Road (Required short circuit current is more than 21.3 kA).

b) Lack of continuous rated current of 11 kV line: L3301 (require more than 462 A)
c) Lack of continuous rated current of 11 kV line: L3302 (require more than 569 A)
d) Lack of continuous rated current of 11 kV line: L3601 (require more than 403 A)
e) Lack of continuous rated current of 11 kV line: L3901 (require more than 738 A)
f) Lack of continuous rated current of 11 kV line: L102 (require more than 531 A)
g) Lack of continuous rated current of 11 kV line: L105 (require more than 1,018 A)
h) Lack of continuous rated current of 11 kV line: L107 (require more than 1,381 A)
i) Lack of continuous rated capacity of 11 kV line: L106 and CB of both sides (require more than 1,408A)
j) Lack of continuous rated capacity of 11 kV line: L150 and CB of both sides (require more than 1,300A)
k) Lack of continuous rated capacity of 11 kV line: L202 (require more than 1,125A)
l) Lack of continuous rated current of 11 kV line: L440 (require more than 771 A)
m) Lack of continuous rated current of 11 kV line: L523 (require more than 632 A)
n) Lack of continuous rated current of 11 kV line: L522 (require more than 631 A)
o) Lack of capacity of Blackhall Road 33/ 11 kV transformer (required capacity is more than 21.3 MVA)
p) Lack of capacity of Wilberforce 33/ 11 kV transformer (required capacity is more than 10.1 MVA)

It is obvious that the lack of thermal capacity of the lines and countermeasure to voltage drop is increasing according to the increase in demand and it is necessary to implement an adequate solution.
And also thermal capacity problems are increasing from 2015 to 2020 because of the countermeasures to the lack of short circuit capacity.

Meanwhile, replacement of CB incurs a lot of cost and power stoppages and should be avoided as much as possible.

It is recommendable to provide basic conditions to the system such as short circuit current, 20 kA for 11 kV and 25 kA for 33 kV systems respectively. However, Lumpa S/S which may be connected to the international transmission line from Kenema – Mokango - Lumpa, shall be considered 25 kA for 11 kV and 31 kA for 33 kV.

It is also recommendable to establish adequate system by 2015 including setting of SC;

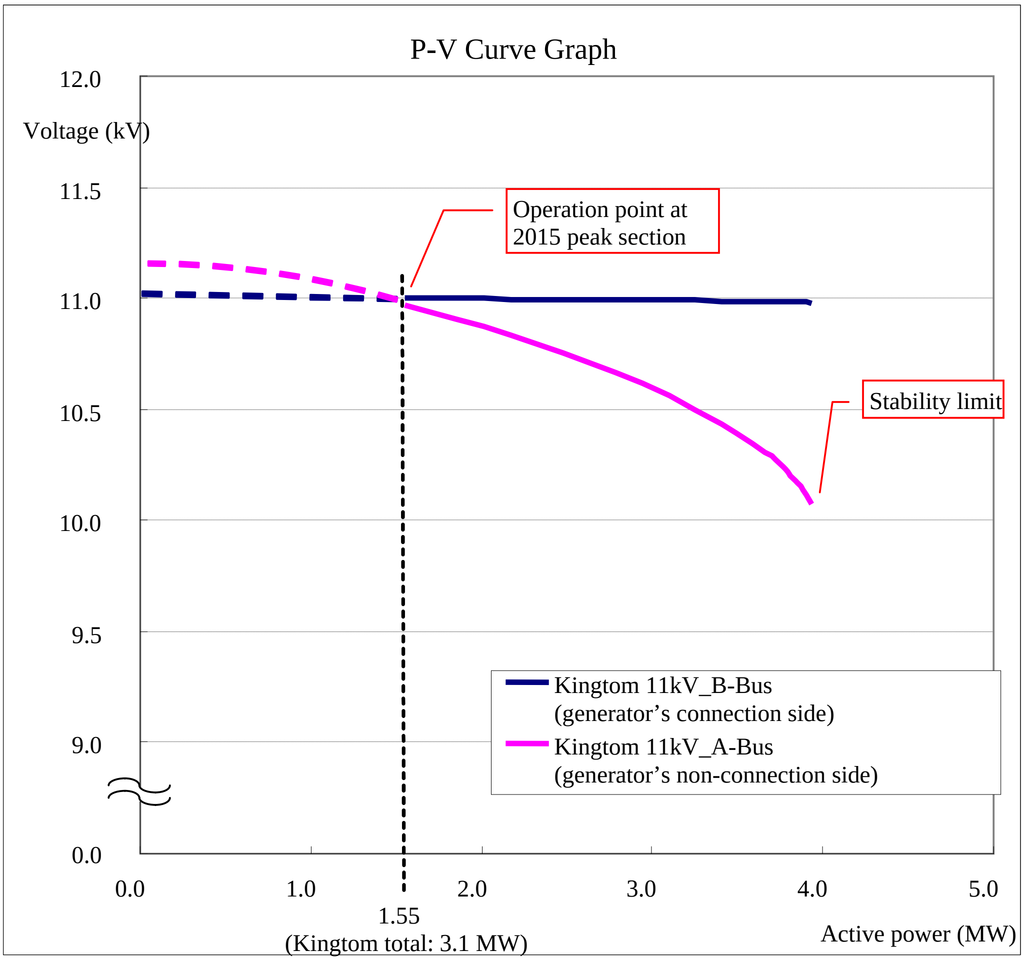
a) Countermeasures to short circuit capacity;
   Re-check the countermeasures to the 11 kV CB in Blackhall Road P/S
   - Actual number of new generator sets with actual technical specifications, and
   - Line constant of 11 kV and 33 kV lines (length, specification, route and arrangement).

b) Countermeasures to the lack of line capacity
   There is a lack of line capacity between Kingtom P/S and Brookfields J/S. Re-check the following items;
   - The size of new trunk lines between Freetown S/S and Brookfields J/S shall be more than 185 sq which was supposed in this study to consider cables as much as possible considering the capital of Sierra Leone,
   - Re-check continuous rated current of all 11 kV and 33 kV lines to use manufacturers information,
   - Re-check peak demand at Brookfields J/S, and
   - Re-check actual power flow on 11 kV radial systems between Brookfields J/S and Kingtom P/S/ Congo Cross S/S/ Brackhall Road P/S/ Wilberforce S/S.

5) Analysis of Voltage Stability

Voltage stability study shall normally be conducted after taking adequate countermeasures on the faulty points. However, there are a lot of unknown factors until year 2015, such as the number of new generator sets and 11 kV/ 33 kV lines and also international connections. Therefore, the voltage stability analysis shall be conducted based on the present assumptions to year 2015.
Analysis shall be applied at Kingtom P/S.
There is an enough operation margin and generator can operate at stable conditions in 2015 as shown in Fig. 6.4-20.

【Peak in 2015】



[Source] JICA Study Team

Fig. 6.4-20 P-V curve at 11 kV Bus of Kingtom P/S

6) Calculation of Frequency

The power supply to Western Area in 2015, with peak demand supposed as 67 MW, consists of 50 MW from Bumbuna P/S by 161 kV, single circuit of about 205 km long.

It is necessary to know the system conditions when this 161 kV system has fault, and it is required to minimize the power outage area when faults happen.

Frequency calculation shall be applied to the above severe conditions.

【Year 2015】

＜Frequency when Bumbuna 161 kV line has a fault＞

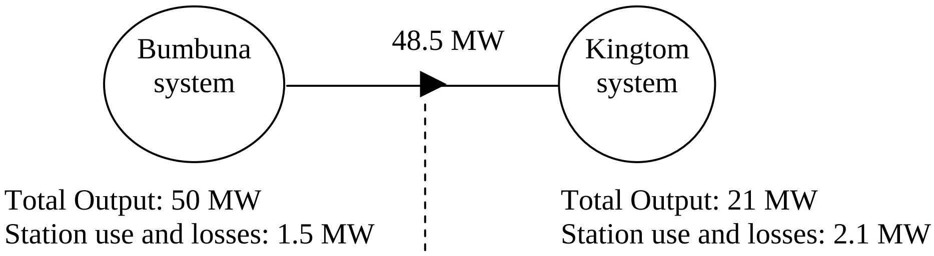


Fig. 6.4-21 Bumbuna 161 kV Transmission line

The relation between imbalance of supply/ demand and variation of frequency can be calculated with characteristic of system frequency: K [MW/0.1 Hz],

$$\Delta P = K \cdot \Delta F$$

Where; (ΔP : Imbalance of supply/ demand [MW], ΔF : variation of frequency [0.1 Hz])

Generally, system frequency constant K [MW/0.1 Hz] is from 1 to 2 [% MW/0.1 Hz] of the capacity of the system,

K = System capacity: 71 MW (total generated capacity) x 1～2 %
＝ 0.7～1.4［MW/0.1 Hz］

Therefore, when Bumbuna 161 kV line has a fault, power supply from Bumbuna to Kingtom system (48.5 MW) shall be reduced, and frequency drop will be:

$$\Delta F = \frac{\Delta P}{K} = \frac{\blacktriangle 48.5 MW}{0.7 \sim 1.4 \mathrm{MW/0.1Hz}} = \blacktriangle 6.9 \sim \blacktriangle 3.5 \mathrm{Hz}$$

Therefore, system frequency will drop from 50 Hz to 46.5～43.1 Hz.

This calculation shall be applied to the system so that the variation of the frequency is within 1 Hz.

Therefore, actual frequency drop shall be more than the above calculation. This frequency change is more than the adjustable range of the generator as is shown in Table 6.4-68. It seems that the generator connected to Kingtom system will drop out when 161 kV system is at fault.

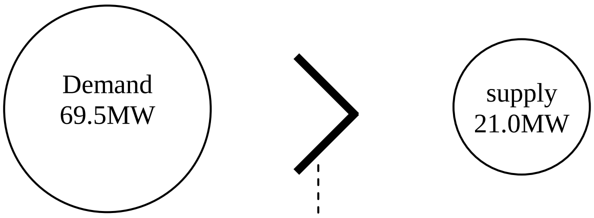
Table 6.4-68 Requirements for frequencies of rotating electrical machines

Frequency range	**Requirements at voltage values from 0.95 ~ 1.03 [p.u.]**
0.98 ~ 1.02 [p.u.]	No practical problems should be caused by continuous operation.
0.95 ~ 1.03 [p.u.]	No practical problems should occur.

[Source] JIC C4034-1

<Kingtom system operation when Bumbuna 161 kV has a fault>

Fig. 6.4-21 shows Kingtom System after 161 kV line fault.



Name of Station	Demand [MW]	Name of Station	Supply [MW]
Kingtom A-Bus	1.55	Kingtom P/S	4.4
Kingtom B-Bus	1.55		
Station of Kingtom	0.3		
Falcon Bridge	10.2		
Blackhall Road	11.8		
Station of Blackhall Road	1.2		
Congo Cross	5.8		
Brookfields	9.7	Blackhall Road P/S	16.6
Wilberforce	9.1		
Wellington	5.2		
Regent	2.5		
Goderich	5.1		
Jui	4.8		
System losses	0.6		
Total	69.4		21.0

Fig. 6.4-22 Kingtom System after 161 kV transmission line fault

It can be seen that the demand and supply balance will be dropout as is shown in Fig. 6.4-22 which shows lack of supply causing the drop of frequency. To prevent this frequency problem, it is necessary to reduce the demand in Kingtom system to 21 MW.

Priority demand was assumed around Kingtom P/S and considering system configuration in 2015, and estimated demand is shown in Table 6.4-69.

Table 6.4-69 Demand to be supplied by Kingtom system

Name of Station	Demand [MW]	Remarks
Kingtom B-Bus	1.55	
Station of Kingtom	0.3	
Half of Falcon Bridge	5.1	
Blackhall Road	11.8	
Station of Blackhall Road	1.2	
System losses	—	
Total	19.95	Supply by Kingtom: 21 MW

It is necessary to make adequate load shedding in order to fulfill the above load requirement and some of the CBs shall be opened.

After considering load shedding as mentioned in Table 6.4-69, Kingtom System has an excess supply which is about 1 MW and system frequency will go up. This frequency variation is,

$$\Delta F = \frac{\Delta P}{K} = \frac{1.0MW}{0.7\sim1.4\text{MW}/0.1\text{Hz}} = 0.07\sim0.14\text{Hz}$$

Frequency will go up from 50 Hz to 50.07～50.14 Hz. However, this frequency range is within the permissible range. Therefore, Kingtom system can be operated continuously. The excess supply power of about 1 MW will be adjusted by existing generator at Kingtom and/or Brackhall Road P/S.

It is necessary to provide adequate facilities including communication and protection system to comply with the above countermeasure that is load shedding.

7) Analysis of Stability

The frequency calculation in item 6) above confirmed continuous operation of Kingtom system with different frequency through implementation of load shedding after a system fault in the Bumbuna 161 kV transmission line and maintaining the supply demand balance of the Kingtom system. The analysis of stability confirms whether the generators inside the Kingtom system are capable of maintaining synchronous operation under the influence of a system fault in the Bumbuna line and load shedding of fault cascading prevention system.

【2015】

【Conditions of stability analysis】

- Duration of Bumbuna 161 kV transmission fault: 100 msec
- Duration of load shedding time: After fault 1000 msec

[Feeders for load shedding]

- ○ Open 33 kV feeders: L3903,L3301,L3302,L3902
- ○ Open 11 kV feeders: L105,L106,L151,L103,L104
- ○ Open 11 kV feeder: Half of demand on Falcon Bridge

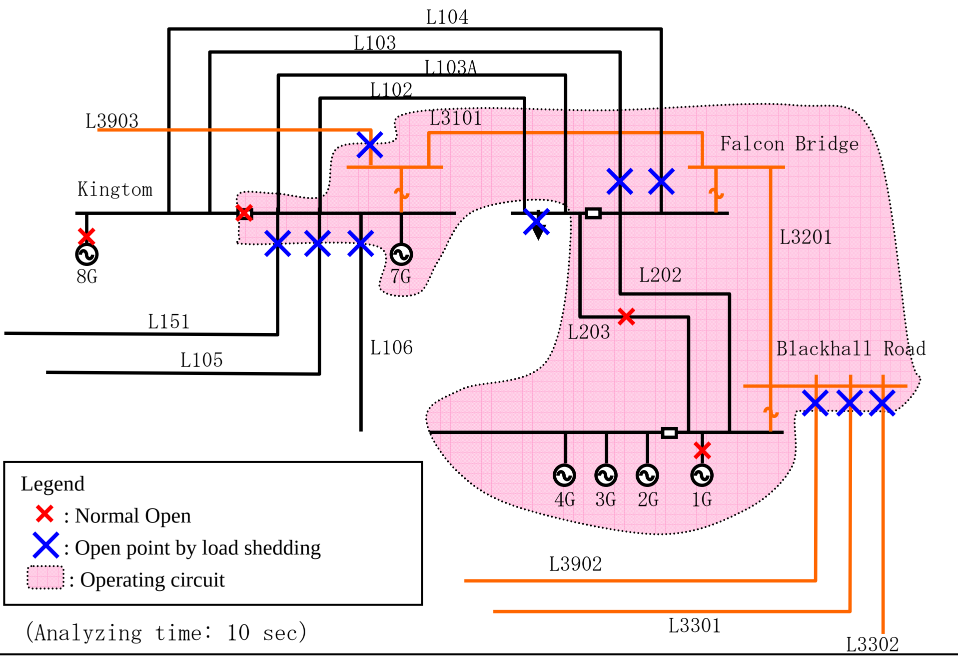


Fig. 6.4-23 Kingtom system after considering fault countermeasures

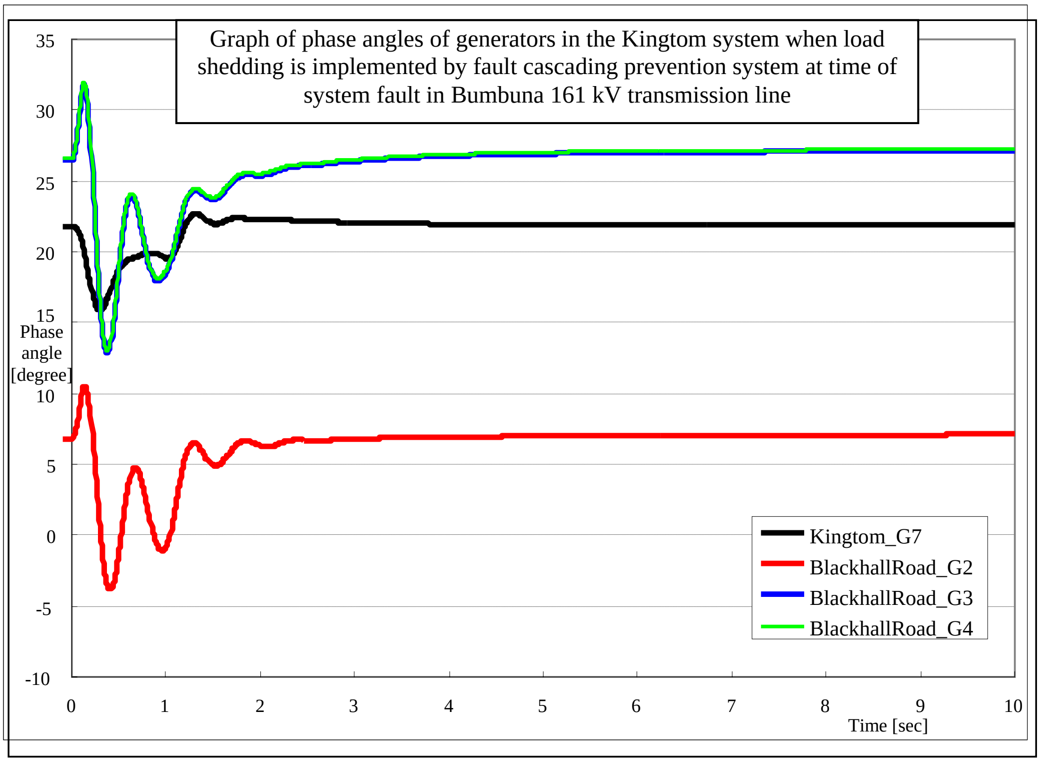


Fig. 6.4-24 Phase angle of generator

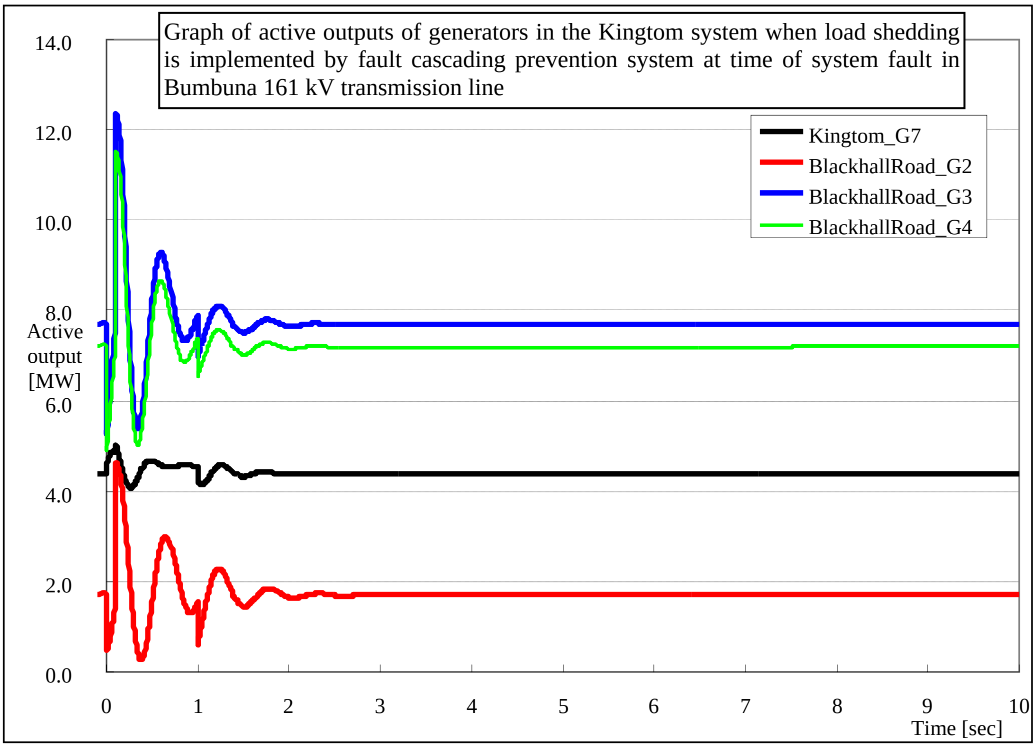


Fig. 6.4-25 Positive power of generator

Kingtom system can continue the operation to take adequate load shedding during161 kV Bumbuna transmission line fault. Fig. 6.4-24 and fig. 6.4-25 shows these operating conditions.

【Conclusion】

Peak demand from 2015 to 2025 at Western Area is increasing about 7 to 8% of average annual increasing rate that is Demand at 2025 is more than ten times of 2015 as is shown on Table 6.4-70.

Based on the above assumption, the result of system analysis up to analysis ⑦ [N-1 fault] is shown in Table 6.4-71.

Table 6.4-70 Transition of Power System Development

Description	Unit	2015	2020	2025
Peak demand	[MW]	67.4	97.0	136.3
11 kV Lines (Except feeder)	[Lines]	18	18	18
33 kV Lines	[Lines]	11	13	14
161 kV Lines	[Lines]	1	2	2
No. of power stations	[station]	3	4	4
Total of output	[MW]	76.4	156.2	154.6
11 kV substation	[station]	2	2	2
33 kV substation	[station]	6	8	8
161 kV substation	[station]	1	1	1

[Source] JICA Study Team

Table 6.4-71 List of the Outcome on each Phase

Items of analysis	Unit	2015	2020	2025
① Required capacity of SC	[MVA]	36	72	114
② Open lines for countermeasure to short circuit	[circuit]	2	5	5
③ Lines which have no adequate countermeasures	[circuit]	0	1	1
④ No. of lines less capacity to the requirement at normal conditions	[circuit]	0	3	7
⑤ Countermeasures to voltage drop in case of N-1 fault	[case]	0	1	3
⑥ Thermal capacity problem in case of N-1 fault	[case]	6	20	19
⑦ Voltage drop and/or thermal capacity problem in case of N-1 fault	[case]	6	20	21
⑧ Number of thermal faulty facility in case of N-1 fault	[No.]	2	6	15

[Source] JICA Study Team

Table 6.4-71 shows that the required phase regulator capacity, facilities that exceed heat capacity in normal configuration and at times of N-1 fault, and problematic N-1 system faults will increase as the demand increases in the later years.

Since three diesel generators will start operating in Kingtom P/S and the Yiben-I HPP will be on line between 2015 and 2020, it is clear that the number of measures to suppress short circuit capacity and facilities with inadequate rated short circuit capacity is also increasing.

Adequate SC capacity was studied up to 2015 which is calculated based on a lot of assumptions. And it seems that there are a lot of alternative systems to 2020 and 2025, therefore in this study, system analysis to 2020 and 2025 is omitted.

It is recommendable that the system analysis to 2020 and 2025 be conducted after installation of new DEG sets and 33 kV system.

Distribution system in this study is the loop system which has reliable power supply but it is a little bit complicated. Also, the loop system can dispatch the power when N-1 fault happens. However, it shall be noted that initial cost is higher than the radial system and power flow is complicated.

It shall be noted that the load on some sound lines will increase during N-1 fault in the loop system. That is, the facility capacity shall be installed considering these overload factor to prevent serious faults. And also note that it is necessary to study all cases which may be occur during N-1 faults.

It is recommendable to promote capacity building and provision of supporting systems to the power flow analysis in order to operate the distribution system adequately.

6.5 Optimal Distribution System

It is necessary to install SC as shown in Table 6.4-7 in the major distribution stations by 2015 according to increasing demand and 33 kV system configuration as a loop system.
Also, it is necessary to take adequate countermeasures to solve the N-1 fault as mentioned in Table 6.4-21 such as lack of line capacity on L106 and L107, which can be solved by replacing these cables. However, before applying the above solution, following items shall be studied.

1) Review of ongoing project
   Upgrading of 11 kV lines (L550 and L551) between Freetown and Brookfields with size upgrading from 3c-185 sq to 1c-300 sq x 3

2) Re-check peak demand at Brookfields J/S
   Present open points on sub-trunk lines between Brookfields and Kingtom/Congo Cross/Wilberforce/ Falcon Bridge is decided based on experience. It shall be recommended that the open points on sub-trunk line between Brookfields and other major distribution stations shall be decided considering coverage area and minimum energy loss points based on actual power flow.

3) Data for system analysis
   There are a lot of assumed data in this analysis. These data shall be checked and actual data used as much as possible. Also, actual data to ongoing projects such as the 11 kV and 33 kV distribution systems and new generating facilities shall be used.

When 161 kV transmission line has fault, it is necessary to minimize the blackout area and prevent blackout of the capital.
It is necessary to conduct load shedding to keep the system stability. In this connection, it is strongly recommended to establish operating rules including priority order for load shedding and to install frequency relay in the 11 kV and 33 kV SWGRs.

Optimal system by 2015 is shown in Fig. 6.5-5 in item 6.7 and single line diagrams for each major distribution station are shown in item-3: Drawings in Appendices.

Regarding the distribution system by 2020 and 2025, there are a lot of unclear factors including connection points of international transmission line and it is very complicated to have adequate optimal systems in each year. Therefore, preliminary system study is conducted for reference and future consideration.

As a result, it is recommendable that the 33 kV overhead line conductor for which specification is AAAC 150 sq may be upgraded to AAAC 240 sq, then the lack of line capacity problems mentioned in Table 6.4-28 can be solved. As for other problems in 2020 and 2025, peak demand and data shall be reviewed and also design standards including standard short circuit current should be decided as soon as possible to prevent further trouble.

There are three power sources to Western Area, i.e. Kingtom P/S, Blackhall Road P/S and Freetown S/S, which do not seem to be enough for the capital area. Lumpa S/S seems to be an adequate location as new power source which can be considered as a future Load Dispatching Center.

It is necessary to conduct new power projects to establish adequate distribution system as shown in Fig. 6.3-2 by 2025. Table 6.5-1 shows an outline of new projects with target year and project cost in each phase and objectives and results are shown in Table 6.5-2. Details are shown in Item-1 of Appendices.

Table 6.5-1 Rehabilitation, Reinforcement and Expansion of Distribution System

No.	Name of Project	Outline of the Project	Cost [10^6US$]	Target Year
A.	**Phase-I**：（**2010～2015**）			
	1. Rehabilitation and Reinforcement of 11/33 kV systems	・Rehabilitation of 11 kV, SWGR ・Reinforcement of 33 kV facilities (Kingtom P/S, Blackhall Road P/S, Falcon Bridge S/S) ・Reinforcement of 33 kV lines (6 km)	25.6	2012
	2. Construction of 33 kV lines and S/S	・Reinforcement of 33 kV facilities (Construction of Goderich S/S, Jui S/S and 33 kV lines) ・Reinforcement of 33 kV line (20 km)	35.4	2014
	3. Rehabilitation of 11 kV facilities	・Rehabilitation of distribution transformer ・Reinforcement of LV lines	32	2015
B.	**Phase-II**：（**2016 ～2020**） 1. Reinforcement of 33 kV lines	・Construction of Lumpa and Tombo S/S ・Reinforcement of 33 kV lines (32 km)	33.7	2017
	2. Reinforcement and expansion of 33 kV lines	・Reinforcement of 33 kV facilities (New 161/33 kV trans. at Freetown S/S) ・Expansion of 33 kV lines (33 kV line from Goderich to York town: about 29 km)	31.4	2020
C.	**Phase-III**：（**2021～2025**） 1. Reinforcement and Expansion of Distribution network	・Reinforcement of 11 kV lines ・Expansion of 33 kV lines (36 km) ・Expansion of LV network	16.3	2025

[Source] JICA Study Team

Table 6.5-2 Objectives and Result

Phase	Present situation and objectives	Result
I- (1)	[Name of Project]: Rehabilitation and Reinforcement of 11/33 kV systems [Present Situations] It is urgently required to install new 33 kV system to meet increasing demand inWestern Area. Especially, Falcon Bridge, Brackhall Road, Wilberforce and Brookfields area will have serious demand increases and 33 kV system shall be established in these areas. [Objectives] In order to secure the power supply to the capital of Freetown, it is necessary to install 33 kV system from Kingtom P/S to Brackhall Road P/S through Falcon Bridge. This is because Falcon Bridge S/S is supplying power to the center of Freetown. Also, it is necessary to install 33/ 11 kV substation at Falcon Bridge. In order to minimize the fault area, it is necessary to rehabilitate existing 11 kV SWGR, such as protection and metering systems, and this will also help with providing actual records.	Secure power supply system and minimize the fault area and reduce energy losses.
I- (2)	[Name of Project]: Construction of 33 kV lines and S/S [Present situation] It is observed that the demand in Jui area will increase largely and Goderich will not have enough power supply lines. Especially, Goderich area suffers terrible voltage drop problems compared to the demand, only one 11 kV line is coming from Wilberforce S/S and many consumers cannot access the electricity. Also, this area is the base of power supply to Sussex and York town where there are a lot of development plans and demand is expected to increase. [Objectives] (1) To secure the reliability of the distribution system. Complete 33 kV loop from Kingtom, Falconbridge, Brackhall Road, Wellington, Regent, Wilberforce, Freetown (2) Construct Goderich S/S with 33 kV line from Wilberforce S/S	Secure reliability and improve quality
I- (3)	[Name of Project]: Rehabilitation of 11 kV facilities [Present Situation] There are a lot of faults because of old transformers and SWGRs. [Objectives] Replace old transformers and SWGRs which are more than 30 years old.	Secure stable power supply and reduce energy losses
II-(1)	[Name of Project]: Reinforcement of 33 kV lines [Present Situation] Present 11 kV system is connected up to Waterloo, and Koya rural does not have distribution system. Lumpa and Tombo are also not connection to the grid.	Secure reliable power supply and promote rural electrification

Phase	Present situation and objectives	Result
II-(2)	[Name of Project]: Reinforcement and expansion of 33 kV lines [Present situation] Present 33 kV capacity is not enough to cover the demand in 2025. Therefore, new 161/ 33 kV transformer needs to be installed at Freetown S/S.	Reinforce 33 kV system and secure reliable power supply
III-(1)	[Name of Project]: Reinforcement and Expansion of Distribution network [Objectives] There is no 33 kV loop from Wilberforce, Regent, Jui, Lumpa, Tombo, York and Goderich. This route shall be connected by 33 kV lines to have adequate power supply. 33 kV lines shall be installed from York to Tombo and Lumpa to Fogbo for promotion of rural electrification.	Promote rural electrification

[Source] JICA Study Team

6.6 Others

It is recommendable to take into consideration e reliability, quality and safety, operation and maintenance following improvement.

(1) Preparation of Operation Rules

Before connection to Bumbuna system in the existing Freetown system, it is necessary to establish operation rules such as;

1) Grounding protection system,
2) Operation conditions of incoming and bus-tie circuit breaker,
3) Normal and emergency power distribution on each trunk line,
4) Minimum required interlocking on trunk line feeders, and
5) Preparation of operation rules including load shedding.

Considering the above, some modifications shall be required to the existing systems. This step is also required when new DEGs at Kingtom and Blackhall Road P/S are completed and also 33 kV lines from Freetown S/S.

(2) Rules for Electrification

Basic conditions to connect new branch lines to the customers shall be established, such as new connections shall be limited to registered customers in order to reduce work volume to the uncertain connections and also to reduce non-collection of electric tariff.

(3) Preparation of facility registers

It is strongly recommended that the electrical facility registers should be provided. Refer to preliminary facility registers attached in this report. Missing information shall be filled in the registers and they shall be reviewed and modified every end of month and reported every year in annual report;

1) Facility resister for transformers
2) Facility register for 11 kV and 33 kV Lines

3) Facility register for ring main unit (RMU)

In addition to the above registers, it is necessary to provide the same but for low voltage systems which should clearly mention phase connection and each consumer to meet three phase four wire methods and/or three phase five wire method where it is applied to street lighting system.

(4) Standardization of design, installation and O&M

In order to secure easy installation and maintenance, standardization of design, installation and operation & maintenance are required. Proposed design basis is shown on attachment of Part-3 of Chapter-1 in Supplemental Volume-1.

(5) Establishment of 11 kV operation rules

It is recommendable to establish operation rules on 11 kV distribution systems to reduce energy losses, to minimize fault area and to have high reliability. Major items to be concsidered are as follows.

1) Normal conditions;

It is necessary to have open point on 11 kV sub-trunk lines between substations and/or junction stations where there is minimum energy losses and without voltage problems.

2) Abnormal conditions;

It is necessary to have adequate protection coordination between substations and/or junction stations to minimize the fault area. Also it is required to set back-up lines to the black-out area which can be separated from fault points.
It seems that auto-recloser is useful to install in substations and on the long 11 kV line where it is also necessary to consider protection coordination.

(6) Capacity building to engineers and technicians for the above items (3) and (4).

After establishment of organization for T&D, adequate capacity building shall be conducted considering future development. Major contents are planning, design, construction, operation and maintenance.

(7) Expedite IT and prepare reliable communication system

It is required that the computerization for not only data sorting but also for general purposes is urgently required since this will be useful for supervision/control of systems, future system analysis and so on.

6.7 Power System Analysis Data and Result of Analysis (Figures and Tables)

Table 6.4-1 Line Constants

Base capacity＝ 1 MVA

Line No.	From	To		Line Information: Laying Method	Length [m]	Spec. of Conductor: Materials	Core	Size (mm2)	TYPE	Voltage [kV]	Status	Line Constant: Resistance [μΩ/m]	Reactance [μΩ/m]	Capacitance [pF/m]	Sustained Current [A]	Short Circuit [kA]	For Analysis: 1 MVA Base, pu value) Resistance p.u.	Reactance p.u.	admittance p.u.	Sustained Current [MW]	Short Circuit [MW]	Remarks
0915611	Freetown	Bumbuna		O/H	204,750	Al	1*3	400	ACSR	161		83.2	395.4	9.18	810	37.2	0.00066	0.00312	7.65311	225.9	10374	Operation: 2009
1516611	Bumbuna	YIBEN		O/H	26,000	Al	1*3	400	ACSR	161		83.2	395.4	9.18	810	37.2	0.00008	0.00040	0.97182	225.9	10374	Operation: 2019
0102331	Kingtom	Falcon Bridge	L3101	Marine	2,000	Cu	3*2	500	M-XLPE	33		18.3	55.6	720	1080	67	0.00003	0.00010	0.24633	61.7	3830	Operation: 2012
0109331	Kingtom	Freetown	L3903	U/G	100	Cu	1*3*2	500	XLPE	33		18.45	67.65	1300	1200	67	0.00000	0.00001	0.02224	68.6	3830	Operation: 2011
				O/H	400	Al	1*3	500	ACSR	33		56.8	303.8	12.13	904	46.5	0.00002	0.00011	0.00083	51.7	2658	
											Total						0.00002	0.00012	0.02307	51.7	2658	
0203331	Falcon Bridge	Blackhall Road	L3201	Marine	3,000	Cu	3*2	500	M-XLPE	33		18.3	55.6	720	1080	67	0.00005	0.00015	0.36949	61.7	3830	Operation: 2013
				O/H	1,000	Al	1*3	500	ACSR	33		56.8	303.8	12.13	904	46.5	0.00005	0.00028	0.00207	51.7	2658	
											Total						0.00010	0.00043	0.37156	51.7	2658	
0306331	Blackhall Road	Wilberforce	L3301	U/G	1,000	Cu	3	185	XLPE	33		110	127.2	240	420	26.6	0.00010	0.00012	0.04105	24.0	1520	Operation: 2010
				O/H	9,000	Al	1*3	150	AAAC	33		198	343.7	10.66	407	14	0.00164	0.00284	0.01641	23.3	800	
											Total						0.00174	0.00296	0.05747	23.3	800	
0307331	Blackhall Road	Wellington	L3302	U/G	1,000	Cu	3	185	XLPE	33		110	127.2	240	420	26.6	0.00010	0.00012	0.04105	24.0	1520	Operation: 2010
				O/H	9,000	Al	1*3	150	AAAC	33		198	343.7	10.66	407	14	0.00164	0.00284	0.01641	23.3	800	
											Total						0.00174	0.00296	0.05747	23.3	800	
0309331	Blackhall Road	Freetown	L3902	U/G	1,000	Cu	3	185	XLPE	33		110	127.2	240	420	26.6	0.00010	0.00012	0.04105	24.0	1520	Operation: 2010
				O/H	12,000	Al	1*3	150	AAAC	33		198	343.7	10.66	407	14	0.00218	0.00379	0.02188	23.3	800	
											Total						0.00228	0.00390	0.06294	23.3	800	
0608331	Wilberforce	Regent	L3601	U/G	3,200	Cu	3	185	XLPE	33		110	127.2	240	420	26.6	0.00032	0.00037	0.13137	24.0	1520	
				O/H	1,300	Al	1*3	120	ACSR	33		250	338.1	10.84	388	11.1	0.00030	0.00040	0.00241	22.2	634	
											Total						0.00062	0.00078	0.13378	22.2	634	
0609331	Wilberforce	Freetown	L3901	U/G	1,000	Cu	3	185	XLPE	33		110	127.2	240	420	26.6	0.00010	0.00012	0.04105	24.0	1520	Operation: 2010
				O/H	2,400	Al	1*3	150	AAAC	33		198	343.7	10.66	407	14	0.00044	0.00076	0.00438	23.3	800	
											Total						0.00054	0.00087	0.04543	23.3	800	
0610331	Wilberforce	Goderich	L3602	U/G	1,000	Cu	3*2	185	XLPE	33		55	63.6	480	714	26.6	0.00005	0.00006	0.08211	40.8	1520	Operation: 2013
				O/H	6,000	Al	1*3	240	ACSR	33		120	322.6	11.39	593	22.3	0.00066	0.00178	0.01169	33.9	1275	
											Total						0.00071	0.00184	0.09380	33.9	1275	
0711331	Wellington	Jui	L3701	O/H	7,000	Al	1*3	240	ACSR	33		120	322.6	11.39	593	22.3	0.00077	0.00207	0.01364	33.9	1275	Operation: 2013
0811331	Regent	Jui	L3804	U/G	1,000	Cu	3	185	XLPE	33		110	127.2	240	420	26.6	0.00010	0.00012	0.04105	24.0	1520	Operation: 2013
			L3604	O/H	12,000	Al	1*3	120	ACSR	33		250	338.1	10.84	388	11.1	0.00275	0.00373	0.02225	22.2	634	
											Total						0.00286	0.00384	0.06331	22.2	634	
1016331	Goderich	York	L31001	O/H	29,000	Al	1*3	120	ACSR	33		250	338.1	10.84	388	11.1	0.00666	0.00900	0.05377	22.2	634	Operation: 2016
1112331	Jui	Lumpa	L31101	U/G	1,000	Cu	3*2	185	XLPE	33		55	63.6	480	714	26.6	0.00005	0.00006	0.08211	40.8	1520	Operation: 2017
				O/H	14,000	Al	1*3	240	ACSR	33		120	322.6	11.39	593	22.3	0.00154	0.00415	0.02728	33.9	1275	
											Total						0.00159	0.00421	0.10939	33.9	1275	
1213331	Lumpa	Tombo	L31201	U/G	1,000	Cu	3	185	XLPE	33		110	127.2	240	420	26.6	0.00010	0.00012	0.04105	24.0	1520	Operation: 2017
				O/H	16,000	Al	1*3	120	ACSR	33		250	338.1	10.84	388	11.1	0.00367	0.00497	0.02967	22.2	634	
											Total						0.00377	0.00508	0.07072	22.2	634	
1314331	Tombo	York	L31001	O/H	20,000	Al	1*3	120	ACSR	33		250	338.1	10.84	388	11.1	0.00459	0.00621	0.03709	22.2	634	Operation: 2022
0102111	Kingtom	Falcon Bridge	L103	U/G	2,880	Cu	3	185	PILC	11	Faulty	118	80	580	355	22.0	0.00281	0.00190	0.03175	6.8	419	
0102112	Kingtom	Falcon Bridge	L104	U/G	2,750	Cu	3	185	PILC	11	Faulty	118	80	580	355	22.0	0.00268	0.00182	0.03032	6.8	419	Operation: 2014
0102113	Kingtom	Falcon Bridge	L103A	U/G	2,880	Al	1*3	240	XLPE	11		161	109	460	405	22.3	0.00383	0.00259	0.02518	7.7	425	
0102114	Kingtom	Falcon Bridge	L102	U/G	2,880	Cu	3	185	PILC	11	Faulty	118	80	580	355	22.0	0.00281	0.00190	0.03175	6.8	419	Operation: 2014
0104111	Kingtom	Congo Cross	L120	U/G	500	Cu	3	185	XLPE	11		128	93.1	430	430	26.6	0.00053	0.00038	0.00409	8.2	507	
				O/H	3,300	Al	1*3	120	AAAC	11		270	354	10.3	351	11.0	0.00736	0.00965	0.00065	6.7	210	
											Total						0.00789	0.01004	0.00473	6.7	210	
0104112	Kingtom	Congo Cross	L105	U/G	2,862	Cu	3	185	PILC	11		118	80	580	355	22.0	0.00279	0.00189	0.03155	6.8	419	
0105111	Kingtom	Brookfield	L107	U/G	2,360	Cu	3	185	PILC	11		118	80	580	355	22.0	0.00230	0.00156	0.02602	6.8	419	
0105112	Kingtom	Brookfield	L106	U/G	2,360	Cu	3	185	PILC	11		118	80	580	355	22.0	0.00230	0.00156	0.02602	6.8	419	
0109111	Kingtom	Freetown	L150	U/G	500	Cu	1*2*3	500	XLPE	11		18.5	67.6	1300	1210	72.3	0.00008	0.00028	0.01235	23.1	1378	Operation: 2010
0109112	Kingtom	Freetown	L151	U/G	500	Cu	1*2*3	500	XLPE	11		18.5	67.6	1300	1210	72.3	0.00008	0.00028	0.01235	23.1	1378	Operation: 2010
0203111	Falcon Bridge	Blackhall Road	L203	U/G	2,700	Cu	3	185	XLPE	11		128	93.1	430	430	26.6	0.00286	0.00208	0.02207	8.2	507	
				O/H	1,500	Al	1*3	120	AAAC	11		270	354	10.3	351	11.0	0.00335	0.00439	0.00029	6.7	210	
											Total						0.00620	0.00647	0.02236	6.7	210	
0203112	Falcon Bridge	Blackhall Road	L202	U/G	3,400	Cu	3	185	XLPE	11		128	93.1	430	430	26.6	0.00360	0.00262	0.02779	8.2	507	
0406111	Congo Cross	Wilberforce	L440	O/H	2,500	Al	1*3	120	AAAC	11		270	354	10.3	351	11.0	0.00558	0.00731	0.00049	6.7	210	
0409111	Congo Cross	Freetown	L450	O/H	3,400	Al	1*3	240	ACSR	11		120	322.6	11.39	593	22.3	0.00337	0.00906	0.00074	11.3	425	Operation: 2014
0506111	Brookfield	Wilberforce	L523	U/G	3,000	Al	3	300	PILC	11	Faulty	123	103	490	455	22.5	0.00305	0.00255	0.02794	8.7	429	Operation: 2014
0506112	Brookfield	Wilberforce	L522	U/G	3,000	Al	3	300	PILC	11		123	103	490	455	22.5	0.00305	0.00255	0.02794	8.7	429	
0509111	Brookfield	Freetown	L550	U/G	500	Cu	3	185	XLPE	11		128	93.1	430	430	26.6	0.00053	0.00038	0.00409	8.2	507	Operation: 2014
				O/H	2,500	Al	1*3	240	ACSR	11		120	322.6	11.39	593	22.3	0.00248	0.00667	0.00054	11.3	425	
											Total						0.00301	0.00705	0.00463	8.2	425	
0509112	Brookfield	Freetown	L551	U/G	500	Cu	3	185	XLPE	11		128	93.1	430	430	26.6	0.00053	0.00038	0.00409	8.2	507	Operation: 2014
				O/H	2,500	Al	1*3	240	ACSR	11		120	322.6	11.39	593	22.3	0.00248	0.00667	0.00054	11.3	425	
											Total						0.00301	0.00705	0.00463	8.2	425	

[Source] JICA Study Team

Table 6.4-2 Transformer Constants

Description	Unit	Kingtom	Falcon Bridge	Blackhall Road	Wilber-force	Wellington	Regent	Freetown (161 kV)			Goderich	Jui	Lumpa	Tombo	Bumbuna HPP		Yiben-I HPP		
								No.1 MTr	No.2 MTr	No.3 MTr					No.1 MTr	No.2 MTr	No.1 MTr	No.2 MTr	No.3 MTr
Capacity																			
1) HV/LV	[MVA]	20	20	10	10	10	5	–	–	80	15	15	15	5	33.7	33.7	30	30	30
2) H1/H2	[MVA]	–	–	–	–	–	–	40	40	–	–	–	–	–	–	–	–	–	–
3) H1/H3	[MVA]	–	–	–	–	–	–	35	35	–	–	–	–	–	–	–	–	–	–
4) H2/H3	[MVA]	–	–	–	–	–	–	15	15	–	–	–	–	–	–	–	–	–	–
Impedance																			
1) HV/LV	[%]	9.49	9.49	9.49	9.32	9.49	8.04	–	–	13.5	9.49	9.49	9.49	9.49	11.45	11.45	11.45	11.45	11.45
2) H1/H2	[%]	–	–	–	–	–	–	13.50	13.50	–	–	–	–	–	–	–	–	–	–
3) H1/H3	[%]	–	–	–	–	–	–	10.02	9.95	–	–	–	–	–	–	–	–	–	–
4) H2/H3	[%]	–	–	–	–	–	–	5.00	5.00	–	–	–	–	–	–	–	–	–	–
Impedance at 1 MVA base																			
1) HV/LV	[%]	0.4745	0.4745	0.949	0.932	0.9490	1.608	–	–	0.1688	0.6327	0.6327	0.6327	1.898	0.3398	0.3398	0.3817	0.3817	0.3817
2) H1/H2	[%]	–	–	–	–	–	–	0.3375	0.3375	–	–	–	–	–	–	–	–	–	–
3) H1/H3	[%]	–	–	–	–	–	–	0.2863	0.2843	–	–	–	–	–	–	–	–	–	–
4) H2/H3	[%]	–	–	–	–	–	–	0.3333	0.3333	–	–	–	–	–	–	–	–	–	–
%Z converted to Delta-Star																			
1) Between HV-LV	[%]	0.4745	0.4745	0.949	0.932	0.9490	1.608	–	–	0.1688	0.6327	0.6327	0.6327	1.898	0.3398	0.3398	0.3817	0.3817	0.3817
2) H1	[%]	–	–	–	–	–	–	0.1452	0.1442	–	–	–	–	–	–	–	–	–	–
3) H2	[%]	–	–	–	–	–	–	0.1923	0.1933	–	–	–	–	–	–	–	–	–	–
4) H3	[%]	–	–	–	–	–	–	0.1411	0.1401	–	–	–	–	–	–	–	–	–	–
Rated Voltage																			
1) HV	[kV]	33	33	33	33	33	33	–	–	161	33	33	33	33	165	165	165	165	165
2) LV	[kV]	11	11	11	11	11	11	–	–	34.5	11	11	11	11	13.8	13.8	15	15	15
3) H1	[kV]	–	–	–	–	–	–	161	161	–	–	–	–	–	–	–	–	–	–
4) H2	[kV]	–	–	–	–	–	–	11.5	11.5	–	–	–	–	–	–	–	–	–	–
5) H3	[kV]	–	–	–	–	–	–	34.5	34.5	–	–	–	–	–	–	–	–	–	–
Base voltage for analysis																			
1) HV	[kV]	33	33	33	33	33	33	–	–	161	33	33	33	33	161	161	161	161	161
2) LV	[kV]	11	11	11	11	11	11	–	–	33	11	11	11	11	13.8	13.8	15	15	15
3) H1	[kV]	–	–	–	–	–	–	161	161	–	–	–	–	–	–	–	–	–	–
4) H2	[kV]	–	–	–	–	–	–	11	11	–	–	–	–	–	–	–	–	–	–
5) H3	[kV]	–	–	–	–	–	–	33	33	–	–	–	–	–	–	–	–	–	–
%Z to Base Voltage																			
1) Between HV-LV	[%]	0.4745	0.4745	0.949	0.932	0.9490	1.608	–	–	0.1688	0.6327	0.6327	0.633	1.898	0.357	0.357	0.401	0.401	0.401
2) H1	[%]	–	–	–	–	–	–	0.145	0.144	–	–	–	–	–	–	–	–	–	–
3) H2	[%]	–	–	–	–	–	–	0.210	0.211	–	–	–	–	–	–	–	–	–	–
4) H3	[%]	–	–	–	–	–	–	0.154	0.153	–	–	–	–	–	–	–	–	–	–
P.U. value																			
1) Between HV-LV	[p.u.]	0.00475	0.00475	0.00949	0.00932	0.00949	0.01608	–	–	0.00169	0.00633	0.00633	0.00633	0.01898	0.00357	0.00357	0.00401	0.00401	0.00401
2) H1	[p.u.]	–	–	–	–	–	–	0.00145	0.00144	–	–	–	–	–	–	–	–	–	–
3) H2	[p.u.]	–	–	–	–	–	–	0.00210	0.00211	–	–	–	–	–	–	–	–	–	–
4) H3	[p.u.]	–	–	–	–	–	–	0.00154	0.00153	–	–	–	–	–	–	–	–	–	–
Tr No.																			
1) Between HV-LV	[p.u.]	0101331	0202331	0303331	0606331	0707331	0808331	–	–	0909613	1010331	1111331	1212331	1313331	1515611	1515612	1616611	1616612	1616613
2) H1	[p.u.]		–	–	–	–	–	0909611	0909612	–	–	–	–	–	–	–	–	–	–
3) H2	[p.u.]	–	–	–	–	–	–	0909111	0909112	–	–	–	–	–	–	–	–	–	–
4) H3	[p.u.]	–	–	–	–	–	–	0909331	0909332	–	–	–	–	–	–	–	–	–	–
Remarks		Operation by 2015	Operation by 2015	Operation by 2015	Operation by 2015	Operation by 2015				Operation by	Operation by 2015	Operation by 2015	Operation by	Operation by			Operation by	Operation by	Operation by

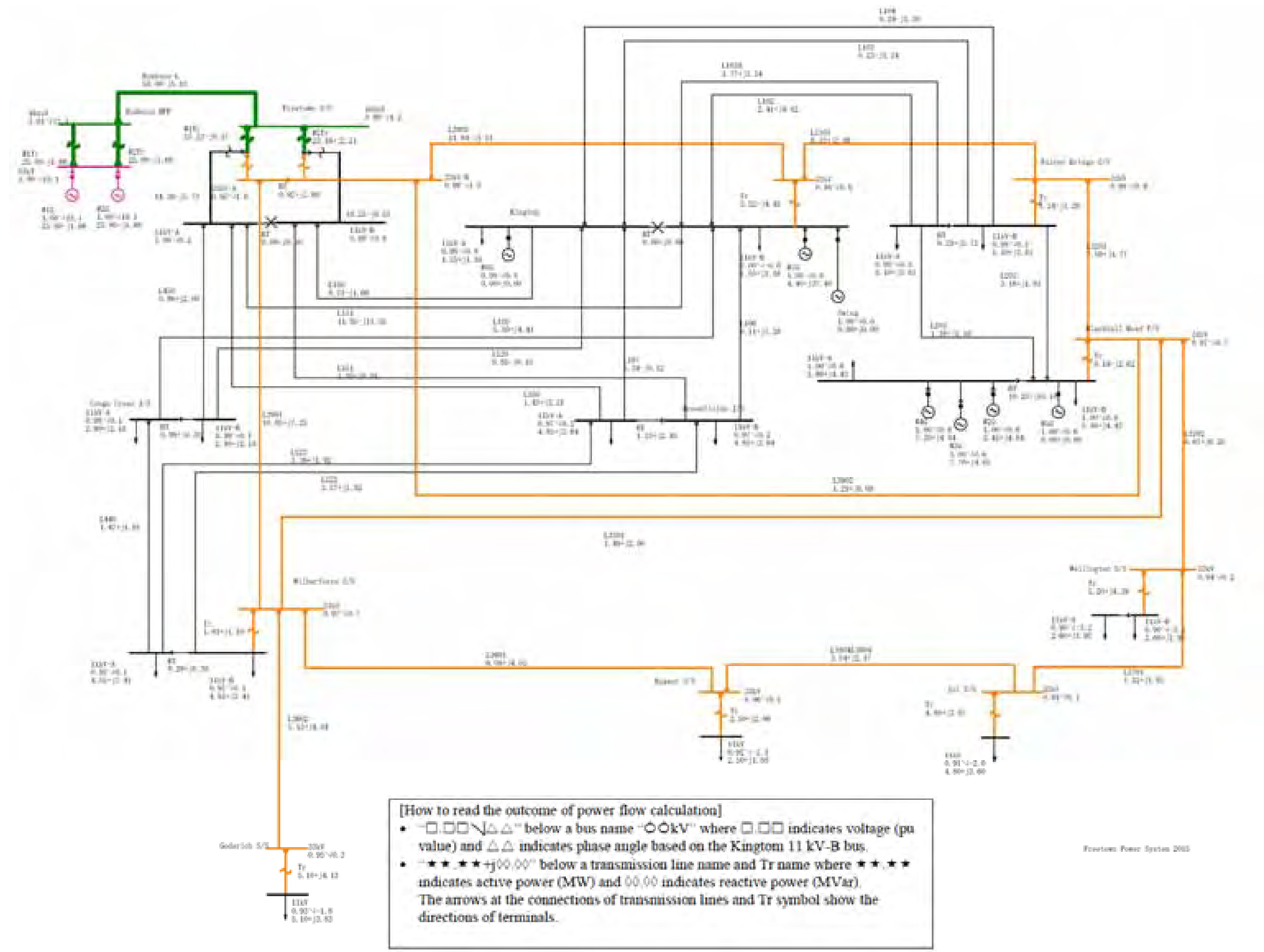
Tap	1-tap range [p.u.]	0.025	0.025	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.025	0.025	0.025	0.0125	0.0375	0.0375	0.0375	0.0375	0.0375
	No. of up-Tap [Tap]	+4	+4	+8	+8	+8	+4	+10	+10	+10	+4	+4	+4	+4	+2	+2	+2	+2	+2
	No. of down-Tap [Tap]	-4	-4	-8	-8	-8	-12	-10	-10	-10	-4	-4	-4	-12	-2	-2	-2	-2	-2

[Source] JICA Study Team

Table 6.4-3 Generator Constants

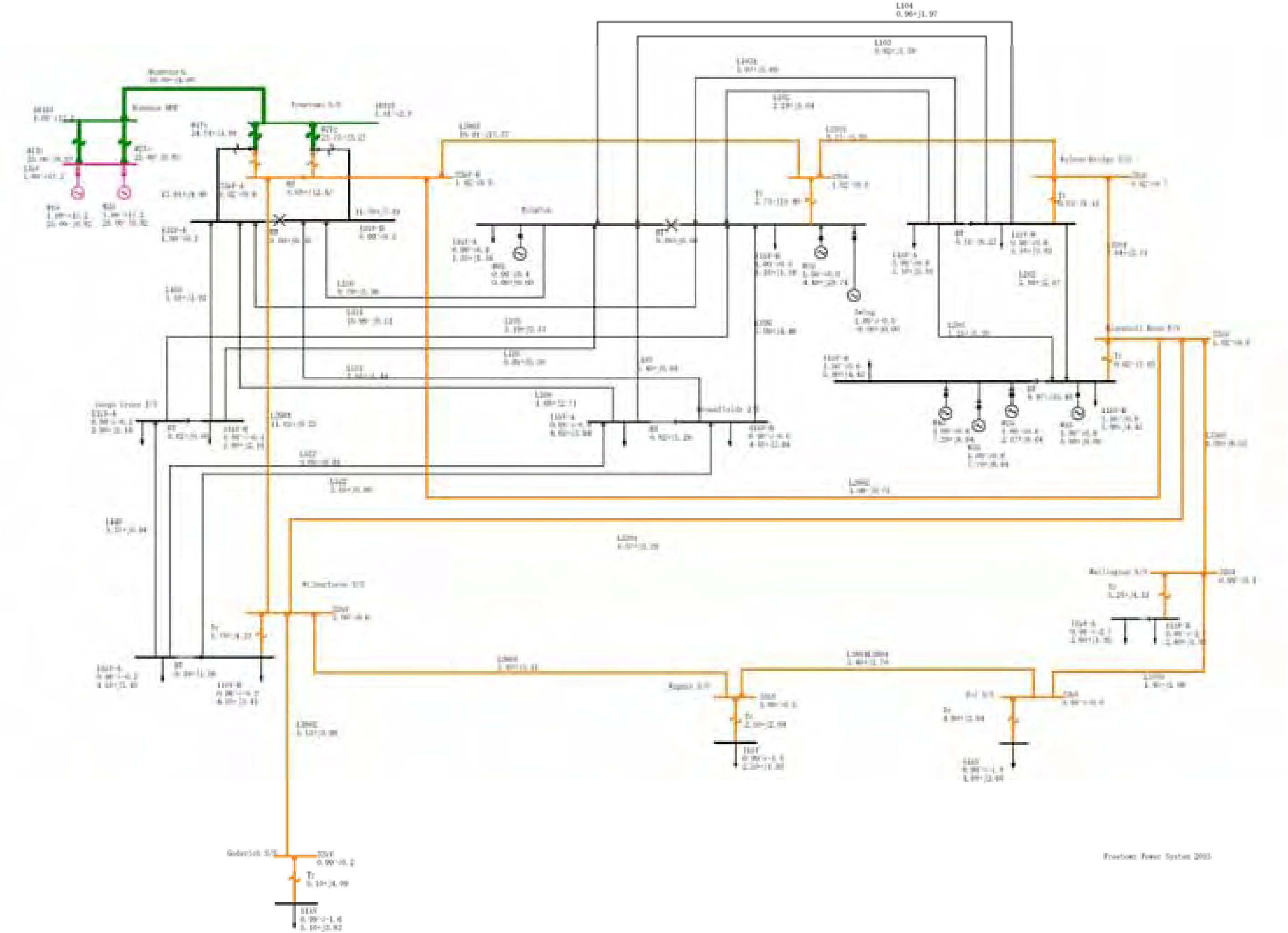
Unit	Node No.	Capacity [MVA]	Power factor	Output [MW]	Voltage [kV]	Revolution [rpm]	GD^2 [$Kg \cdot m^2$] Turbine	GD^2 [$Kg \cdot m^2$] Generator	Inertia constant [s]	Reactance Synchronous Xd	Reactance Synchronous Xq	Reactance Transient Xd'(=Xq')	Reactance Sub-transient Xd"	Reactance Sub-transient Xq"	Time Constant Transient Td'	Time Constant Sub-transient Td"	Armature Leakage Reactance Xl	Armature Time constant Ta	Reactance Zero X0	Reactance Negative X2	Technical Data AVR	Technical Data Governor	Remarks
【Kingtom P/S（Diesel）】																							
Sulzer4	011114	11.50	0.80	9.20	11.0																		To be retired by 2011
New DEG-7(Japan's Grant)	011117	6.25	0.80	5.00	11.0	750	NA	6,544	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Operation by 2010
New DEG-8(Japan's Grant)	011118	6.25	0.80	5.00	11.0	750	NA	6,544	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Operation by 2010
【Blackhall Road P/S（Diesel）】																							
New DEG-1(BADEA-I)	031111	10.90	0.80	8.72	11.0	750	NA	NA	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Same as No. 7 & 8 of Kingtom, Operation by 2010
New DEG-2(BADEA-II)	031112	10.90	0.80	8.72	11.0	750	NA	NA	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Same as No. 7 & 8 of Kingtom, Operation by 2010
New DEG-3(BADEA-III)	031113	10.90	0.80	8.72	11.0	750	NA	NA	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Same as No. 7 & 8 of Kingtom, Operation by 2011
New DEG-4(mid-speed)	031114	10.00	0.80	8.00	11.0	750	NA	NA	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Same as No. 7 & 8 of Kingtom, Operation by 2015
New DEG-5(mid-speed)	031115	10.00	0.80	8.00	11.0	750	NA	NA	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Same as No. 7 & 8 of Kingtom, Operation by 2016
New DEG-6(mid-speed)	031116	10.00	0.80	8.00	11.0	750	NA	NA	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Same as No. 7 & 8 of Kingtom, Operation by 2017
New DEG-7(mid-speed)	031117	10.00	0.80	8.00	11.0	750	NA	NA	3.60	1.400	0.810	0.320	0.230	0.270	0.980	0.029	0.200	0.130	0.130	0.250	NA	NA	Same as No. 7 & 8 of Kingtom, Operation by 2018
【Bumbuna P/S（Hydraulic）】																							
No.1	151311	33.70	0.90	30.33	13.8	333.33	NA	700,000	6.32	0.940	0.570	0.210	0.170	0.180	1.160	0.030	0.160	0.160	0.100	0.175	NA	NA	
No.2	151312	33.70	0.90	30.33	13.8	333.33	NA	700,000	6.32	0.940	0.570	0.210	0.170	0.180	1.160	0.030	0.160	0.160	0.100	0.175	NA	NA	
【YIBEN-I P/S（Hydraulic）】																							
No.1	161511	28.20	0.90	25.38	15.0	NA	NA	NA	6.32	0.940	0.570	0.210	0.170	0.180	1.160	0.030	0.160	0.160	0.100	0.175	NA	NA	
No.2	161512	28.20	0.90	25.38	15.0	NA	NA	NA	6.32	0.940	0.570	0.210	0.170	0.180	1.160	0.030	0.160	0.160	0.100	0.175	NA	NA	Assumed as same as Bumbuna. Operation by 2019
No.3	161513	28.20	0.90	25.38	15.0	NA	NA	NA	6.32	0.940	0.570	0.210	0.170	0.180	1.160	0.030	0.160	0.160	0.100	0.175	NA	NA	

[Source] JICA Study Team



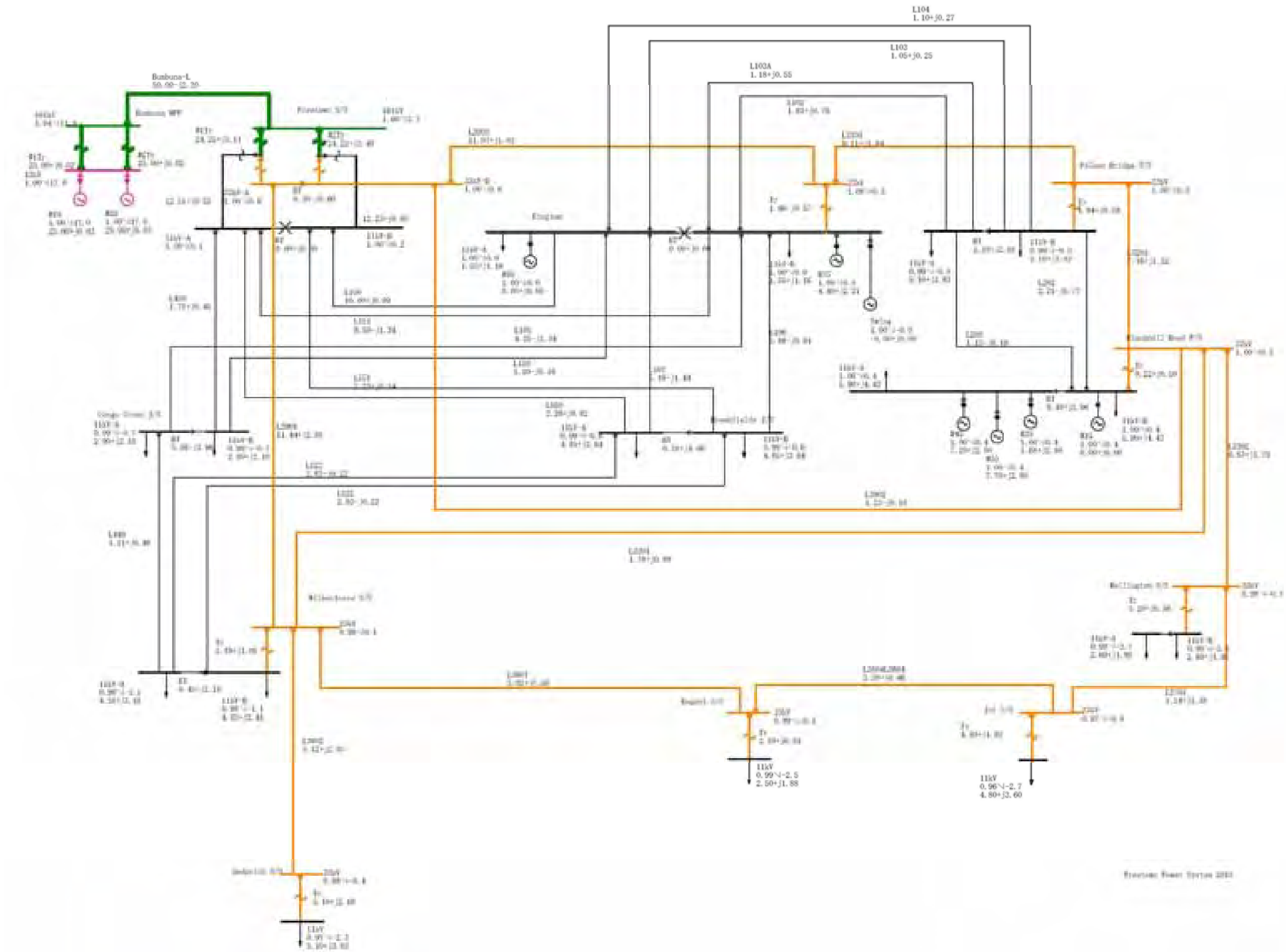
[Source] JICA Study Team

Fig. 6.4-1 Power Flow: 2015 (Base)



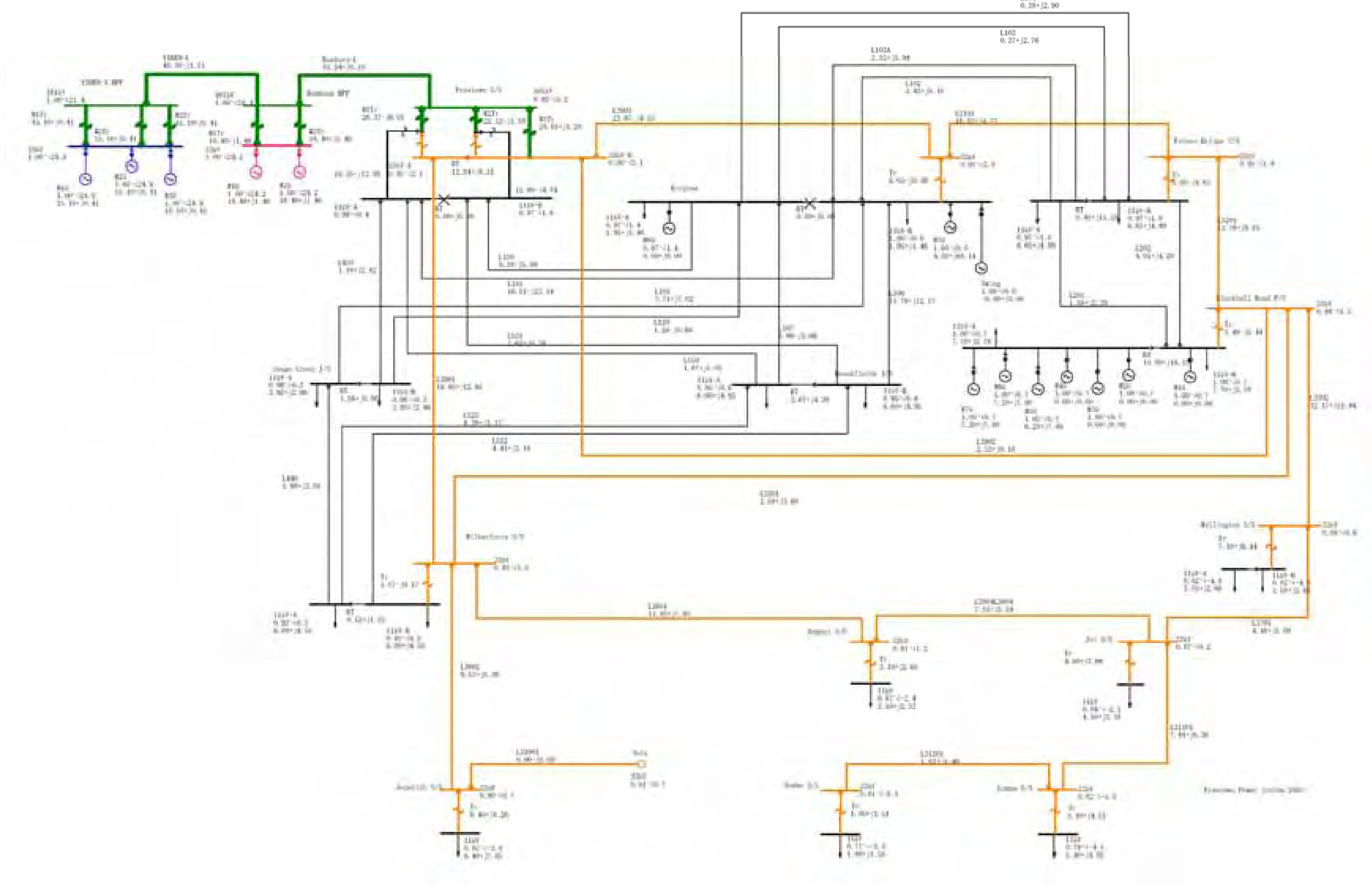
[Source] JICA Study Team

Fig. 6.4-2 Power Flow: 2015 (Adjusting of Transformer Tap)



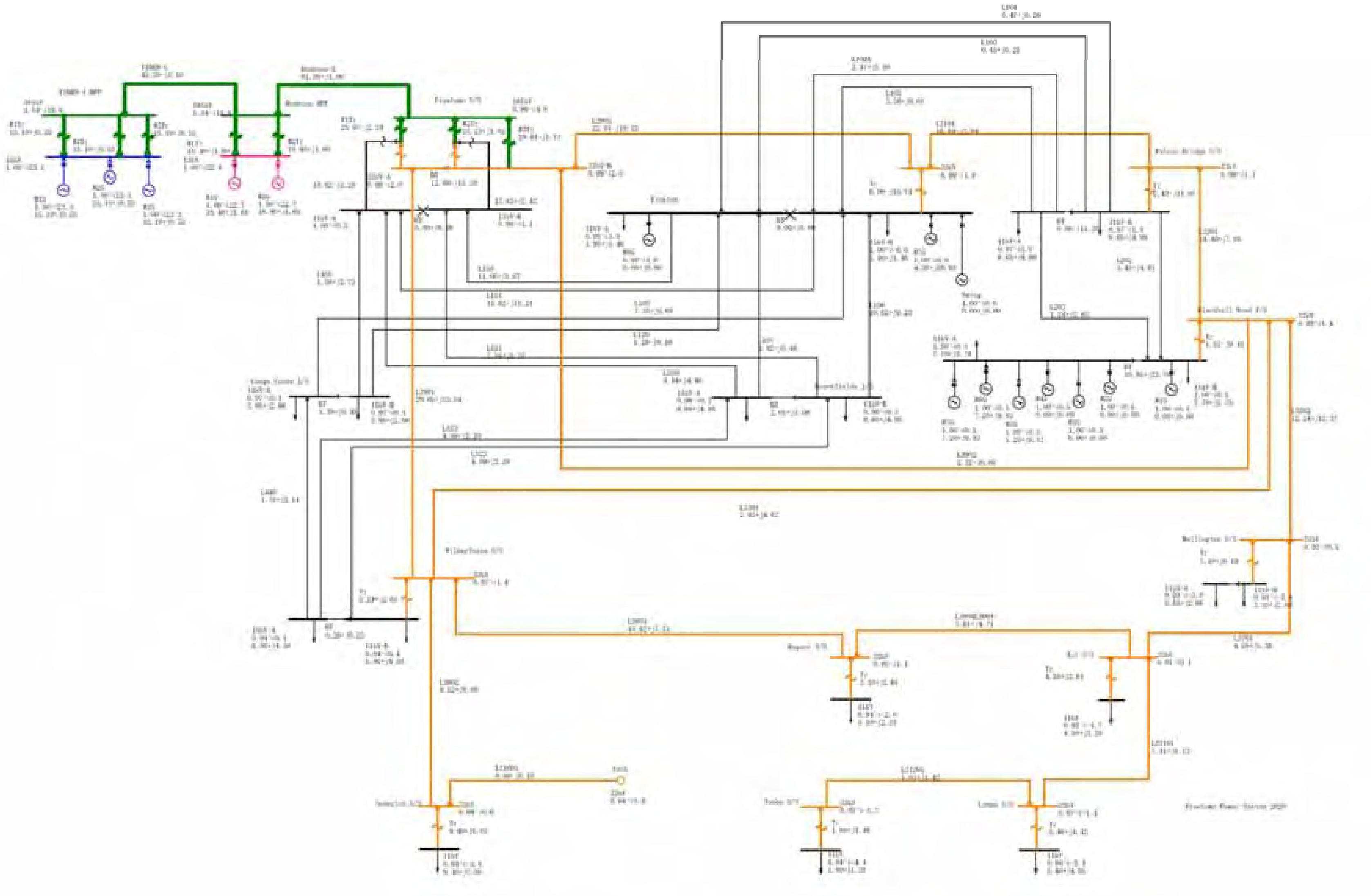
[Source] JICA Study Team

Fig. 6.4-3　Power Flow: 2015 (Adjusting Tap and Installation of SC)



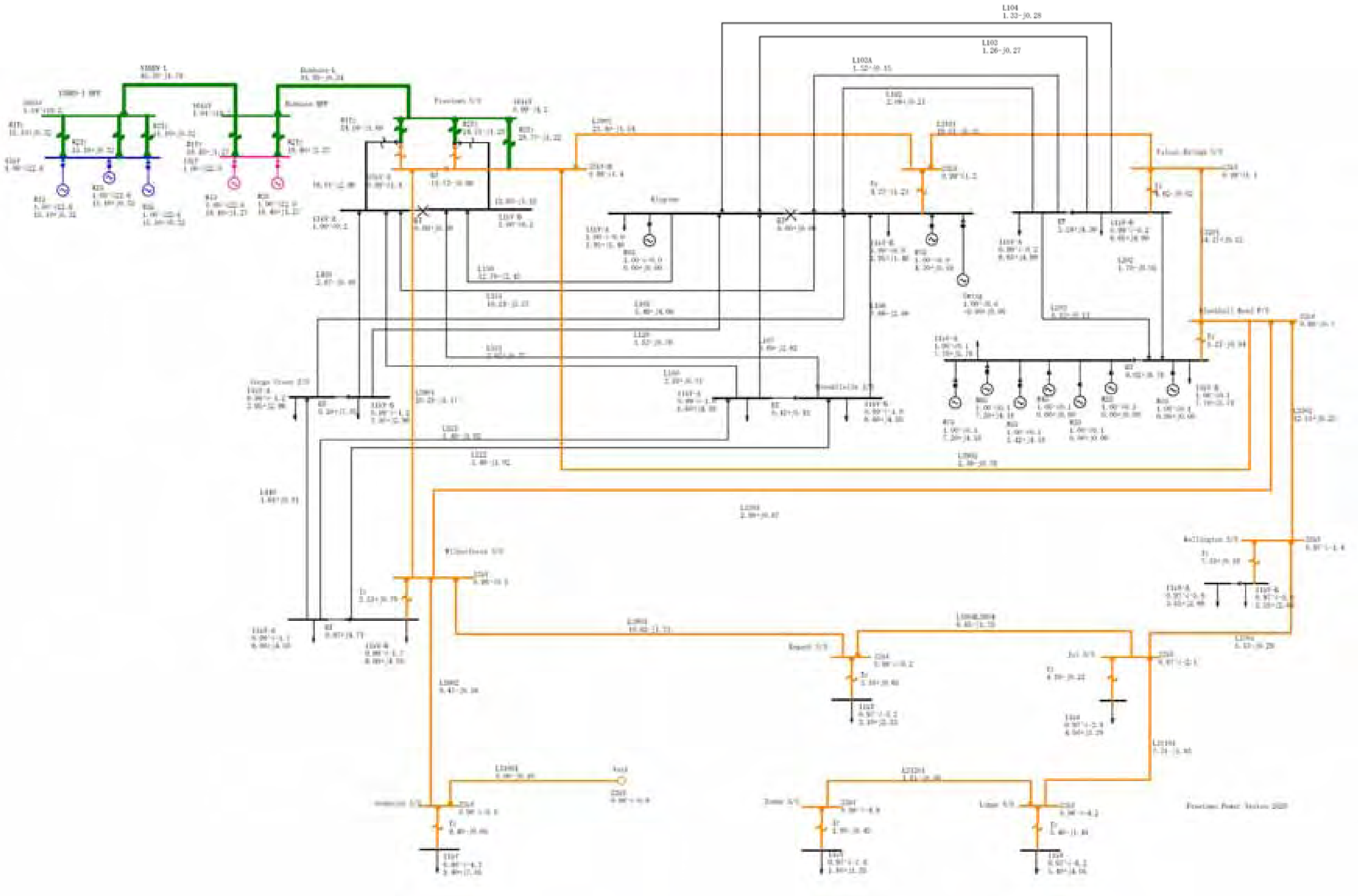
[Source] JICA Study Team

Fig. 6.4-4 Power Flow: 2020 (Base)



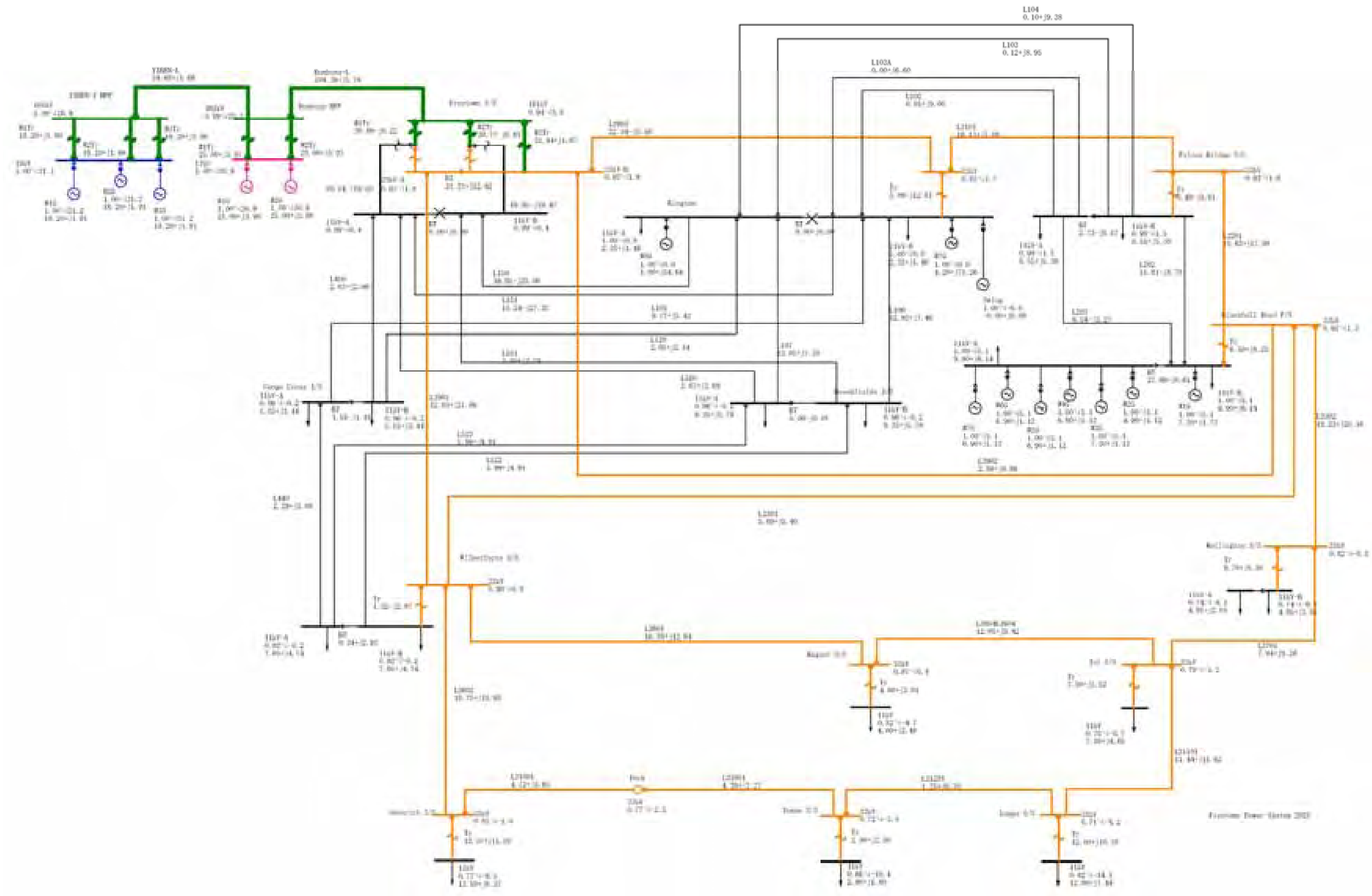
[Source] JICA Study Team

Fig. 6.4-5 Power Flow: 2020 (Adjusting of Transformer Tap)



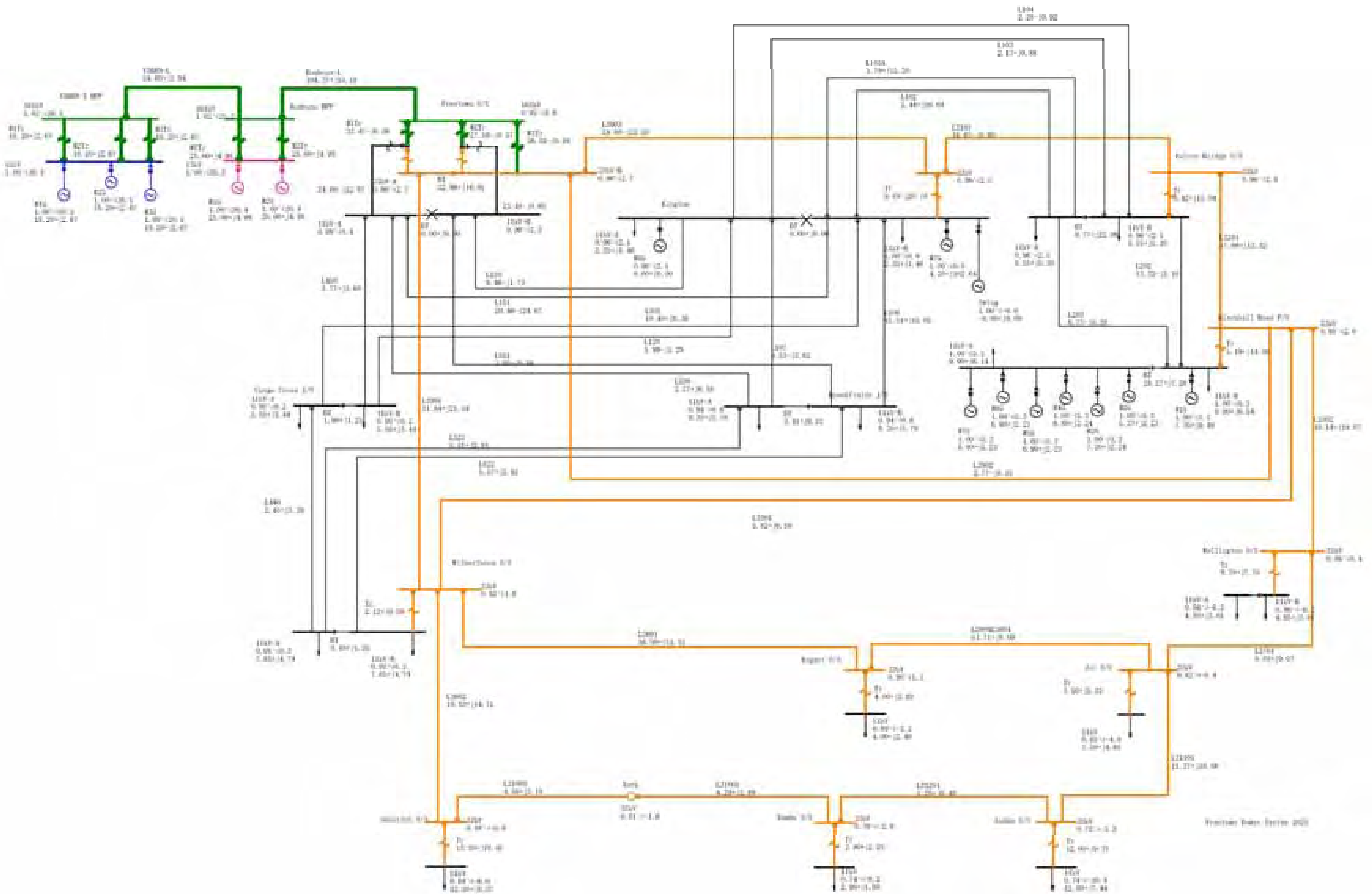
[Source] JICA Study Team

Fig. 6.4-6 Power Flow: 2020 (Adjusting Tap and Installation of SC)



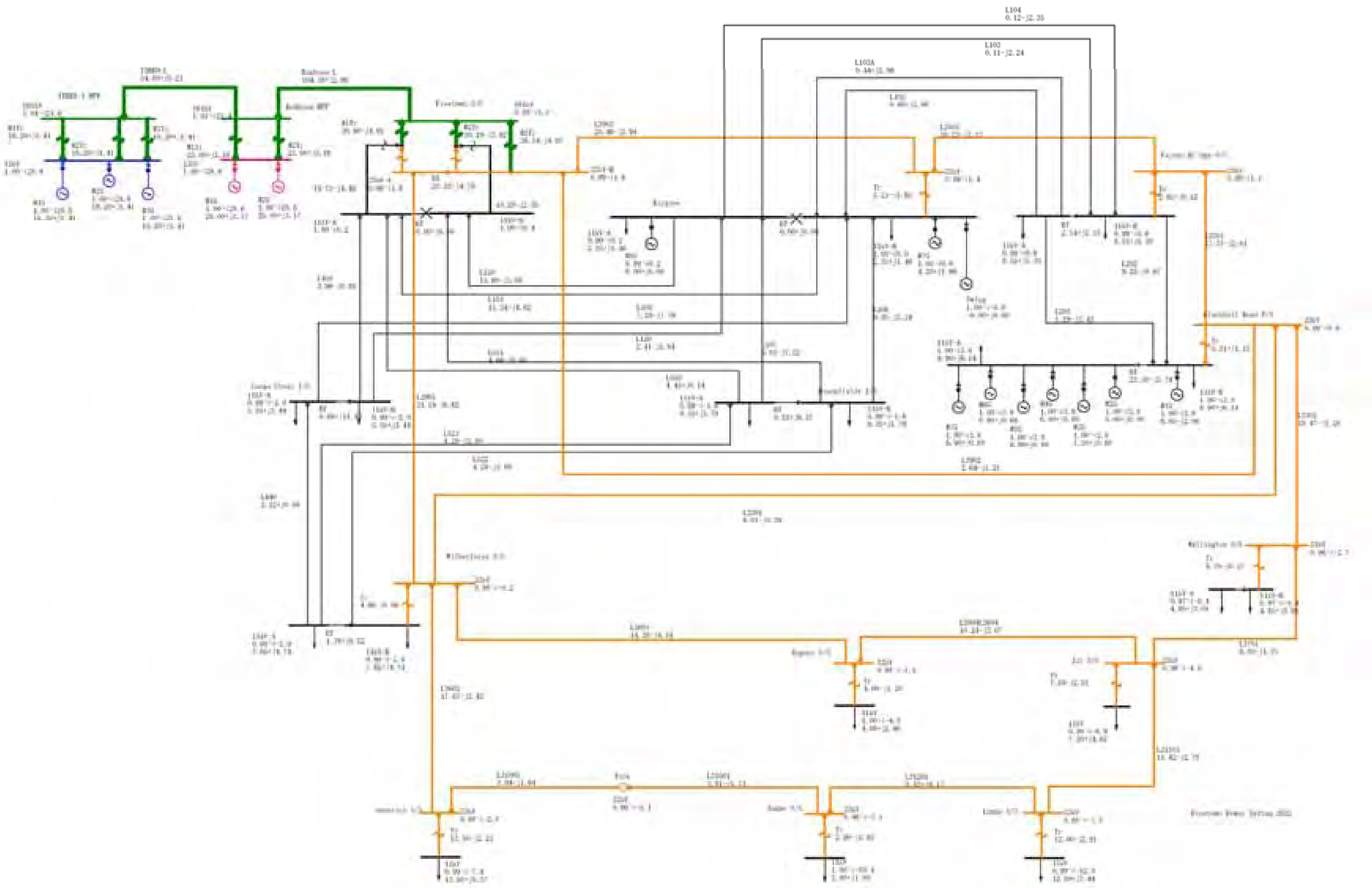
[Source] JICA Study Team

Fig. 6.4-7 Power Flow: 2025 (Base)



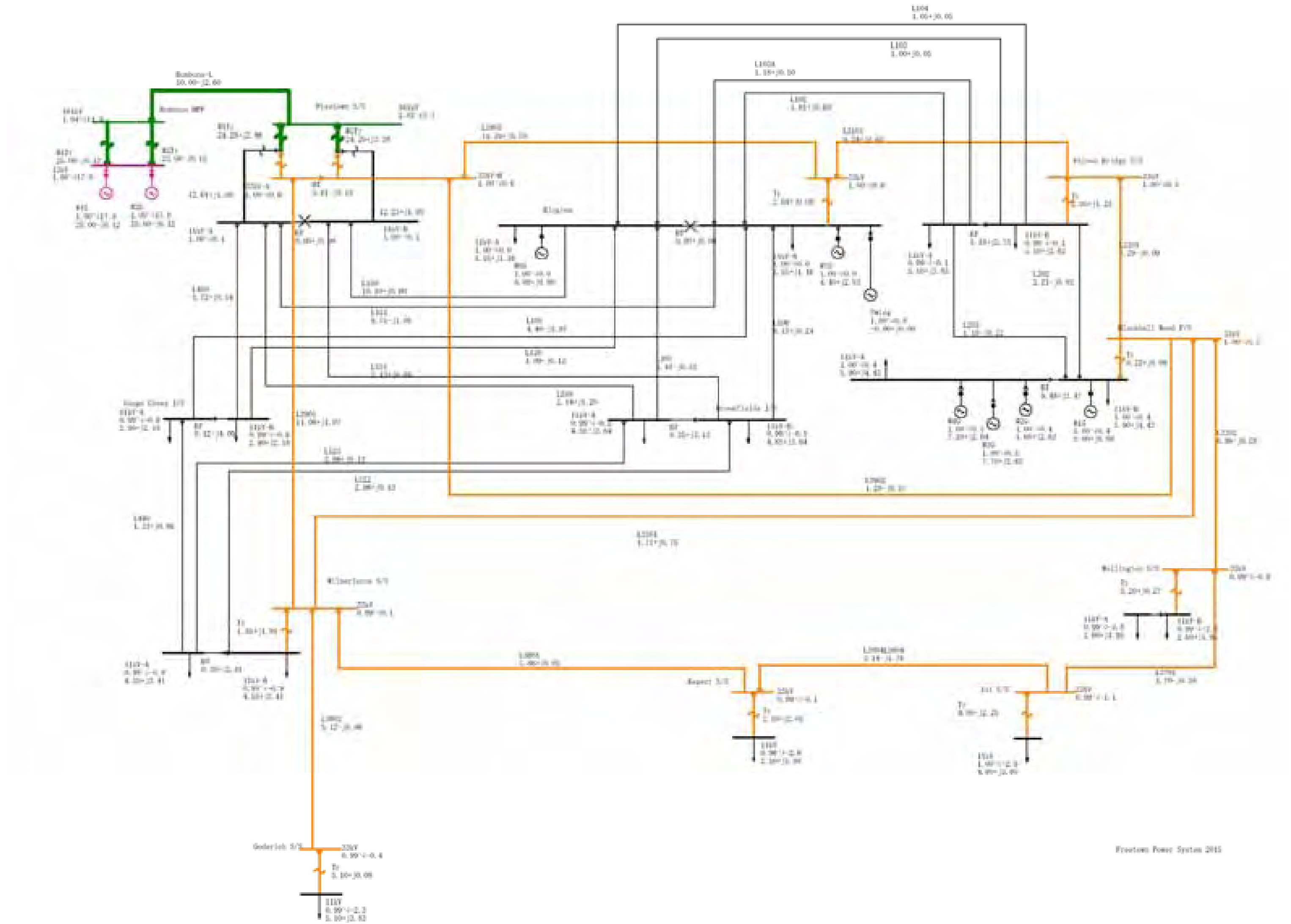
[Source] JICA Study Team

Fig. 6.4-8 Power Flow: 2025 (Adjusting of Transformer Tap)



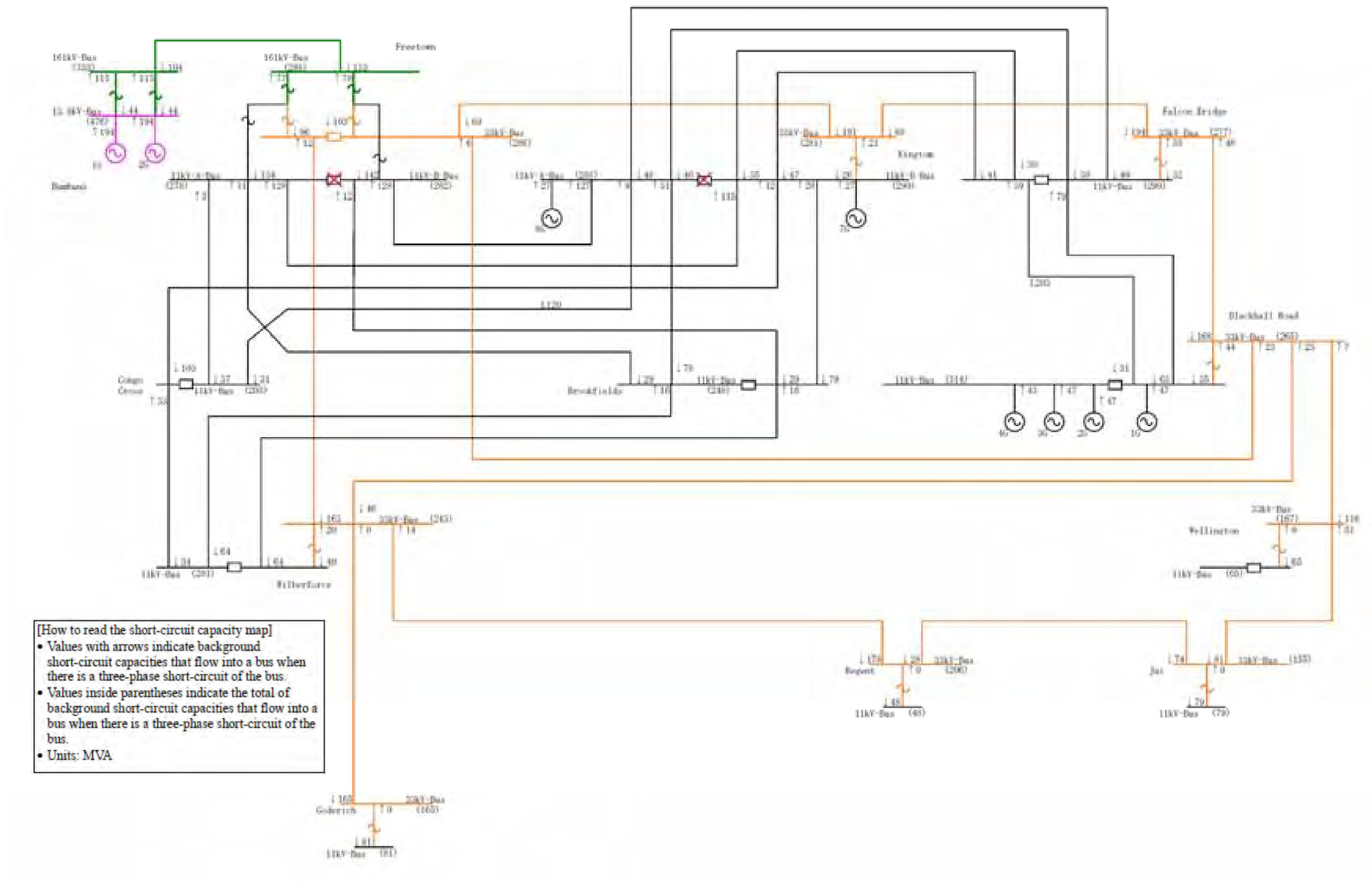
[Source] JICA Study Team

Fig. 6.4-9 Power Flow: 2025 (Adjusting Tap and Installation of SC)



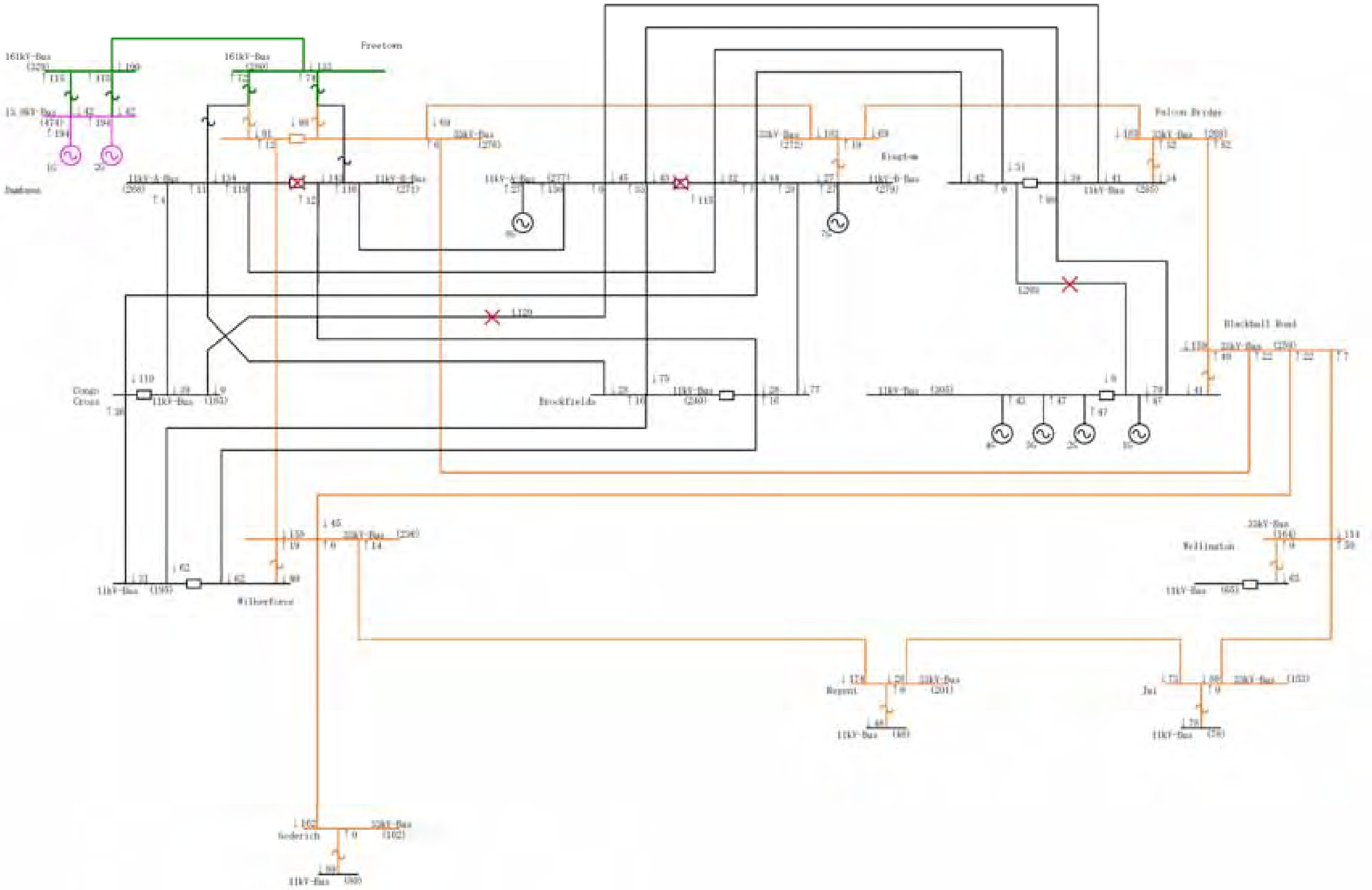
[Source] JICA Study Team

Fig. 6.4-10 Power Flow: 2015 (with proposed Static Condenser)



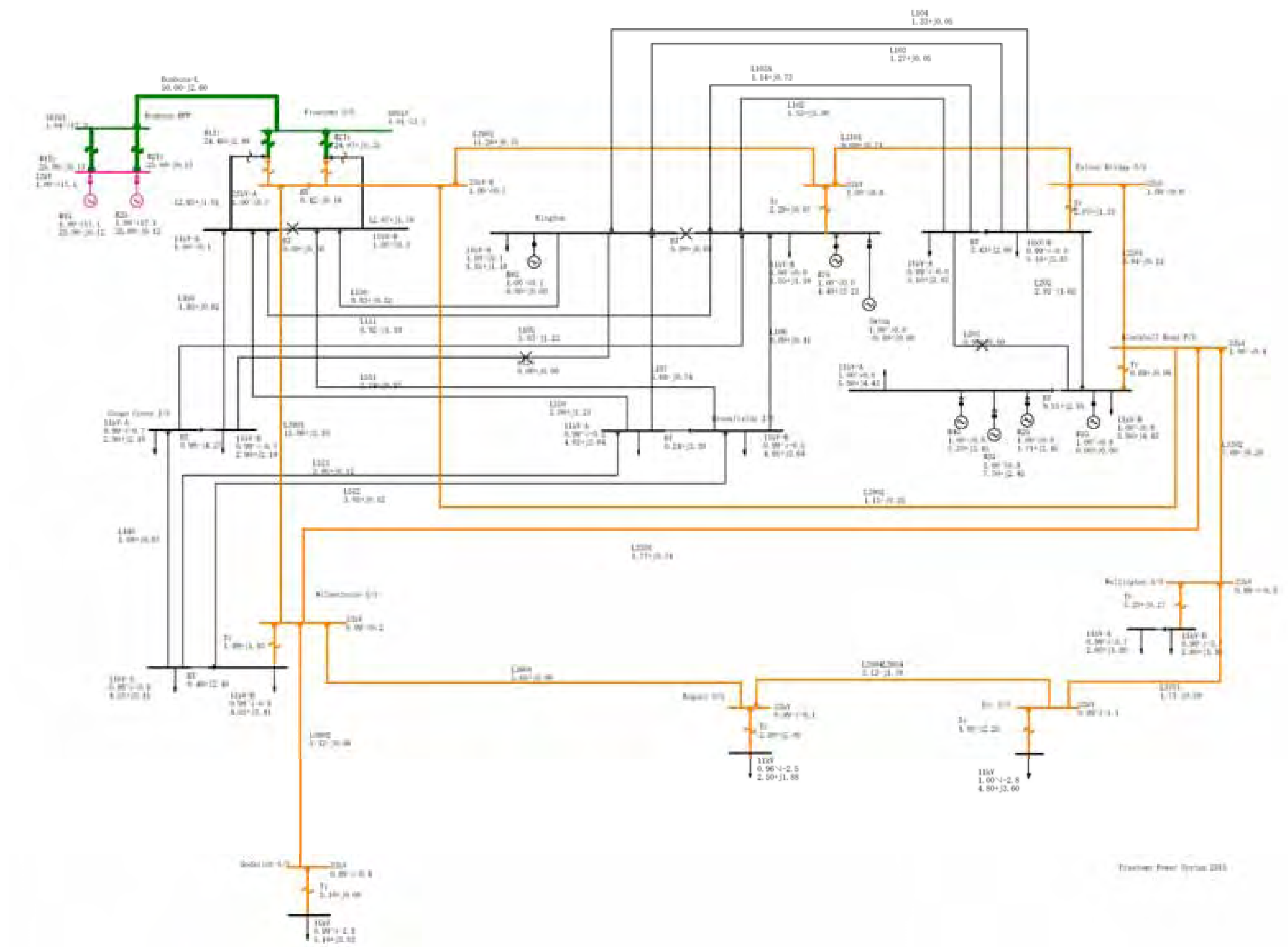
[Source] JICA Study Team

Fig. 6.4-11 Short Circuit Calculation: 2015 (Base)



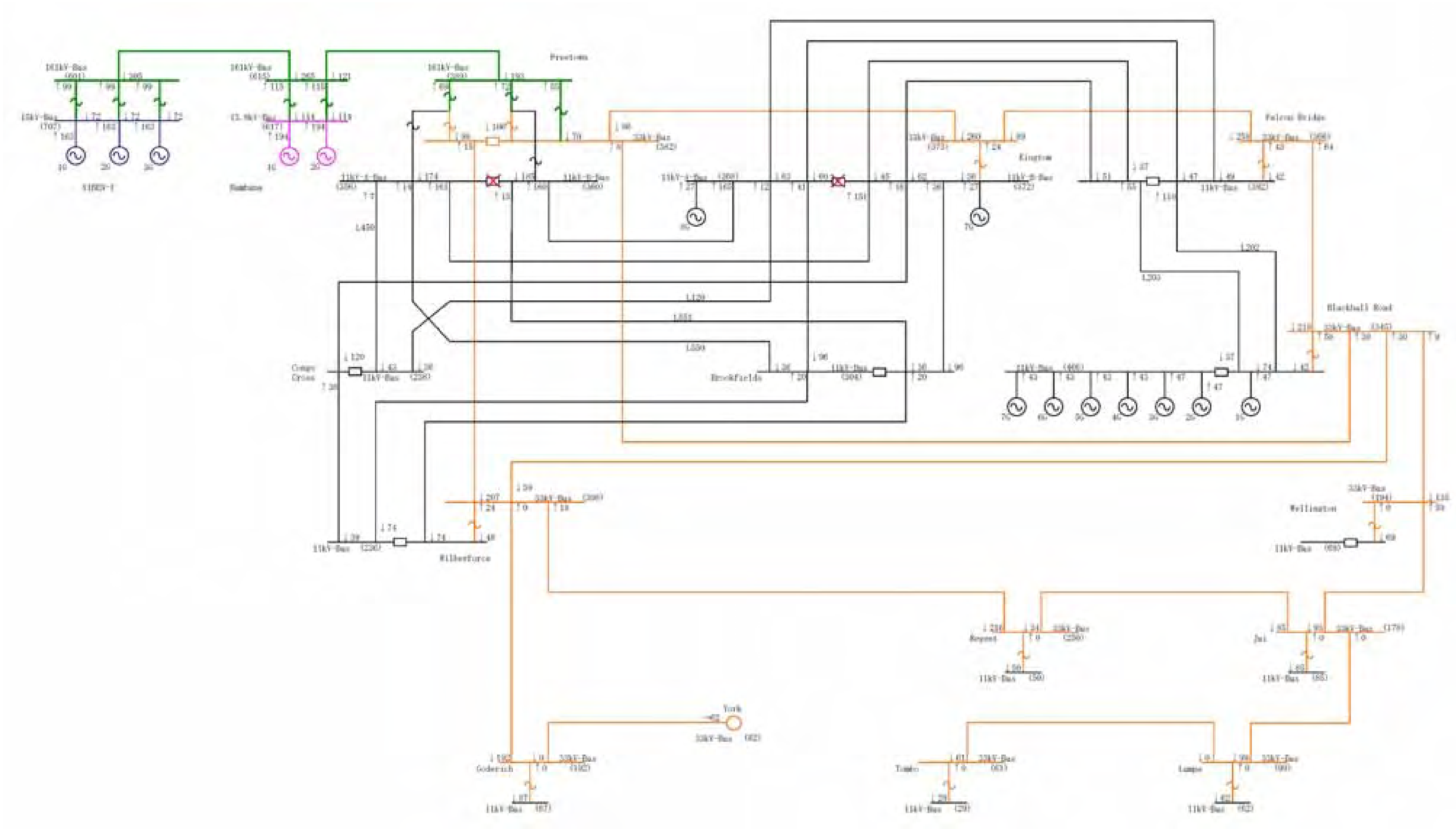
[Source] JICA Study Team

Fig. 6.4-12 Short Circuit Calculation: 2015 (Selection of Open Circuit)



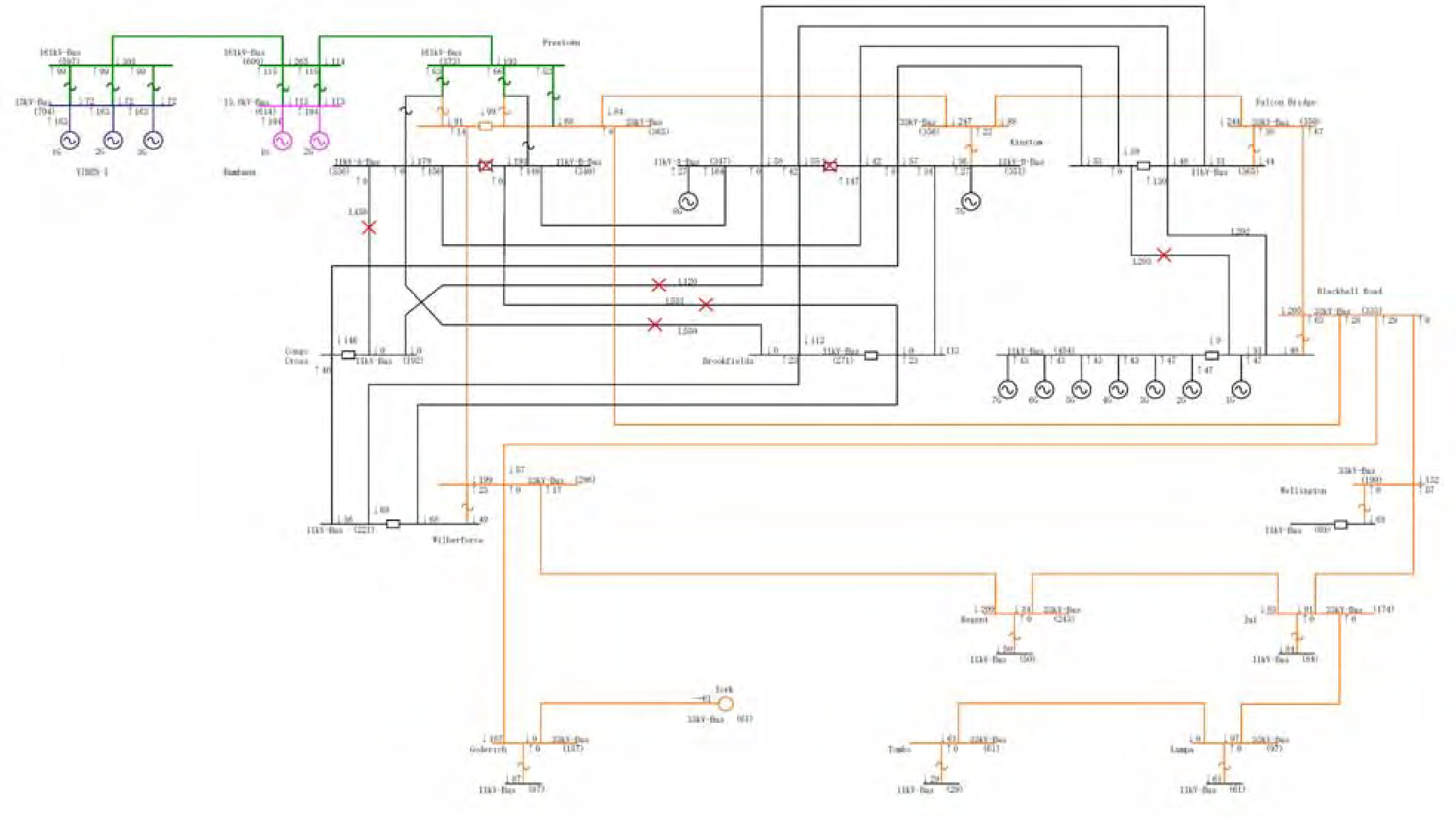
[Source] JICA Study Team

Fig. 6.4-13 Power Flow: 2015 (After Open Circuit)



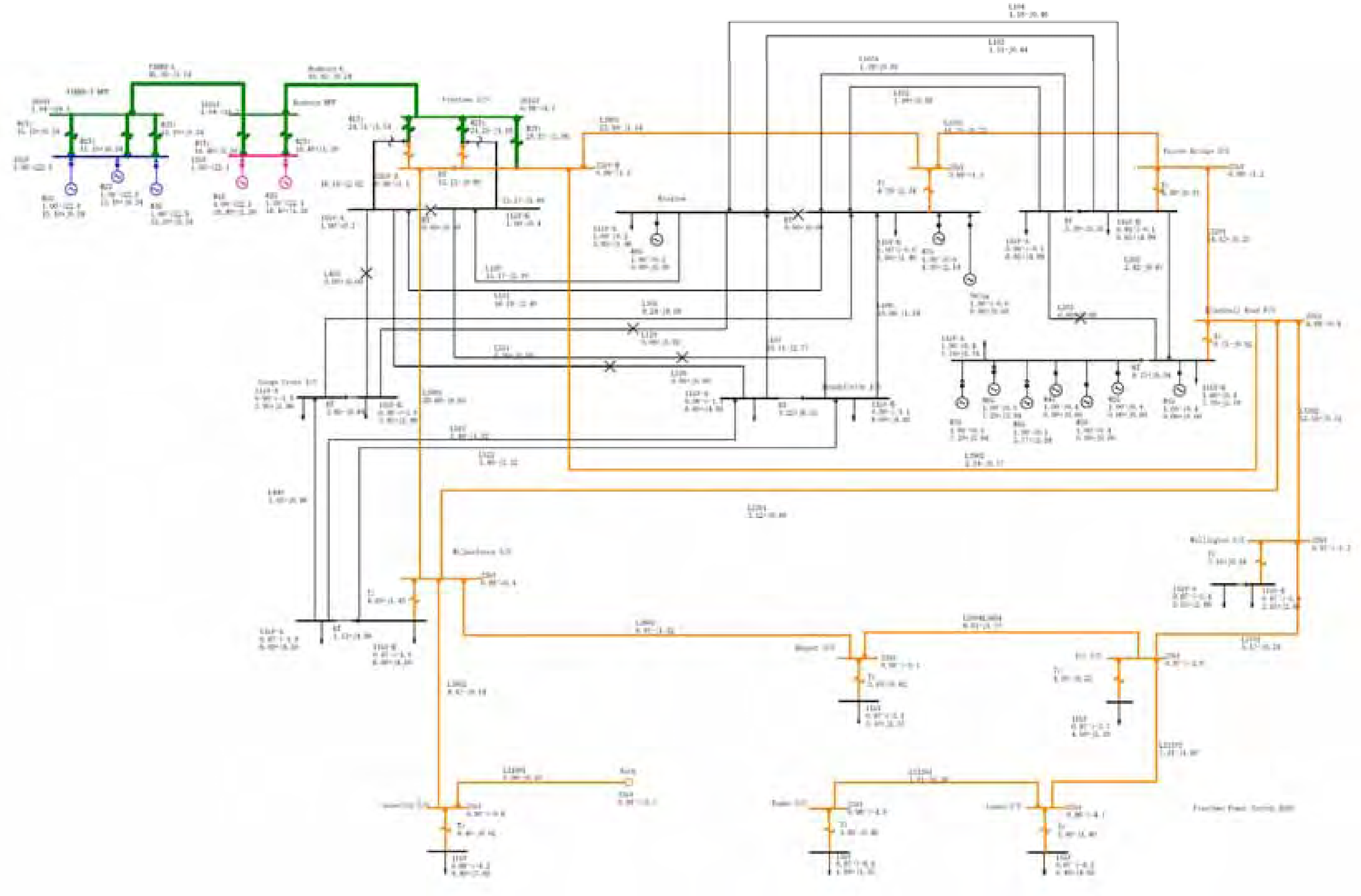
[Source] JICA Study Team

Fig. 6.4-14 Short Circuit Calculation: 2020 (Base)



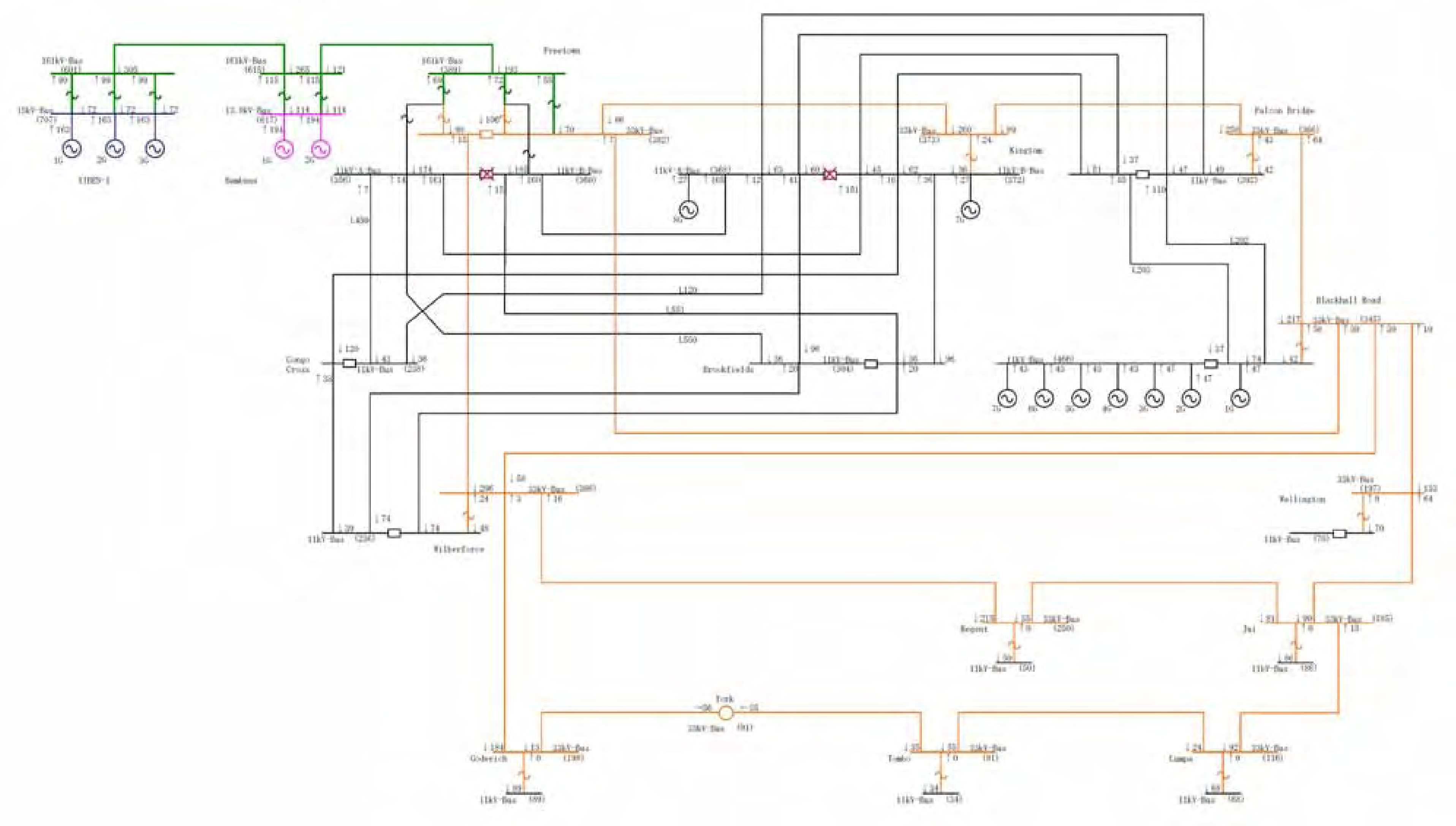
[Source] JICA Study Team

Fig. 6.4-15 Short Circuit Calculation: 2020 (Selection of Open Circuit)



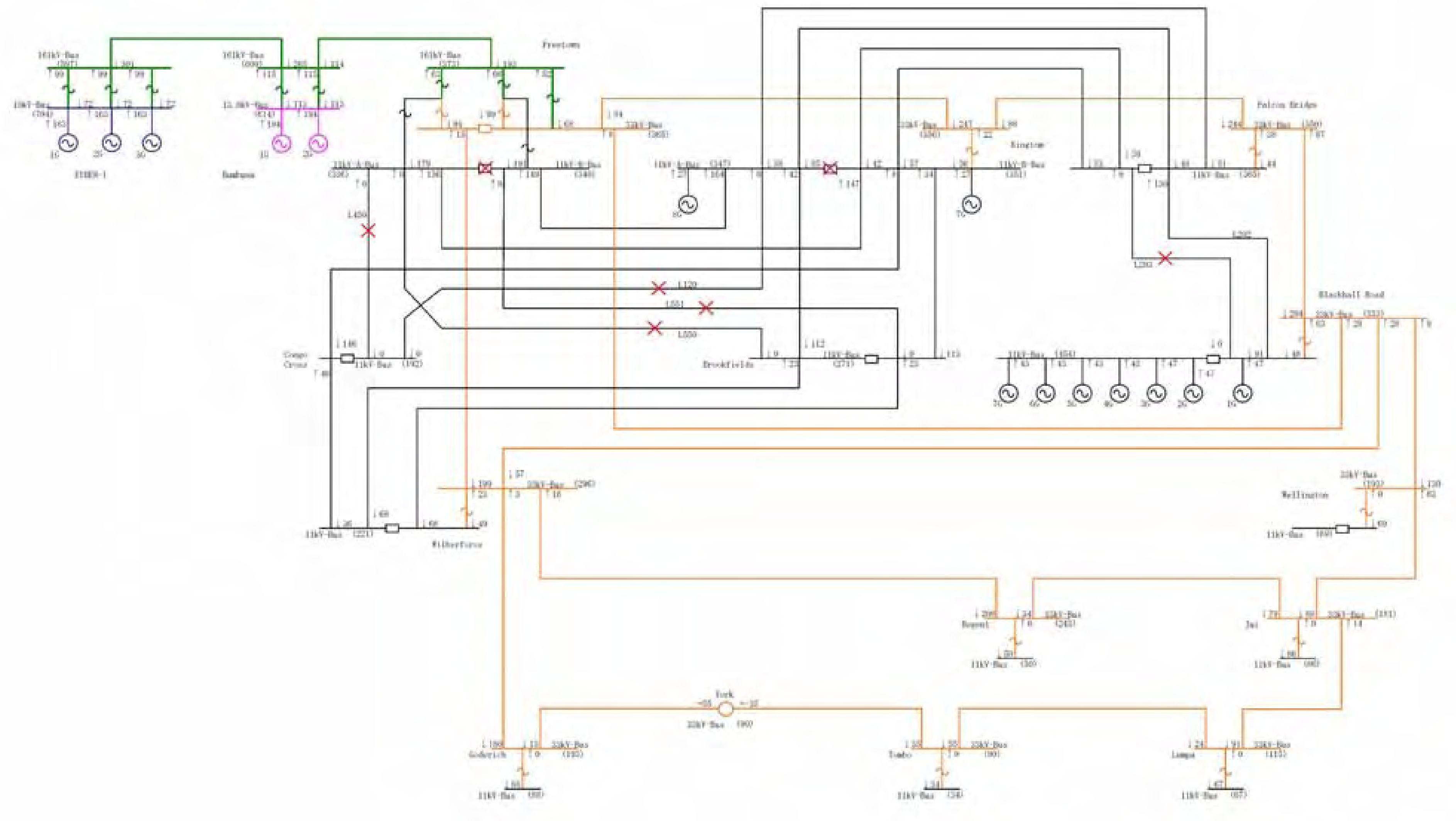
[Source] JICA Study Team

Fig. 6.4-16 Power Flow: 2020 (After Open Circuit)



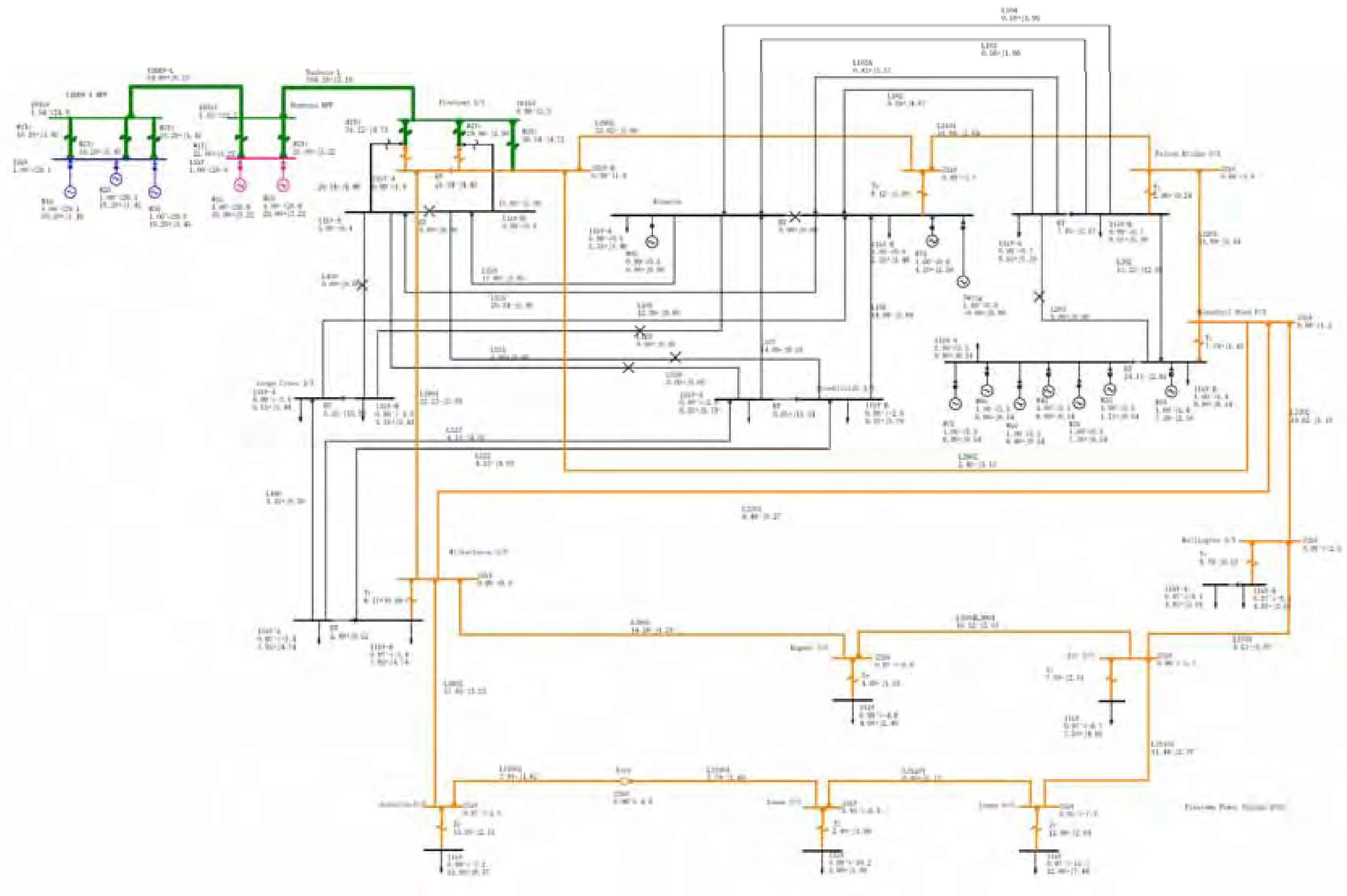
[Source] JICA Study Team

Fig. 6.4-17 Short Circuit Calculation: 2025 (Base)



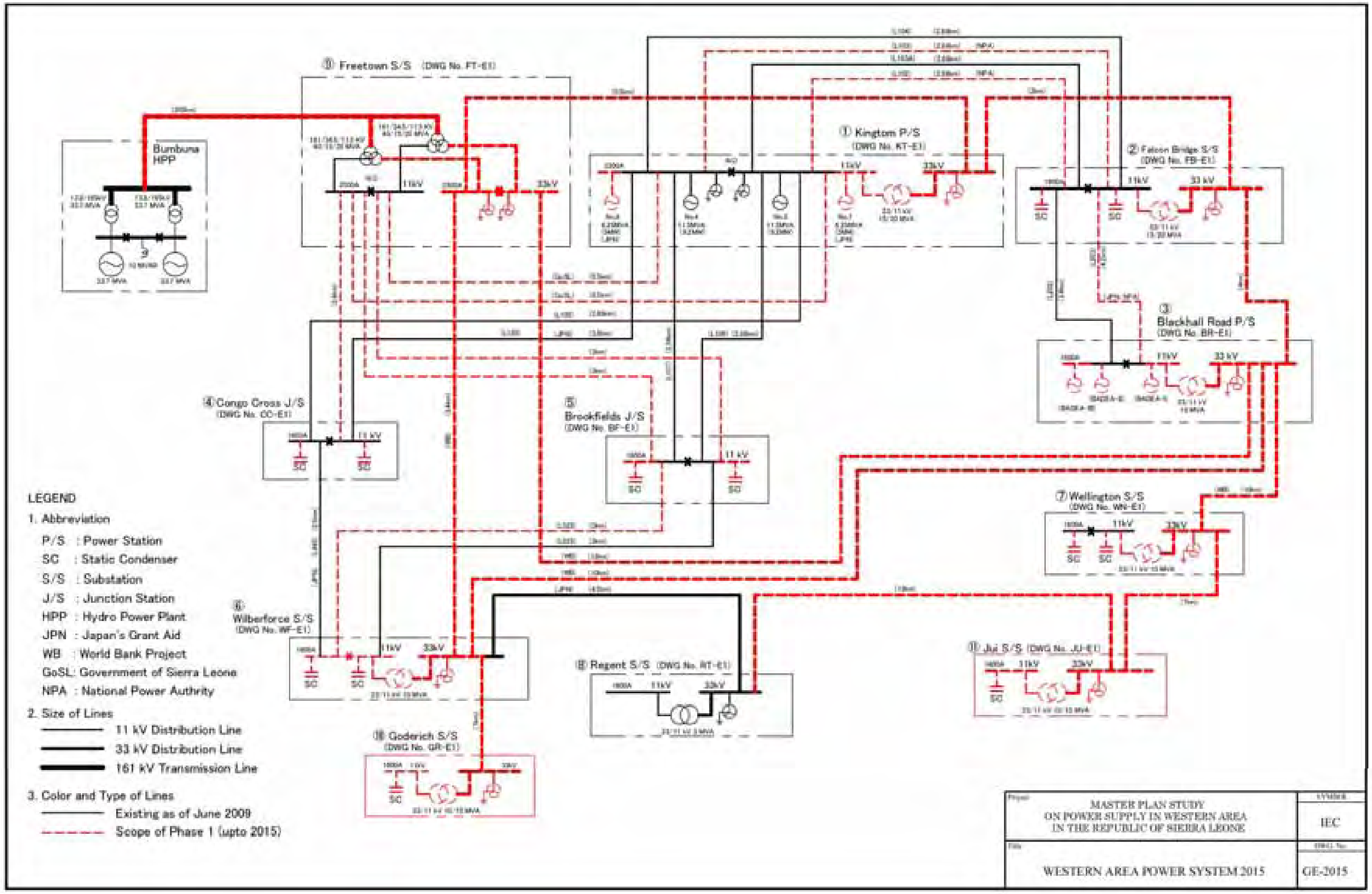
[Source] JICA Study Team

Fig. 6.4-18 Short Circuit Calculation: 2025 (Selection of Open circuit)



[Source] JICA Study Team

Fig. 6.4-19 Power Flow: 2025 (After Open Circuit)



[Source] JICA Study Team

Fig. 6.5-1 Western Area Power System 2015

[Generator Output Balance adjustment Method]

Follow the procedure below when generator output needs to be increased to compensate for transmission loss.

In principle, allocate orders from the first to the last based on the operation dispatching order, "Loading Order" described on the left side of the table "Generator Output Allocation in Western Area Power System (Base Growth, WASP Hydro Scenario)".

The upper limit of a diesel generator output is 90% of the rating in order to maintain spinning reserve.

(1) 2015

1) Increase the output of Bumbuna until its output reaches 50 MW.
2) Increase the outputs of Blackhall Road Power Station's NewDEG-3 and NewDEG-1, Kingtom Power Station's NewDEG-7 that are in operation until they reach 90% of the ratings.
3) Increase the output of Blackhall Road Power Station's NewDEG-2 until it reaches 90% of the rating.
4) Repeat the same procedure as the section 3) above on the generator assigned in the next order in "Loading Order."

(2) 2020

1) Increase the total output of Yiben until it reaches 45.2 MW.
2) Increase the total output of Bumbuna until it reaches 36.8 MW.
3) Increase the outputs of Blackhall Road Power Station's NewDEG-7 and NewDEG-6 and Kingtom Power Station's NewDEG-7 that are in operation until they reach 90% of the ratings.
4) Increase the output of Blackhall Road Power Station's NewDEG-5 until it reaches 90% of the rating.
5) Repeat the same procedure as the section 4) above on the generator assigned in the next order in "Loading Order."

(3) 2025

1) Increase the total output of Yiben until it reaches 54.6 MW.
2) Increase the total output of Bumbuna until it reaches 50.0 MW.
3) Increase the outputs of BlackhallRoad Power Station's NewDEG-7, 6, 5, 4, 3 and Kingtom Power Station's NewDEG-7 that are in operation until they reach 90% of the ratings.
4) Increase the output of Blackhall Road Power Station's NewDEG-1 until it reaches 90% of the rating.
5) Repeat the same procedure as the section 4) above on the generator assigned in the next order in "Loading Order."

[Source] JICA Study Team

Appendix-6.4-1 Balancing Method of Generator Output

7. Environmental and Social Considerations

7.1 Legal and Institutional Framework of Environmental and Social Considerations

7.1.1 Organizations for Environmental Protection and Regulation

(1) Environment Protection Agency

The Environment Protection Agency was newly established in December 2008, based on the Environment Protection Agency Act 2008, under the Ministry of Lands, Country Planning and the Environment. Before the establishment of the Environment Protection Agency, the Department of Environment under the Ministry of Lands, Country Planning and the Environment was in charge of protection of the environment. The main reason for the establishment of the Agency is to give more autonomy to carry out its activities.

The Agency has a board consisting of representatives from Ministry of Land, Country Planning and the Environment, Ministry of Local Government, Ministry of Mineral Resources, Ministry of Marine Resources, Ministry of Agriculture, Forestry and Food Security, Ministry of Tourism and Cultural Affairs, Ministry of Trade and Industry, Ministry of Transport, Ministry of Health and Petroleum Unit. The Board supervises the Agency.

The roles of the Agency are to advise ministries in formulating policies concerning the environment, harmonize the activities of concerned bodies to control pollution and protect the environment, coordinate and monitor the implementation of national environmental policies and so on. The Agency is also in charge of issuing EIA licenses as described in the next part.

The agency, however, has currently only eight staff. Although the agency has a plan to increase the number of staff, this shortage of manpower and capacity make it difficult to carry out the expected roles.

Since there is no national environmental regulation or standard, Sierra Leone uses the regulations or standards of international organizations such as WHO (water, air) or other countries. One of the agency's new functions is to establish national environmental standards and prescribe guidelines relating to ambient air, water and soil quality, the pollution of air, water, land and other forms of environmental pollution including the discharge of wastes and the control of toxic substances.
It is though it takes time to establish the national environmental standards, considering the capacity of the agency. Thus, it is necessary to use international environmental standards for some time.

(2) Forestry Division, Ministry of Agriculture, Forestry and Food Security

The forestry division under the Ministry of Agriculture, Forestry and Food Security is in charge of management and protection of forests and wildlife. The forestry division has branches in districts. There are two relevant laws, namely the Forestry Act 1988 and the Wild Life Conservation Act 1972.

According to the Forestry Act, a chief conservator compiles a national inventory of forest resources, and prepares a management plan based on the inventory for each forest. Nobody is allowed to cut down trees, construct structures, cultivate and mine in protected forests without authorization. However, in practice, the government does not have enough personnel and budget to prepare such an inventory and management plan or patrol to stop illegal activities in forests.

When somebody wants to cut trees in a protected forest, he/she is required to submit a letter to the director of the forestry division to obtain his permission.

Even though there is the Wild Life Conservation Act, the lack of budget makes the Forestry Division unable to conduct a survey and protect wild animals from illegal hunting.

7.1.2 Procedures of Environmental Impact Assessment (EIA)

Projects mentioned in the First Schedule below are required to apply for an EIA license to the Agency before starting the projects. The sections from 23 to 39 of the Environment Protection Agency Act explain the procedures of EIA. The flow of the EIA procedures is summarized in Fig. 7.1-1.

1) Any person who will undertake a project under the First Schedule (Please refer to the First Schedule: Project Requiring Environmental Impact Assessment Licenses-in the box below) needs to apply for a license to the Agency with a description of the project.
2) The Agency decides whether EIA is required in fourteen days after the agency receives an application. The Second Schedule (Please refer to the Second Schedule:Factors for Determining Whether a Project Requires an Environmental Impact Assessment) is considered when a decision of EIA requirement is taken.
3) If EIA is not required, the Executive Director informs the applicant in written form.
4) When an applicant is required to submit EIA, the applicant needs to prepare and submit EIA including the information set out in the Third Schedule （Please refer to the Third Schedule: Contents of EIA）to the Agency.
5) The Agency circulates a received EIA to professional bodies or associations, Government Ministries and NGOs for their comments. In addition, the Agency makes the EIA open to the public for their comments and inspection in Gazette or newspaper.
6) After receiving the comments, the EIA is submitted to the Board. Then, the Board decides whether a) to issue a license b) to require additional information from the applicant in 21 days, or c) to reject the EIA which has adverse impacts on the environment, people and society.
7) When the EIA has been approved, the Board directs the Executive Director to issue a license to the applicant.
8) The Agency will monitor all projects which licenses have been issued to assess the effects on the environment.

First Schedule: Projects Requiring Environmental Impact Assessment Licenses

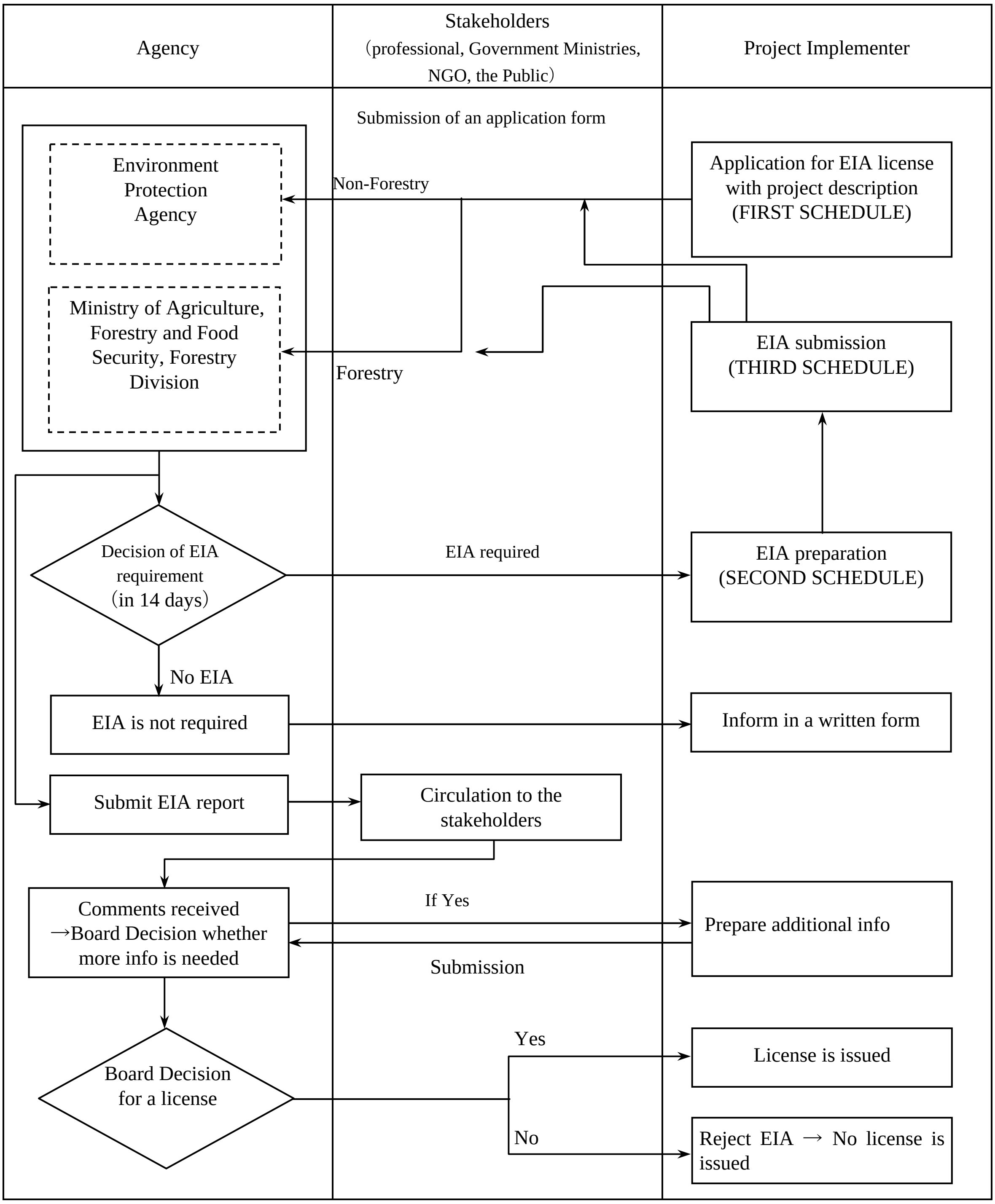
(a) Substantial changes in renewable resource use (e.g. conversion of land to agricultural production, forestry or to pasture land, rural development, timber production)
(b) Substantial changes in farming and fisheries practices (e.g. introduction of new crops, large scale mechanization or use of chemicals in agriculture)
(c) Exploitation of hydraulic resources (e.g. dams, drainage and irrigation project, water basin development, water supply)
(d) Infrastructure (e.g. roads, bridges, airports, harbors, transmission lines, pipelines, railways)
(e) Industrial activities (e.g. metallurgical plants, wood processing plants, chemical plants, power plants, refinery and petro-chemical plants, agro-industries)
(f) Extractive industries(e.g. mining quarrying extraction of sand, gravel, salt, peat, oil and gas)
(g) Waste management and disposal (e.g. sewerage systems and treatment plants, landfills, treatment plants for household and hazardous waste)
(h) Housing construction and development schemes
(i) Establishment of places of entertainment, motor repair garages and welding shops
(j) Importation of second hand vehicles

Second Schedule: Factors for Determining Whether a Project Requires an Environmental Impact Assessment

(a) The environment impact on the community
(b) The location of the project
(c) Whether the project transforms the locality
(d) Whether the project has or is likely to have substantial impact on the ecosystem of the locality
(e) Whether the project results in the diminution of the aesthetic, recreational, scientific, historical, cultural or other environmental quality of the locality
(f) Whether the project will endanger any species of flora or fauna or the habitat of the flora and fauna
(g) The scale of the project
(h) The extent of the degradation of the quality of the environment
(i) Whether the project will results in an increase in demand for natural resources in the locality
(j) The cumulative impact of the project together with other activities or projects on the environment

Third Schedule: Contents of Environmental Impact Assessment (EIA)

(a) The location of the project and its surroundings
(b) The principle, concept and purpose of the project
(c) The direct or indirect effects that the project is likely to have on the environment
(d) the social, economic and cultural effect that the project is likely to have on people and society
(e) The communities, interested parties and government ministries consulted
(f) Any actions or measures which may avoid, prevent, change, mitigate or remedy the likely effect on people and society
(g) Any alternatives to the proposed project
(h) Natural resources in the locality to be sued in the project
(i) The plans for decommissioning of the project
(j) Such other information as may be necessary for a proper review of the potential impact of the project



[Source] JICA Preparatory Study Report

Fig. 7.1-1 Flow of EIA

As above, projects of transmission lines and power plants are required to apply for an EIA license, and then a submission of EIA is required in most cases.

7.1.3 Legal Framework for Land Acquisition and Compensation

(1) Land Tenure System

There are two land tenure systems in Sierra Leone. One is the customary land tenure system, which is controlled by paramount chiefs, who are traditional rulers in Sierra Leone, and land is owned by communities, families and individuals. This is practiced in provinces outside Western Area. The Provinces Land Act regulates the ownership of land by non-natives in the provinces other than Western Area. According to the definition in the act, “non-natives” are any person who is not entitled by customary law to have land rights in the provinces. Section 4 of the Province Land Act provides that non-natives are able to acquire only rights of leasehold of land for 50 years.

The other one is the modern freehold land tenure system governed by law and practiced in Western Area. Land in Western Area is either state land or private land, and it can be sold, purchased or leased.

Therefore, the procedures of land acquisition and the way how to compensate land differ between Western Area and the other provinces.

(2) Land Acquisition and Compensation

To implement this Master Plan, land acquisition for a new power plant, sub station, and transmission and distribution lines will be needed. The Constitution 1991 states that the state can acquire land compulsorily for public interest if the state pays adequate compensation.

The Public Lands Act (the Public Lands Ordinance 1961) stipulates that land can be acquired by agreement or compulsory for public work, and then how to compensate the taken land and damages incurred to owners, occupiers and other persons who have interest in the land. The act also provides settlement of disputes, judicial procedures and grievance procedures. However, the Public Lands Act applies only in Western Area.

Section 18 of the Act explains the matters which should be considered in determining the amount of compensation as follows.

1) The market value of the land
2) Increase in the value of other land likely to accrue from the use to which the land acquired will be put
3) Damage incurred by the person who possesses the land caused by separating the land from his/her other land
4) Damage to other property and his/her actual earnings when the land is taken
5) Expense if the person is forced to change his residence and place of business

The Compulsory Acquisition of Property (Constitutional Safeguards) 1961 provides the procedure of compulsory acquisition.

A person who does not hold land title is not entitled to receive compensation under the national laws. In practice, however, if a person has settled in some land without land title for certain years, he/she can receive some compensation in some cases.

The Ministry of Lands, Country Planning and the Environment (MLCPE) is the main body to acquire land for public use and valuate assets. In case of in-kind compensation, MLCPE finds alternative land and prepares necessary documents. In case of cash compensation, a project implementer (NPA) in collaboration with MLCPE negotiates with affected people. The government prefers in-kind compensation as it costs less.

(3) National Power Authority Act (NPA Act)

The National Power Authority Act 1982 explains the two different cases for Western Area and the other provinces. According to section 40 (1) (a) of the NPA Act, if the authority cannot acquire land by private treaty or agreement in Western Area, land can be obtained in a compulsory manner for public use in accordance with the Public Lands Act (Ordinance). Section 40 (1) (b) provides that if the authority cannot acquire leasehold of any land by private treaty or agreement in the provinces, the Minister of Interior may authorize any person to execute a lease of any land to the Authority under fair and reasonable conditions. In either case, all expenses and compensation for the acquisition is paid by the authority.

There are sections for Bumbuna hydro project in the NPA Act. Section 49(1) provides that the Authority may acquire any land either permanently or temporarily and either by agreement or compulsorily.

Section 33 of the NPA Act provides that when any trees or structures interfere the supply line, a Magistrate can order it to be removed only if appropriate compensation is paid to the owners.

Section 42 of the NPA Act explains that if the NPA thinks it is necessary, the NPA may lay supply lines at any height along, across and under any streets or roads, erect structures such as posts and poles in or on streets and roads, and sometimes break up any streets and roads in previous consultation with concerned ministries.

7.2 Natural and Social Environment of the Target Area

7.2.1 Natural Environment

The climate of Sierra Leone is tropical. The rainy season is from May to October, and the dry season is from November to April. The monthly temperature is around 27ºC in Freetown. Freetown, being near the ocean, has high rainfall, about 3,000 mm/ year. Humidity is high, especially in the rainy season when it is about 80%, and 60-70% in the dry season.

The target area of the study, Western Area, is located in Western Area Peninsula. Even though urbanization and deforestation have destroyed the environment, there is still beautiful nature in Western Area, such as forests, beaches, ocean, and wetlands (mangrove forests).

It is estimated 85% of energy sources in the urban and rural areas for heating and cooking are fuel wood and charcoal due to lack of other energy sources such as electricity. They come from forests or mangrove swamps.

A thin costal line can be seen around the peninsula in the north, west and south. There are beautiful white sand beaches along the coastal line in the west. Foreign tourists used to visit these beaches before the civil war. Still, there are hotels and restaurants along the beaches. The beaches are potential sites for tourism development.

(1) Flora and Fauna

Sierra Leone is rich in terms of biodiversity, both flora and fauna. But lack of intensive and comprehensive surveys especially after 90’s makes it difficult to grasp the current status of biodiversity. In addition, the ten-year civil war degraded its rich biodiversity as people cleared forests and ate bush meats.

In the 2008 IUCN (International Union for Conservation of Nature and Natural Resources) Red List, 1051 species are categorized as Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near

Threaded (NT), Data Deficient (DD), and Least Concerned (LC) in Sierra Leone. Out of 1051 species, 94 species are categorized as CR, EN, and VU. The number of animal species is 47 and plant species is 47.

Table 7.2-1 Critically Endangered Species in Sierra Leone

1	Animal (fish)	Epinephelus itajara (Goliath Grouper)	
2		Pristis pectinata (Wide Sawfish)	
3		Pristis perotteti (Largetooth Sawfish)	
4		Pristis pristis (Common Sawfish)	
5	Plant	Triclisia macrophylla	Occurs in lowland and submontane forest; 0–1,500 m altitude

[Source] IUCN (International Union for Conservation of Nature and Natural Resources) Red List

Table 7.2-2 Endangered Species in Sierra Leone

1	Animal	Cardioglossa aureoli (Freetown long-fingered frog)
2		Cephalophus jentinki (Jentink's Duiker)
3		Chelonia mydas (Green Turtle)
4		Choeropsis liberiensis (Pygmy Hippopotamus)
5		Epinephelus marginatus (Dusky Grouper)
6		Hylomyscus baeri (Baer's Hylomyscus)
7		Lycaon pictus (African Wild Dog)
8		Malimbus ballmanni (Gola Malimbe)
9		Pan troglodytes (Common Chimpanzee)
10		Procolobus badius (West African Red Colobus)
11		Rhinobatos cemiculus (Blackchin Guitarfish)
12		Rhinobatos rhinobatos (Common Guitarfish)
13		Rhynchobatus luebberti (Lubbert’s Guitarfish)
14		Rostroraja alba (Bottlenose Skate)
15		Scotopelia ussheri (Rufous Fishing-owl)
16	Plant	Neolemonniera clitandrifolia
17		Placodiscus pseudostipularis
18		Tieghemella africana
19		Tieghemella heckelii (Cherry Mahogany)

[Source] IUCN (International Union for Conservation of Nature and Natural Resources) Red List

However, the Government of Sierra Leone has not carried out any national surveys to develop a database. So no detailed national information is available.

(2) Protected Areas

There are two protected areas in Western Area. One is a part of Sierra Leone River Estuary (the total area is 300,000ha), which is one of the wetlands in the list of the Ramsar Convention. The other one is rainforest, Western Area Peninsular Forest Reserve (WAPF), located in the center of the peninsula.
In addition, there is an unprotected wetland called Yawri Bay area in the south of the peninsula. The area is undergoing work to be designated a national protected area and to be a registered site of the Ramsar Convention.

[Remarks] The red lines show the road network
[Source] DACO / SLIS

Fig. 7.2-1 Map of Protected Areas in Western Area

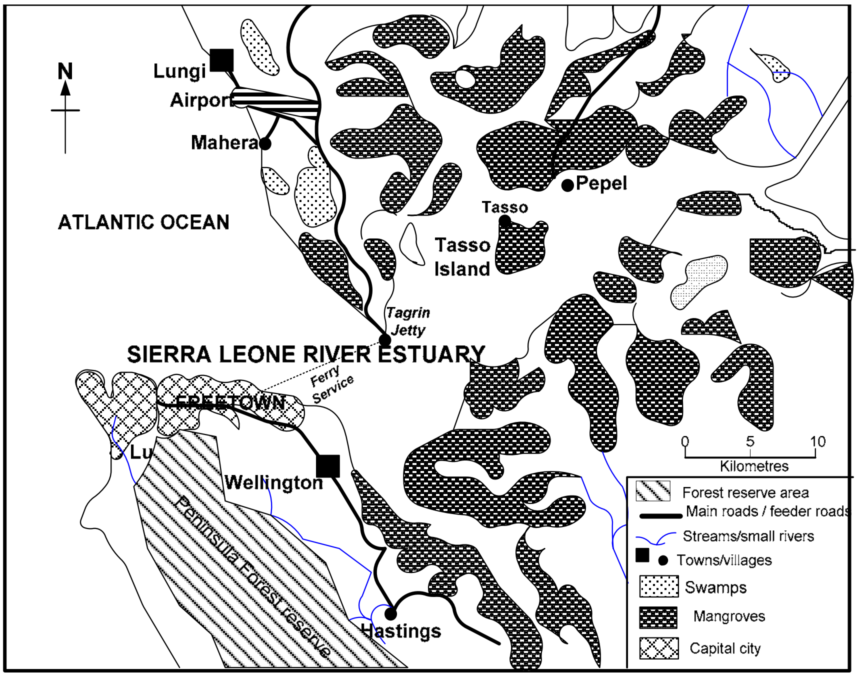
1) Sierra Leone River Estuary

Sierra Leone River Estuary is characterized as mangrove swamp and it is a protected area under international convention, but it is not under the domestic laws. This has led to virtually no study and management of the estuary by the government, although the area is important as a habitat of birds and tree species as well as breeding ground for fish. Studies in the 80's and 90's found that the estuary held over 20,000 birds. The estuary also is an important site for Palaearctic[1] migratory birds which winter in the estuary. Five species of marine turtle live here, and Green Turtle out of the five is an endangered species. It is said that African Manatees live in the estuary.

	
Mangrove swamp near Jui , Sierra Leone River Estuary	Mangrove swamp near Jui , Sierra Leone River Estuary

[1] A zoogeographical region comprising Eurasia north of the Himalayas and North Africa

The clear demarcation of the area is not available. People cut mangrove trees for farmland, housing or for fuel wood. It is said that the size of area has become small. It is prohibited to fish by large fishing vessels in the estuary to protect the environment and to avoid depletion of fish. It has been proposed that Sierra Leone River Estuary become a marine protected area.



[Source] Conservation Society of Sierra Leone

Fig. 7.2-2 Map of Sierra Leone River Estuary

As in the above map, the mangrove swamp stretches from Wellington through Hastings to Waterloo. The road network keeps away from the mangrove swamp, but the road is very close to the mangrove swamp in several parts like Jui and Waterloo.

2) Western Area Peninsula Forest, WAPF (Non hunting forest reserve)

The Western Area Peninsular Forest Reserve is moist forest. WAPF is protected area under a domestic law, and has been proposed to acquire national park status. The range of quite steep hills between 150m to 900m with the highest Picket Hill in the south is covered by closed moist forest. WAPF is unique and the only place in West Africa where mountains occur near the coast.

WAPF is an important water catchment area for the population in Freetown who depend on water supply from Guma valley dam located in WAPF. Two reservoirs are in WAPF, that is, Guma Valley and Congo dams.

Forest near River No.2

Hills Covered by Forest near River No.2

WAPF has heavy rainfall with annual mean rainfall from 3000 to 7000mm. Daily temperatures vary from 25 to 30ºC in the dry season and 22-27ºC in the rainy season. Humidity is from 45% to 80%.

In Fig. 7.2-3, the areas in orange show the already extinct parts and the areas in yellow show the actual stretch of the forest.

For instance, Regent area used to be in the forest reserve. But it was developed as a housing area. Consequently, the area has been deforested. Not only in Regent area, but in other areas, in particular, the areas along the road running along the western coast line trees have been cut down.

Regent Area

No Trees on Hill Slope near Lakka

There is no detailed information regarding flora in WAPF, as no comprehensive survey for flora has been carried out before. A sample survey in 2003 recorded 53 tree species and 47 shrub species. The forest vegetation is interrupted by natural grassland in laterite plain along the coastal line.

Although WAPF is a non-hunting forest under law, local people or people who belong to hunting societies do hunting in WAPF. This has driven some precious animals to the edge of extinction. It is believed leopards that used to inhabit WAPF are now extinct and the red colobus monkey is nearly extinct.

[Remarks] Note The red lines show the existing roads.
[Source] DACO / SLIS

Fig. 7.2-3 Western Area Peninsula Forest Reserve

As for animals, over 50 mammal species have been recorded so far. But no comprehensive survey has been carried out since the 1990's. According to 2008 ICUN Red List and past surveys, there are several animals which are believed to have their habitats in WAPF, that is, Cardioglossa aureole (Freetown Long-fingerd Flog, EN), Chephalophus jentinki (Jentingk's Duiker, EN), Cercocebus atys (Sooty/white-naped Mangabey, VU), Cercopithecus diana (Diane/roloway Monkey,VU), Pan Troglodytes (Common Chimpanzee, EN), Panthera pardus (Leopard, NT), and Procolobus badius (West African Red Colobus, EN).

Regarding birds, 374 bird species have been recorded so far. According to 2008 IUCN Red list and past surveys, Bleda eximius (Green-tailed Bristlebill, VU) and Picathartes gymnocephalus (White-necked Picathartes, VU) have their habitat in WAPF.

As the original boundary of WAPF by law has been disregarded, the government is now trying to re-demarcate WAPF to protect the forest (its catchments and biodiversity), considering the current condition of degradation and local people's dependence on the forest. The Forestry Division, the Ministry of Lands, County Planning and the Environment, the Police, the Army, and the Guma Valley Water Company are cooperating for this demarcation. EU started a project called "Conservation of the Sierra Leonean Western Area Peninsula Forest Reserve and its Watersheds" in March 2009 to help the demarcation and preparation of management plans for the benefit of the adjacent population (about 50,000).

3) Yawri Bay Area

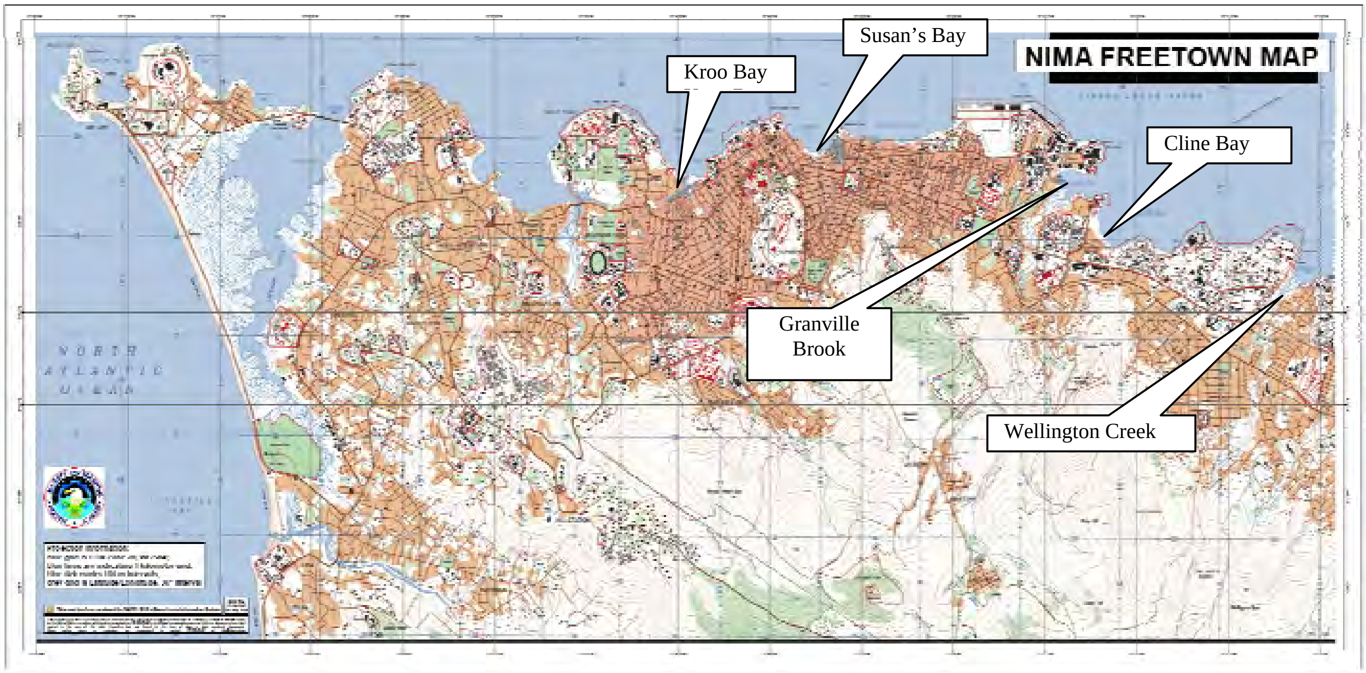
This is an unprotected coastal wetland of mangroves swamp. The area is important for birds and fish. The bay is estimated to hold over 20,000 birds and Palaearctic migratory birds occur in the bay. Surveys on animals except birds have not been carried out. But, it is thought that African Manatee and Green Turtle occur in the bay area.

7.2.2 Social Environment

Sierra Leone was suffering from insufficient provision of social and public services and deterioration of economy due to power game and corruption after achieving independence in 1961. The civil war that started in 1991 made the situation worse.

Since the end of war in 2002, peace has been kept. The country is now in the stage of development after the reconstruction stage. However, basic infrastructure such as water, electricity, roads is not yet developed enough even in the capital, Freetown, which is a negative factor for economic development. The lack of social services such as education or health makes the lives of people more difficult. The unemployment rate and poverty rate are high. The country is ranked at 177, bottom in the Human Development Index (2007/2008) published by UNDP

The size of population is becoming bigger and bigger in Western Area, as refugees or internally displaced persons during the war have been moving in, and people from rural areas have also migrated to seek a better life. The population of Western Area is 950,000 according to the statistics in 2004 (urban 785,000 and rural 165,000).This growth of population has caused heavy congestion in Freetown. Especially, the poor have encroached along bay, river and hilltop areas informally. These kinds of slums with no proper infrastructure and sanitation facilities are scattered in the town. Of them, slums in Kroo Bay, Susan's Bay, Granville Brook, Cline Bay near Fisher Lane and Wellington Creek are big.



[Source] JICA Study Team

Fig. 7.2-4 Location of Big Slums in Freetown

In Western Rural, towns and villages are located along the roads. People have encroached the Right of Way (ROW) of the roads and the forest reserve in some cases. New housing development can be seen in Goderich, Grafton and Waterloo in Western Rural.

Sierra Leone has two poverty lines. One is the food/extreme poverty line, which is translated to expenditure of 1,000 leones per day. The other one is the full poverty line, which is expenditure of 2,100 leones per day. Western area is rich compared to the other areas in Sierra Leone. But, poverty still prevails. According to the Annual Statistics Digest 2005/2006, the ratio of people who live under the two poverty lines is 3.2% and 17.1% respectively in Western Urban, and 26.3% and 70.1% respectively in Western Rural. (National average is 14.7% and 54.3% in urban, and 32.8% and 78.9% in rural.)

The employment pattern in Western Area differs vastly from the other areas. While over 60% of the national population depends on agriculture, only 6.5% in Western Area does. 60% of people in Western Area have their jobs in the service sector. From this, it can be said that power demand in Western Area is higher than the other areas.

Table 7.2-3 Share of Employment by Sector

	Nation	South	East	North	West
	2007	**2007**	**2007**	**2007**	**2007**
Crop farming	61.3	68.1	71.7	75.7	1.7
Livestock/poultry	0.4	0.1	0.8	0.1	0.1
Forestry/logging	0.4	0.3	0.1	0.2	1.3
Fishing	1.7	0.4	2.0	1.5	3.4
Agriculture total	**63.8**	**69.0**	**74.6**	**77.6**	**6.5**
Mining/quarrying	2.6	7.1	0.4	2.0	0.9
Manufacturing/processing	1.9	1.0	1.0	1.6	6.0
Electricity/gas/water	0.8	0.6	0.5	0.2	2.8
Construction	1.9	1.6	1.0	1.2	6.0
Industry total	**7.1**	**10.3**	**2.9**	**5.0**	**15.6**
Wholesale/retail/ hotel/restaurant	19.8	14.8	16.8	12.0	48.0
Transport/storage/com.	1.6	0.7	0.5	0.9	6.7
Banking/finance	0.7	0.1	0.1	0.0	4.4
Services total	**22.1**	**15.6**	**17.4**	**12.9**	**59.2**
Community/ government (*)	**5.0**	**4.1**	**3.0**	**3.1**	**14.8**
Others	**1.9**	**1.1**	**2.0**	**1.4**	**4.0**
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

[Source] Poverty Reduction Strategy 2008-2012

7.3 Case Study of Environmental and Social Considerations for Power Project in Sierra Leone

The World Bank project “Power and Water Project” will be reviewed to learn lessons.

7.3.1 33kv Distribution Line in Freetown

One of the components of the Power and Water Project assisted by the World Bank is rehabilitation, reinforcements and extension of the transmission and distribution system in the Western Area. The planned line is from Kingtom Power Station through Tengbeh Town to Wilberforce Sub Station and Blackhall Sub Station for 9.2km in total.

The work had to be stopped due to the civil war in 1997 with 60% of the work unfinished. The network was damaged during the war, and people settled in under and along the line sometimes without formal land titles during and after the war. After the end of war, an EIA was conducted, and a resettlement action plan was prepared to continue the work. However, the work did not go straightforward since the government did not release the counter fund to NPA to implement the action plan and a contract between the WB and a contractor was not made. This rehabilitation, reinforcement and extension of the network system finally re-started in April 2009 after the contract was made. The WB has decided to finance the whole budget for the resettlement as a special case due to the emergency conditions. The increase of settlers under the lines is being reviewed as of June to implement the second resettlement action plan. After compensation for the resettlement to the project affected persons is paid, the construction work will start.

(1) EIA

An EIA was conducted in 2004 by a Ghanaian consulting company, referring to the Environmental Protection Act 2000 and World Bank procedures and guidelines (OP 4.01 Environmental Assessment and EA Source Book). The main adverse impacts are summarized in the next table.

Table 7.3-1 Summary of EIA

	Pre-Construction Phase	Construction Phase	Operational and Maintenance Phase	Project Activities	Mitigation Measures
Waste Generation	✓			To clean up substations	Provide waste disposal site by NPA
		✓		Replace cables/ conductors	Segregate and dispose, reuse, recycle as appropriate by NPA and a contractor
Vegetation			✓	Vegetation Control	Replant as necessary
Visual Intrusion/ Aesthetics		✓		Erecting Towers/Poles and Stringing Lines	Improve alignment and tensioning
Tourism		✓		Erecting Towers/Poles and Stringing Lines	

[Source] Power and Water Project EIA of the 33kV and 161kV Transmission and Distribution Network of the Western Area in Sierra Leone 2004

In addition, the followings were raised as special issues.

Table 7.3-2 Summary of Special Issues

	Impact	Remarks	Mitigation Measures
PCB in Insulating oils	Health hazard	Tests to be carried out to determine if PCB exists in NPA systems.	Safe handling procedures and personnel protection
Transformer Oil Leaks	Pollution Health and safety hazards		Construct bunds around transformers

[Source] Power and Water Project EIA of the 33kV and 161kV Transmission and Distribution Network of the Western Area in Sierra Leone 2004

The Study Team made an inspection of the existing substations, referring the Power and Water Project EIA. It was observed that rubbish, old cables and so on were scattered and oil leaked from transformers. The covers of several switch boards were removed so that electrodes were dangerously exposed, which may lead to accidents. It is required to keep the substations clean by implementing waste management and to take preventive measures for oil leak and operate and maintain the equipment properly. As the distribution network of NPA is old and old transformers are still used, the possibility of PCB inclusion in the transformers is very high. The old transformers will be disposed with the renewal of the distribution network. Therefore, appropriate measures should be taken.

(2) Resettlement Action Plan (RAP)

A first survey to develop a resettlement action plan for 9.2 km of 33kV line was conducted in 2004. But, the WB requested to review it, as the scale of resettlement was relatively large, and the total amount of compensation was big. The second survey was conducted by another consulting company in 2007 to minimize the number of affected people and the cost of compensation. Both RAPs were prepared to meet the WB Operation Policy 4.12 on Involuntary Resettlement, which is more favorable to protect affected people than national laws in Sierra Leone. Even people who do not have land title can receive some kind of cash or in-kind compensation. Therefore, the differences between the amount payable under the national laws in Sierra Leone and amount payable under the WB policy were clarified. As the Government of Sierra Leone wanted to avoid setting a precedent, it was informed to the public the latter would be paid in addition to the former as an exceptional case.

The first RAP can be summarized in the table below. The project affected people can receive in-kind compensation (alternative land and house), which was a priority of this RAP, or to receive cash compensation as a next choice.

Table 7.3-3 Summary of the First Resettlement Action Plan

ROW of 33kv Lines	5m on each side from the center of the lines but if it is not possible 2m from the nearest existing structures
Number of household affected	153 (144 need to be relocated)
Number of individual affected	1144 (1075 need to be relocated)
Total cost for RAP	2,502,478 USD
Implementation Period	8 months

Note that budget for alternative land and land title should be borne by the government of Sierra Leone. It was estimated 349,180USD, and in a separate budge.
[Source] Resettlement Action Plan for the 33kV Sub Transmission Line in the Western Area

The breakdown of compensation for RAP is as follows. The cost of implementation and contingencies (10%) was added to the total cost.

Table 7.3-4 Breakdown of Compensation of the First Resettlement Action Plan

Coverage		Amount in USD
Compensation for loss asset	14,098m² ×100 $	1,409,800
Compensation for land	17,459 m²×20 $	349,180
10% of disturbance		176,000
Compensation for business		50,000
Cultural property mitigation		10,000
Forest asset		5,000
Compensation for crop		5,000
		Total 2,004,980

[Source] Resettlement Action Plan for the 33kV Sub Transmission Line in the Western Area

The second RAP was developed to see the expansion of encroachment after the first survey and to decrease the number of structures to be demolished under the line and the number of affected people by adopting the new clearance limit (distance from the lowest live conductor to the roof top), slightly re-routing the 33kV line and changing the height of the pylons.[2] Priority is put on cash compensation rather than in-kind compensation for assets (land, house, etc.) in this plan by considering the results of socio economic survey of the affected area, which found that over 80 % of the affected people were tenants. The second RAP expects the affected people to resettle by themselves after receiving cash compensation.

Table 7.3-5 Summary of the Second Resettlement Action Plan

ROW of the towers (Safety limit on the ground)	7m from the center of the towers
Clearance limit (from the lowest live conductor to the roof top)	5m
Number of household affected	44(8 asset owners, 36 tenants)
Number of individual affected	243
Number of affected structures	14
Total cost for RAP	319,710USD
Implementation Period	6 months

[2] The cost of relocating the pylons was not calculated in the study.

[Source] Review of the Resettlement Action Plan-33kV Sub-Transmission Line from Kingtom to Wilberforce and Blackhall Road

The breakdown of the total cost is in the next table.

Table 7.3-6 Breakdown of the Total Cost of the Second Resettlement Action Plan

1.Compensation	USD
Value of affected assets	86,840
Tenant compensation （rent for six months, transportation cost, disturbance allowance, 10% contingencies）	43,470
Income restoration	32,000
2.Operational Budget	157,400
	Total 319,710

[Source] Review of the Resettlement Action Plan-33kV Sub-Transmission Line from Kingtom to Wilberforce and Blackhall Road

The lesson we can learn from the two action plans is that it is possible to minimize the scale of involuntary resettlement by changing the route of distribution line and location of pylons and poles, increasing the height of pylons and so on. It is ideal that there are no structures in the ROW of distribution lines. But if it is difficult to secure ROW due to the high number of structures to be resettled, the scale of resettlement can be slimmed down by alternatively introducing the clearance limit (distance from the lowest live conductor to the roof) which is able to maintain the safety of people. This can be a model example when a distribution network is constructed in an already developed housing area.

7.4 Environmental and Social Considerations for Power Development Plan

This Master Plan consists of two components which need environmental and social considerations. One is the plan for power development and the other one is rehabilitation, reinforcement and extension of distribution lines.

There are several types of power generation. The environmental impacts of each type are summarized in the next table.

Table 7.4-1 Comparison of Environmental and Social Impacts of Various Power Generation Methods

	Environmental Factors	Hydropower: Dam type	Hydropower: Flow-in type	Hydropower: Micro hydro	Thermal Power: Steam-Power Generation: Coal	Thermal Power: Steam-Power Generation: Heavy Oil	Thermal Power: Steam-Power Generation: Gas	Thermal Power: Internal Combustion Power Generation: Gas Turbine	Thermal Power: Internal Combustion Power Generation: Diesel	Wind Power	Solar Power
Social Environment	Involuntary resettlement	A	B	C	B	B	B	B	B	B	C
	Local economy, such as employment and livelihood	A	B	C	B	B	B	C	C	C	C
	Land use and utilisation of local resources	A	B	B	B	B	B	B	B	B	B
	Social institutions, such as social infrastructure and local decision-making system	B	C	C	C	C	C	C	C	C	C
	Existing social infrastructure and services	C	C	C	C	C	C	C	C	C	C
	The poor, indigenous and ethnic people	A	B	B	B	B	B	C	C	C	C
	Erroneous communication of interests	C	C	C	C	C	C	C	C	C	C
	Cultural heritage	B	C	C	B	B	B	C	C	C	C
	Local conflict of interests	B	C	C	C	C	C	C	C	C	C
	Water usage or water rights and rights in common	A	B	C	B	B	B	C	C	C	C
	Public hygiene	B	C	C	C	C	C	C	C	C	C
	Infectious diseases	B	C	C	C	C	C	C	C	C	C
Natural Environment	Topography and geographical features	A	B	C	C	C	C	C	C	C	C
	Soil erosion	B	C	C	B	B	B	B	B	C	C
	Groundwater	C	C	C	C	C	C	C	C	C	C
	Hydrogical conditions	A	B	C	C	C	C	C	C	C	C
	Coastal zone	C	C	C	C	C	C	C	C	C	C
	Flora, fauna and biodiversity	A	B	C	B	B	B	B	B	B	C
	Meteorology	C	C	C	C	C	C	C	C	C	C
	Landscape	A	B	C	B	B	B	B	B	B	B
	Global warming	C	C	C	A	B	B	B	B	C	C
Pollution	Air pollution	C	C	C	A	B	B	B	B	C	C
	Water pollution	A	B	C	A	A	A	C	C	C	C
	Soil contamination	C	C	C	B	B	B	B	B	C	C
	Waste	B	B	C	B	B	C	B	B	C	C
	Noise and vibration	B	B	C	B	B	B	B	B	B	C
	Ground subsidence	C	C	C	C	C	C	C	C	C	C
	Offensive odour	C	C	C	C	C	C	C	C	C	C
	Bottom sediment	A	B	C	C	C	C	C	C	C	C
	Accident	B	B	C	B	B	B	B	B	C	C

Rating:
A : Serious impact is expected
B : Some impact is expected
C : No or minimal impact is expected

[Source] JICA Study Team

Power generation by clean energy such as solar and wind can minimize impacts on the environment. However, solar or wind power is dependent on the weather. For the time being, solar and wind energy is not an optimal option for the Western Area which is facing serious power shortages. Stable and reliable supply of electricity is necessary in this emergency stage. Thus, the Study Team suggests two types of power generation, that is, hydro power and thermal power in this Master Plan.

7.4.1 Thermal Power Development

If the above five types of thermal power generation methods are compared, it can be said that the environmental impact of diesel generator is smaller than the others'. In addition, diesel power generation is the easiest to operate and maintain. Since NPA has only experience of operating diesel engine generators, it is considered the diesel power generation method is the optimal option. Therefore, the diesel power generation method is recommended. In this Master Plan, it is proposed to use the Blackhall Road sub-station as a new power plant as well as the Kingtom power station to avoid adverse environmental impact by developing a new power plant at a new site. However, if the "Thermal Dominant Scenario" is chosen, it is required to construct another new power plant.

(1) Adverse Environmental and Social Impact Identified

Adverse environmental and social impacts identified for the thermal plant development are summarized in the next table. The natural and social environment in the target area and the condition of the existing power plan was taken into consideration to identify the impacts.

Table 7.4-2 Assessment of Adverse Environmental and Social Impacts of Thermal Plant (Diesel Generation)

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Social Environment	Involuntary Resettlement	**B**	**B**	**C**	Construction of a new power plant may require land acquisition.
	Local Economy, Employment and Livelihood	**C**	**C**	**C**	
	Use of Land and Other Local Resources	**B**	**B**	**C**	It may be necessary to acquire land for a new power plant and change the use of land.
	Social Institutions such as Social Infrastructure and Local Decision-Making Institutions	**C**	**C**	**C**	
	Existing Social Infrastructure/Services	**C**	**C**	**C**	
	The Poor, Indigenous of Ethnic People	**C**	**C**	**C**	
	Misdistribution of Benefit and Damage	**C**	**C**	**C**	
	Cultural Heritage	**C**	**C**	**C**	Although there are cultural heritages in Western Area, most of them are small monuments.
	Conflict of Local Interests	**C**	**C**	**C**	
	Water Rights and Rights of Common	**C**	**C**	**C**	
	Public Health	**C**	**C**	**C**	
	Infectious Diseases	**C**	**C**	**C**	
Environ	Topographical and Geographical Features	**C**	**C**	**C**	

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
	Soil Erosion	**B**	**B**	**C**	Construction of a power plant and installation of generators may cause soil erosion caused by site preparation.
	Groundwater	**C**	**C**	**C**	
	Hydro geological Conditions	**C**	**C**	**C**	
	Coastal Zone	**B**	**B**	**B**	If a power plant is located near the coast or mangrove swamp, it carries risk of polluting the areas without necessary auxiliary facilities.
	Flora, Fauna and Bio-Diversity	**B**	**B**	**B**	If a power plant is located near the important protected sites, it may give impact to the flora and fauna.
	Meteorology	**C**	**C**	**C**	
	Landscape	**B**	**B**	**B**	A power plant may not be in harmony with the surrounding environment.
	Global Warming	**B**	**C**	**B**	New diesel engine generators will discharge CO^2.
Pollution	Air Pollution	**B**	**C**	**B**	New diesel engine generators will discharge NOx and SOx.
	Water Pollution	**B**	**C**	**B**	New diesel engine generators may pollute water without necessary auxiliary facilities
	Soil Contamination	**B**	**C**	**B**	New diesel engine generators may contaminate soil by oil leak without necessary auxiliary facilities.
	Waste	**B**	**B**	**B**	Increase of the capacity of power supply by adding diesel-engine generators increases the amount of waste oil.
	Noise and Vibration	**B**	**B**	**B**	New diesel-engine generators will discharge noise and cause vibration. Construction noise and vibration are usually observed.
	Ground Subsidence	**C**	**C**	**C**	
	Bad Odour	**C**	**C**	**C**	
	Benthic Sediment	**C**	**C**	**C**	
	Accidents	**B**	**C**	**B**	There is a risk of fire.

Rating
A: serious impact is expected
B: some impact is expected
C: minimum or hardly any impact is expected
[Source] JICA Study Team

(2) Mitigation Measures

To mitigate the expected impacts in the table above, the following measures are recommended.

1) Involuntary Resettlement

Careful consideration of the location of a new power plant can avoid or minimize involuntary resettlement.

2) Use of Land and Other Local Resources

To choose a site which does not change the use of land widely as much as possible or to avoid a site where people depend on their lives is necessary.

3) Soil Erosion

Before site preparation of a new diesel engine generator or a power plant, survey of geological condition should be conducted to take necessary measures to avoid soil erosion.

4) Coastal Zone

It is better to avoid constructing a new plant near the Sierra Leone River Estuary and Yawri Bay area in order not to cut mangrove forests and give adverse impact on the environment. When a new generator is installed in the Kingtom Power station, it is a must to install necessary auxiliary facilities not to pollute the sea around the power station or give impacts on marine animals and plants, because effluent from the power plant used to be discharged to the sea.

5) Flora, Fauna and Bio-Diversity

Threatened species of flora and fauna can be observed in Western Area. The location of a new plant has to be decided carefully to avoid interference to threatened species of animals and plants in particularly in WAPF and the Sierra Leone River Estuary.

6) Landscape

Planting trees in a power plant and designing a power plant in harmony with the surrounding environment is necessary.

7) Global Warming

New diesel engine generators to be installed should have high thermal efficiency and keep the emissions of CO^2 low.

8) Air Pollution

An exhaust gas system, which meets the international standards for the emissions of NOx, SOx and dust, for the generators and an engine with low NOx emissions should be installed. Installing a higher stack is also effective.

9) Water Pollution

A new diesel generator should have a sludge treatment system to meet the international standards for oil content emission to avoid water pollution.
Water containing waste oil used to be discharged to the ocean in the Kingtom Power Station when the generators were operating, as the sludge treatment system was not working. Currently, the Moroccan government is trying to fix one of the broken down generators in the Kingtom power station. If the generator operates again, it is recommended to install a new sludge treatment system or at least clean up the pond of the existing sludge treatment system to boost efficiency.

10) Soil Contamination

Oil stains by lubricant or oil leaks from the waste oil tanks or from the sludge treatment system are observed on the ground and in the drains of Kingtom Power Station. When the Sulzer 4 is fixed by Morocco and starts operation again, the present sludge treatment system in the Kingtom Power

Satiation, which is not working properly, should be changed to a new one, and proper maintenance system should be introduced. Not only for the sludge treatment system, but proper operation and maintenance of generators and other facilities and equipment should be introduced to avoid oil leak. Oil retaining bunds should be installed around waste oil tanks. And the ground surface should be covered by concrete to avoid penetration of oil to the ground.

11) Waste

Oil is one of the major wastes generated from a power plant, and it has a risk to pollute the environment. The NPA used to give waste oil to an oil treatment company for reuse. It was reported that oil spill was observed everywhere in the treatment facility. Since this company stopped its business and the NPA is not generating electricity by their generators, waste oil has been kept in waste oil tanks in the Kingtom power plant. If an oil treatment facility which operates in an environment-friendly manner cannot be found, it will be necessary to install an incinerator to burn waste oil when a new generator is installed.

There is no separate waste collection system in Sierra Leone. Wastes are not separated in two dump sites in Freetown either. A separate waste collection system for normal solid waste, hazardous waste and recyclable should be established in the NPA. No landfill or treatment facilities for hazardous waste are available in Sierra Leone. The NPA, as a generator of wastes, should be responsible for all types of wastes. If there is no landfill to dump hazardous wastes such as oil or chemicals, the NPA should separate them and secure a safe place to keep them as a temporary solution.

12) Noise and Vibration

A new diesel engine generator and a power house should be designed to reduce noise and vibration by choosing a low noise level type generator or installing necessary auxiliary facilities and equipment such as sound proof walls. And generators should be installed in a powerhouse with strong platform, roof and walls with certain distance from the surrounding houses.

13) Accidents

Currently no training for fire fighting is held for NPA workers in the power plant. And there are not enough fire extinguishers in good condition. Procedures in case of fire should be taught to NPA workers and the power plants need to equip necessary fire extinguishers.

7.4.2 Hydro Power Development

Potential sites for hydro power development were already identified in the master plan study in 1995 as explained in Chapter 5. As all the volumes of the master plan are not available, environmental and social conditions of the potential sites cannot be compared by using the information in the master plan in 1995.

Alternatively, for the comparison of environmental impacts of each site, the proposed location of each hydro power plant and proximity of protected areas around was checked in the map. The next table shows the protected areas near the potential sites.

Table 7.4-3 Potential Sites for Hydro Power Development and Nearby Protected Areas

Site	Location (Name of district)	Rated Output (MW)	Utilisation Rate (%)	Electric Energy Generated (GWh/yr)	Construction Cost (million USD)	Unit Generating Cost (US ¢ /kWh)	Protected Areas near the site
Benkongor III	Kenema	85.5	70.9	513.1	77.4	3.72	Tama Forest Reserve （30-40km Away） in the upstream
Mange I	Port Loko	35.2	75.3	244.1	84.8	5.72	The Rhombe Swamp site in the downstream (about 40 km away). This swamp is now under process to be a protected site.
Kuse II	Koinadugu	91.8	83.1	679.7	298.0	5.90	Adjacent to Outamba -Killimi National Park
Kambatimbo	Koinadugu	65.7	56.1	322.1	81.2	4.93	Adjacent to Outamba -Killimi National Park
Yiben-I	Koinadugu	61.5	78.9	442.9	90.6	2.89	
Yiben-II	Koinadugu	62.1	75.8	430.2	122.4	3.94	
Betmai I	Tonkolili	52.5	57.7	268.5	69.0	5.88	Tonkoli Forest Reserve in the upstream
Betmai III	Tonkolili	36.6	72.4	249.5	84.5	4.92	

[Source] JICA Study Team

Yiben is recommended as the next site to be developed after the Bumbuna hydro dam in the master plan 1995, because Yiben is advantageous in terms of costs and efficiency. The Yiben hydro dam, located the upstream of the Bumbuna dam, will stabilize the water flow to the Bumbuna dam. This will enable the Bumbuna dam to generate electricity even in the dry season at the same level as in the rainy season. The development of Yiben has already been regarded as the stage two of the development of the hydropower potential of the Seri River in Sierra Leone. As for transmission lines from a new hydro dam to Western Area, the transmission line of Bumbuna can be used if Yiben is developed, which can minimize the environmental impacts of transmission lines.

It may be said that Yiben has less environmental impacts, because it is not located near protected sites. But no detailed data on forest coverage, wild animals are available in the Forestry Division.

Social impacts are unknown since there are no detailed data on population and location of villages which would be affected by development of the hydro dams in the master plan 1995. It was said that Yiben-II would require less resettlement than Yiben-I in the master plan 1995. However, the study was conducted about 15 years ago, and the condition is changing especially after the end of war. Even though population census was conducted in 2004, population data at each village are not available. District maps were prepared after the population census, but the maps show only the locations of big settlements. Therefore, it is difficult to estimate a scale of resettlement from the information available.

According to the Bumbuna Project Implementation Unit (PIU), the natural environment around Yiben and Bunbuna is similar. The vegetation and kinds of wild animals in the two areas are almost the same. But the hunting of wild animals and clearing the forest for farmlands are observed in Yiben, which means the number of animals has decreased and the forest coverage has become small. As for the social environment, there are villages around, but it can be said that it is less populated than Bumbuna in terms of size of villages and population density. They mainly engage in subsistence shifting cultivation. There is no access road to the site yet, so villages are scatted in remote areas where they have no social infrastructure such as schools and health centers.

Detailed biodiversity surveys in Bumbuna by the Bumbuna PIU found that the area is rich in biodiversity. The forest along Seli River has high biodiversity value for plants and has some endemic species. The forest gives habitats to endangered animal species such as bat, sooty mangabey, pygmy hippopotamus, chimpanzee and birds. Therefore, there is a high possibility that wide variety of plants and animals, even endangered species, exist in Yiben.

In the next stage, it is required to assess environmental and social impact of Yiben-I and II. Since both Yiben-I and II are a dam type, environmental and social impact would be big without proper survey and necessary mitigation measures.

(1) Adverse Environmental and Social Impact Identified

As there are not enough data for Yiben, general adverse environmental and social impacts of hydro power are mainly identified as below.

Table 7.4-4 Assessment of Adverse Environmental and Social Impact of Hydro Power Generation

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Social Environment	Involuntary Resettlement	**A**	**A**	**C**	Construction of a hydro dam requires acquiring land. The people have their houses and farmlands in the area and have to be resettled.
	Local Economy, Employment and Livelihood	**A**	**A**	**A**	Resettlement or change of land use may mean changing or losing means of livelihood (farming, fishing, collection of fire woods or non timber forest products in forest) of project affected persons.
	Use of Land and Other Local Resources	**A**	**A**	**B**	Forests or farmlands will be lost.
	Social Institutions such as Social Infrastructure and Local Decision-Making Institutions	**B**	**B**	**B**	Resettlement may divide one community into two or more. Or a whole community may be resettled in a host community. This may affect the role of existing social institutions.
	Existing Social Infrastructure/Services	**C**	**C**	**C**	It is thought that no adequate social services such as education or health are provided in provinces, in particular remote areas.
	The Poor, Indigenous of Ethnic People	**B**	**B**	**B**	The poor or the vulnerable (eg the old or widow) have more difficulties to restore their lives in a resettled site.
	Misdistribution of Benefit and Damage	**C**	**C**	**C**	
	Cultural Heritage	**B**	**B**	**C**	Cultural heritage may be submerged. There is no cultural heritage in the Yiben area. But there are sacred sites in villages.
	Conflict of Local Interests	**B**	**C**	**B**	Host communities of project affected persons (PAPs) sometimes feel unfairness because PAPs receive generous supports.

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
	Water Rights and Rights of Common	A	B	A	The change of water flow and volume may have some impacts.
	Public Health	B	B	B	The influx of construction workers and newcomers seeking an economic opportunity after the completion of a dam will raise the risk of the spread of infectious diseases such as sexual transmission diseases, AIDS/HIV. A reservoir will be a good breeding site for mosquitoes and raise a risk of spread of infectious diseases by mosquitoes.
	Infectious Diseases	B	B	B	
Natural Environment	Topographical and Geographical Features	A	A	C	Construction work of a dam may change topographical and geographical features in the area.
Natural Environment	Soil Erosion	B	B	B	Landslide or earth fall might happen by making a reservoir and change of water level.
Natural Environment	Groundwater	C	C	C	
Natural Environment	Hydrogeological Conditions	A	A	A	A dam might have impact on hydro geological conditions.
Natural Environment	Coastal Zone	C	C	C	
Natural Environment	Flora, Fauna and Bio-Diversity	A	A	A	Habitats of animals and plants will be lost by construction of a dam. Even though there is no protected area nearby Yiben, animals and plants occurring in the dam area will lose their habitats.
Natural Environment	Meteorology	C	C	C	
Natural Environment	Landscape	A	A	A	A dam type hydro power generation leads to a big scale construction. This causes loss of the environment in the surrounding area and drastic change in landscape.
Natural Environment	Global Warming	C	C	C	
Pollution	Air Pollution	C	C	C	
Pollution	Water Pollution	A	B	A	Eutrophication in the reservoir and decayed plants under reservoir may cause water pollution. Construction works and mishandling of wastes may pollute water.
Pollution	Soil Contamination	C	C	C	
Pollution	Waste	B	B	C	Excavated earth of sand and construction wastes will be discharged.
Pollution	Noise and Vibration	B	B	C	Construction noise and vibration are usually observed.
Pollution	Ground Subsidence	C	C	C	
Pollution	Bad Odour	C	C	C	
Pollution	Benthic Sediment	A	B	A	Sedimentation may happen in the

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
					reservoir. The level of riverbed in the upstream of the river may be increased.
	Accidents	**B**	**B**	**B**	Accidents in the construction site may happen. There is a risk of accident in the downstream of the dam caused by discharged water.

Rating
A: serious impact is expected
B: some impact is expected
C: minimum or hardly any impact is expected
[Source] JICA Study Team

(2) Mitigation Measures

To mitigate the expected impacts in the table above, the following measures are recommended.

1) Involuntary Resettlement

To change the location of a dam slightly or to lower the full supply water level of the reservoir could minimize involuntary resettlement.

2) Local Economy, Employment and Livelihood

Livelihood assistance project or income generation projects for example agriculture extension services to teach the skills to produce new agricultural products, vocational training, micro finance service and so on should be implemented to assist projected affected people during and after the construction period.

3) Use of Land and Other Local Resources

During and after the construction of a dam, a project of the watershed management should be implemented to conserve the environment.

4) Social Institutions such as Social Infrastructure and Local Decision-Making Institutions

Consultation with communities and households should be held with host communities to discuss how to keep or modify the existing institutions in a resettled site.

5) The Poor, Indigenous and Ethnic People

It is necessary to identify the vulnerable groups by economic and social survey, and special assistance should be given to them.

6) Cultural Heritage

To avoid cultural heritages in deciding the location of a dam is required. If it is difficult, heritages should be moved to another site. Communities sometimes have sacred sites in a community. The Bumbuna dam project relocated these sacred sites after consultation with the communities and organizing a ceremony. It is necessary to give such consideration.

7) Conflicts of Local Interests

A supporting program which will benefit host communities, such as construction of footpath, community center, school, health center should be implemented too.

8) Water Rights and Rights of Common

A survey of water use and water rights should be conducted in advance to take countermeasures.

9) Public Health and Infectious Diseases

Health education to construction workers during the construction period and to communities and new comers during and after the construction period should be held.

10) Soil Erosion

To conduct a comprehensible geological survey is required to avoid the landslide or earth fall-prone areas. Planting trees around the area is a measure to retain soil.

11) Hydro geological Conditions

A hydro geological survey should be conducted in advance to take countermeasures.

12) Flora, Fauna and Bio-Diversity

To change the location of a dam slightly or to lower the full supply water level of a reservoir could minimize the impacts on flora and fauna.

If endangered species or endemic species are found in the planned site, to create a protected area in near places or other habitats, then to conduct careful monitoring is required. Education programs for the community in the area should be organized to raise their awareness to protect the biodiversity.

13) Landscape

It is necessary to design in harmony with the surrounding environment and to plant trees in the area.

14) Water Pollution

Plants should be removed before impoundment to avoid water pollution caused by decayed plants.

It is necessary to provide necessary sanitation facilities to construction workers and to implement waste management to avoid pollution caused by waste generated during the construction period

After the construction period, to install a fraction fence or aerator to avoid eutrophication in the reservoir can be effective. And to do monitoring of water quality and take necessary measures to avoid water pollution, which may affect the ecosystem in watershed areas and water use of people living in the downstream area, is necessary.

15) Waste

Waste management should be undertaken for waste generated during the construction period such as construction wastes.

16) Noise and Vibration

To give information regarding noise and vibration caused by construction work to the neighboring community to gain understanding is necessary.

17) Benthic Sediment

In the design stage, the amount of expected sediment should be considered to provide enough capacity of a reservoir. If necessary, sand discharge facilities should be installed.

18) Accidents

Contractors should be responsible for occupational health and safety of construction workers.

After a power plant starts operation, to raise awareness of people who live in the downstream about the danger of discharged water and how to act is necessary. And to build an alarm system with sirens or speakers to give notice of discharge schedule is also necessary.

(3) Lessons Learned from the Bumbuna Hydro Project

43 households (186 people) in five villages in the dam area had to relocate because of the project. The project affected people (214 people and communities) received in-kind compensation (house, land, and farmland), cash compensation for economic trees, disturbance allowance, and moving allowance. The total cost of resettlement and compensation was 950,000USD, which excluded the cost for a livelihood and income restoration program.

It was very difficult to identify project affected villages and people because there was no accurate and reliable map or census data. For example, there was no exact data as to where villagers were located and how many people lived there. In addition, for names of villages, the information on a map, names in the census, or locally used names were all different. It is necessary to take enough time to conduct a survey to identify project affected villages and people.

As Bumbuna hydro dam is located in Northern Province, how to acquire land and compensate the land was considered by respecting the customary law. Each tribe or even each locality has different customary law. Thus, consultation at several levels, chiefdom, community, family, and individual are required. When negotiations and consultation are needed with project affected people, a chief, a representative from district council, which is in charge of providing social services, and councilor should be invited. The Public Lands Act was referred to as the guiding principal by the project for compensation although the act is not applied to the provinces outside Western Area.

The pressure on the natural environment is high even without a project, because people cut trees for farmlands, and hunt wild animals for bush meats and for ceremonies. The Bumbuna Hydro Project faced difficulties in asking cooperation to people as people in Sierra Leone are not yet aware of the importance of environmental protection. Therefore, the project established a semi-autonomous government authority called the Bumbuna Watershed Management Authority to protect the environment in the watershed. The authority will raise awareness of community members and enhance community participation. And the project will create a sanctuary for wild animals in the watershed and protect the biodiversity in the Loma Mountain where similar species occur as an offset. This will be a good example for the next hydro dam project.

7.5 Environmental and Social Considerations for Substations, Transmission and Distribution Lines

7.5.1 Strategic Environmental Assessment (SEA) for the Renewal, Reinforcement and Extension of the Distribution Line

Considering the natural and social environment in Western Area, it is required in this Master Plan to conduct SEA regarding the renewal, reinforcement and extension of the distribution lines.

The government of Sierra Leone expresses that the development of energy sector, in particular the provision of constant and reliable power supply, is one of the top priorities for poverty reduction and economic growth in the Second Poverty Reduction Strategy (2008-2012). According to Energy Sector Policy 2008, the government sets the target of electrification rate by 2025 as follows.

- 100% of the urban and peri-urban population
- 45% of the rural population

As described in the chapter 7.2 Natural and Social Environment in the Target Area, there are two main environmental and social concerns regarding the renewal, reinforcement and extension of the distribution lines. The first one is to avoid or mitigate adverse impact on the protected areas and its flora and fauna and the second one is to avoid or minimize involuntary resettlement.

(1) Options for Distribution Network Route in Western Area

Firstly, three options will be compared to determine the route of distribution lines for renewal, reinforcement and extension in the whole Western Area.

1) Without Option

This will not give any adverse impact in Western Area. But, the target in PRSP (2008-2012) and the Energy Sector Policy will not be met. This option also means most of people in Sierra Leon will have no power supply as basic infrastructure, nor will economy grow.
NPA has many problems, but one of them is insufficient capacity of the distribution lines. Even if the capacity of electricity generation increases, electricity energy will be lost during transmission and distribution without reliable line capacity and network.

2) Only North to East Part of the Peninsula Option

Large-scale settlements can be seen mainly along the road connecting from the north to east. And, as it can be seen in Fig. 7.2-3 Western Area Peninsula Forest Reserve, western part of the peninsula is covered by WAPF. So, the second option is to renew, reinforce and extend the distribution lines only in the north-east part of the peninsula.

Again, this plan cannot meet the target of the government. And, this plan will miss a chance to develop tourism, such as eco-tourism, utilizing the beauty of nature along the coast and the forest in the west. Importance of tourism development is now recognized. Tourism development has been newly added as a topic in PRSP (2008-2012). Power supply is required for tourism development, especially for hotels and restaurants.

In addition, there are fishing villages along the coastal line in the west. They use fuel wood to smoke fish as they do not own refrigerators or freezers, which cannot be used without cheap and stable power supply. Smoking consumes fuel wood, and this causes more deforestation in the forest. Stable power supply enables people to preserve or process fish and to have more stable income.

3) Around the Peninsula Option (Ring Trunk Network)

This option is to renew, reinforce and extend the distribution lines around the peninsula. It can increase the electrification rate and stability of electricity supply by making a ring network in case of accident.

But, this plan means the lines run near the two protected areas. It was confirmed by a field survey that some ROW of the roads for public infrastructure and expansion of roads is secured (not always all ROW is secured as planned). If the distribution line is erected along the existing road, no mangrove cutting is required in the Sierra Leone River Estuary as the road runs away from the mangrove forest and there is certain distance from the road to the mangrove swamp. However, Sierra Leone River Estuary is an important wetland for birds. Mitigation measures to avoid electrification of birds should be taken.

As for WAPF, if we follow the original boundary, the existing road runs along the boundary in many parts in the south-west. But the road runs inside WAPF only around the branch point to go to Kent. But if we see the forest extent from the satellite image in 2006 as in Fig. 7.2-3, the boundary has been moved to the mountain side away from the road. But in some parts such as River No.2 and Black Jonh Son, the forest has expanded across the road toward the coastal line. The existing road running in the southern peninsula from Tokeh through York, Jonh Obey, Tombo to Waterloo is already paved with two lanes as in the next picture. The road runs on the foot of the hills, so both sides of the road is cleared in most of parts. To erect distribution line along this road will not require large scale tree cutting nor give serious impacts to the forests and its biodiversity. But, mitigation measures need to be taken as explained in the next part to minimize the impacts.

Road near York (This paved road runs from Tokeh to Waterloo)

The part from River No.2 to Tokeh was a concern because the existing road is very narrow and runs through the forest. But, Sierra Leone Road Authority (SLRA) is now constructing a new road near the coastal line. Using this road will not require tree cutting. Only where enough ROW is not secured, it may need to cut some trees, branches or bushes. SLRA is now also constructing a paved road from Lumley to Tokeh with 15m ROW on each side.

As for involuntary resettlement, some people have constructed structures in the ROW. The Ministry of Lands, Country Planning and the Environment and SLRA are now cooperating to demolish all illegal structures in ROW and compensate them, in particular from Lumley to Sussex, and Wellington to Koya. The SLRA intends to secure ROW for the future expansion of the roads, and wants public infrastructure installed on the edge of ROW. But, if it is difficult, public infrastructure can be installed in ROW. In this case, there is a possibility that existing structures will be on the planned route of distribution lines. But resettlement can been avoided and mitigated by determining the location of each pole carefully as the second RAP of the WB project decreased the number of the affected people dramatically from the first RAP by re-routing the pylon positions.

People living near the forest dependon WAPF for their livelihood. Power supply can expand their job opportunities and stop illegal activities. As a consequence, this can protect the forest and its biodiversity. But it needs a decent management plan for WAPF by the government.

The Study Team proposes the third "Around the Peninsula Option (Ring Trunk Network)" among the three options, because the third option is in accordance with the policy of the government, it can contribute to economic development of the country and improve life of people, and build a ring distribution network which is able to easily back up in cases of accidents. Also it is possible mitigate expected adverse impacts by taking proper mitigation measures.

(2) Options for Distribution Network in Freetown City

Secondly, two options will be compared to determine the route in Freetown. The number of slum areas is increasing as explained in the previous part. People have encroached on hill sides, bay or river areas without formal land title. The Kingtom Power station and Falcon Bridge Sub-station are surrounded by slum areas, which make it difficult to erect distribution facilities.

People engage in small trading or retailing along the narrow streets especially in the downtown, where the Kingtom Power station and Falcon Bridge Sub-station are located. In addition, encroachment within ROW is common. ROW of road or street is set 5-7.5m on each side from the centre. But ROW is often not secured because of congestion of the city. People have their houses or small shops within ROW. The renewal, reinforcement and extension of the lines may require involuntary resettlement of them. Resettlement of slum dwellers in the big slums is a big challenge. Thus, it is necessary to determine the route which can minimize involuntary resettlement.

1) Rehabilitate Only the Lines which Need Emergency Rehabilitation Option

This option can avoid resettlement at minimum. But even now, the fragility of the network increases the workload of NPA workers because the weak network system causes many accidents. And hundreds people are always on the waiting lists to be connected.

2) Ring Trunk Network Option

This option is to develop a ring network in Freetown to increase the reliability of power supply. This option can contribute to meet the target set by the government, 100% electrification rate in urban area by 2025.

There is a possibility of occurrence of involuntary resettlement, as the city is very congested. Necessary mitigation measures should be considered. There are several mitigation measures. One measure is to use high towers instead of normal electric poles for distribution lines and stretch the lines over the crowded area. Especially in slum areas near bay or river, the line will be over the slums (over across river or bay) rather than by locating poles along the slum area on the ground. Even if this measure is taken, people in slums can still connect to electricity from secondary sub station nearby. Secondary, careful determination of location of each pole can decrease the number of affected people. The next option is to use marine cable along the coastal line. This can avoid involuntary resettlement especially in the most congested area along the northern coastal line, but the cost of marine cable installation is much higher than overhead line. The northern costal area is not an important marine site. No coral reefs have been observed before. No threatened marine animal species have been observed near the coast. Therefore, it is though that marine cable will not give adverse impact to the marine environment. However, enough data on marine animals and plants are not available. To conduct a survey on marine animals and plants is needed before installation.

The Study Team proposes the second option "Ring Trunk Network Option" between the two options. The current distribution network is so old that many accidents happen. To make matters worse, the response to such accidents is temporary repairs and this has resulted in high distribution loss. The distribution loss is one of the reasons for the NPA’s bad financial condition. This is the reason we propose a ring trunk network, which is able to back up in case of accidents and to increase electrification ratio. Regarding involuntary resettlement, it is considered that mitigation is possible if necessary measures explained above are taken. As the population of Freetown is increasing, if a plan of renewal, enforcement and extension of a distribution network is postponed, resettlement will be more complicated.

7.5.2 Plan for Rehabilitation, Reinforcement and Extension of Distribution Lines

Based on the SEA, the study team proposes the distribution network as is shown in Fig. 6.3-3 and Fig. 6.3-4.

Fig.6.3-3 shows the routes of 33kV lines in Western Area. Basically, distribution lines are to be constructed along the existing road network except the urban area. Only for a vertical part from Lampa to Fogbo, the road is unpaved and narrow, running from village to village. The road running along the western coast laps over the boundary of WAPF in some parts. The road is quite wide and paved, so expected adverse impacts will be mitigated with proper mitigation measures. The road runs through mountains from Regent and Jui. The area is not in WAPF but surrounded by forests. Therefore, it is necessary to take mitigation measures. Since Jui is adjacent to mangrove forests, the location of a new substation should be carefully decided.

Fig.6.4-4 shows the routes of 33kV lines in the urban area. The routes were determined to avoid densely-populated areas as much as possible in order not to resettle people involuntarily. The Study Team proposes the use of marine cable from Kingtom power station to Falcon Bridge sub station, a part of from Falcon Bridge sub station to Blackhall Road sub station as there are many slums along the northern coastal line and the area is very congested because of proximity to the centre of the town. The distribution line from Wilberforce to Goderich was originally planned to take a route along the coastal road, but the distribution line has to run through densely-populated areas and congested commercial areas by taking this route. Thus, the route has been changed to the hill side. Although the planned area on the hill is already developed as a housing area, some parts are in the original boundary of WAPF. It is necessary to consult with the Forestry Division whether they have any forestation plans before detailed design. There was no concrete forestation plan near the planned route during the Study.

(1) Adverse Environmental and Social Impact Identified

Adverse environmental and social impacts identified for the planned substations, transmission and distribution lines can be summarized in the next table. The natural and social environment in the target area and the current conditions of the existing substations and distribution lines were considered to identify the impacts. Regarding the transmission line from a new hydro dam to Western Area, the route is not determined in this Master Plan. Therefore, general impacts are assessed.

Table 7.5-1 Assessment of Adverse Environmental and Social Impact for Substations, Transmission and Distribution Lines

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Social Environment	Involuntary Resettlement	**B**	**B**	**C**	Construction of a substation (50m×50m) and transmission and distribution lines require land acquisition. The congestion and existence of big slums in Freetown and encroachment in ROW of roads in the whole Western Area raise a concern of involuntary resettlement.
	Local Economy, Employment and Livelihood	**B**	**B**	**C**	There are many small shops along the streets in Freetown. The construction of distribution lines may require them to relocate or affect their livelihood.
	Use of Land and Other Local Resources	**B**	**B**	**C**	It is necessary to acquire land for substations and transmission and distribution lines.
	Social Institutions such as Social Infrastructure and Local Decision-Making Institutions	**C**	**C**	**C**	
	Existing Social Infrastructure/Services	**C**	**C**	**C**	
	The Poor, Indigenous of Ethnic People	**C**	**C**	**C**	
	Misdistribution of Benefit and Damage	**C**	**C**	**C**	
	Cultural Heritage	**C**	**C**	**C**	
	Conflict of Local Interests	**B**	**C**	**B**	There is a possibility of conflict of local interests between electrified and non-electrified areas.
	Water Rights and Rights of Common	**C**	**C**	**C**	
	Public Health	**C**	**C**	**C**	
	Infectious Diseases	**C**	**C**	**C**	
Natural Environment	Topographical and Geographical Features	**C**	**C**	**C**	
	Soil Erosion	**B**	**B**	**C**	Construction of substations and transmission and distribution lines may cause soil erosion by site preparation and cutting tree.
	Groundwater	**C**	**C**	**C**	
	Hydrogeological Conditions	**C**	**C**	**C**	
	Coastal Zone	**B**	**B**	**B**	Sierra Leone River Estuary, a wetland registered in the Ramsar Convention is located in north-east of the peninsula. The extension of distribution lines in this area may give some impact.

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
	Flora, Fauna and Bio-Diversity	**B**	**B**	**B**	Distribution lines run near Western Area Peninsular Forest Reserve and Sierra Leone River Estuary, which may give some impact on flora, fauna and biodiversity. Transmission lines from a new hydro dam might pass through forests.
	Meteorology	**C**	**C**	**C**	
	Landscape	**B**	**C**	**B**	Transmission/distribution lines may not harmonize with the scenery.
	Global Warming	**C**	**C**	**C**	
Pollution	Air Pollution	**C**	**C**	**C**	
	Water Pollution	**C**	**C**	**C**	
	Soil Contamination	**B**	**C**	**B**	Oil leak from transformers at sub stations may happen.
	Waste	**B**	**B**	**B**	Insulating oil in old transformers may contain Poly Chlorinated Biphenyl (PCB).
	Noise and Vibration	**C**	**C**	**C**	
	Ground Subsidence	**C**	**C**	**C**	
	Bad Odour	**C**	**C**	**C**	
	Benthic Sediment	**C**	**C**	**C**	
	Accidents	**B**	**C**	**B**	There are many structures under the unused existing power distribution lines. There is a risk of accidents to the public if electricity is turned on. Safety rules and maintenance methods are not usually observed at NPA. There is a risk of accidents to NPA workers and the general public.
	Electromagnetic field	**C**	**C**	**C**	

Rating
A: serious impact is expected
B: some impact is expected
C: minimum or hardly any impact is expected
[Source] JICA Study Team

(2) Mitigation Measures

To mitigate the expected impacts in the table above, the following measures are recommended to take.

1) Involuntary Resettlement

Routes of transmission and distribution lines and location of each electric tower (pylon) and pole should be carefully determined to avoid unnecessary involuntary resettlement when overhead line is used. High towers for the distribution lines should be used in the crowded areas in Freetown to minimize resettlement.

For the peninsula, distribution will be basically along the existing road. However, people have encroached within ROW of the road. ROW is controlled by SLRA. SLRA intends to secure ROW and to have electric poles on the edge of ROW, but it is not always possible due to the existence of structures in ROW. If the distribution lines happen to be within ROW, consultation with SLRA is needed to avoid involuntary resettlement.

It is ideal to secure ROW of transmission and distribution lines, and to have no structures under the line. But to avoid involuntary resettlement, the safety clearances limit, i.e. “the distance from the lowest conductor to a roof top of a structure,” has been adapted in Sierra Leone by the World Bank assisting projects. This is 7m for 161kV line, and 5m for 33kV line which is consistent with European and American safety standards. If it is possible, ROW should be secured. But if it is difficult, this safety clearance limit can be applied.

Marine cable can avoid involuntary resettlement in the most congested areas in Freetown, although the installation costs are higher than for overhead line and marine survey is needed.

As in the case of WB 33kV RAP, even though the plan was made, it was not implemented because the government did not provide its counterpart funding. Considering the financial capability of the government to provide funds for resettlement is low, resettlement should be avoided and minimized as much as possible.

2) Local Economy, Employment and Livelihood

Many people in Freetown are engaged in the service sector, in particular, petty trading. So along the streets, many small shops can be seen. If relocation of those small shops is needed, compensation should be paid or assistance for income generation should be given to them.

3) Use of Land and Other Local Resources

In case the NPA needs to acquire land, it should choose land which has least impact and avoid acquiring land inside the protected areas in consultation with the Ministry of Lands, Country Planning and the Environment.

4) Conflict of Local Interests

The government and the NPA should disclose the electrification plan to the public to gain their understanding.

5) Soil Erosion

As for the distribution lines, if the lines go along the existing roads, there will be minimum tree cutting. For site preparation of substations or electric towers, survey of geological condition should be conducted to take necessary measures to avoid soil erosion.

6) Coastal Zone

As far as the new distribution lines run along the existing road, which run with certain distance from the wetland, there will be minimum adverse impact. For the future secondary distribution lines to the new points, the lines should also along the existing roads not to cut down mangrove trees or any other plants in the future.
A substation should be constructed away from the mangrove swamp.

7) Flora, Fauna and Bio-Diversity

To avoid interference to threatened species of animals and plants in WAPF and the Sierra Leone River Estuary, substations will not be constructed inside WAPF and in Sierra Leone River Estuary.

The distribution line should be along the existing roads to avoid going deeper in the protected areas.

According to the Forestry Division, it is acceptable to extend the distribution lines along the existing road although one part of the road passes inside the original boundary of WAPF, unless the line goes across WAPF without following the existing roads. The existing roads run along the foot of hills, so they will not have serious adverse impact on flora and fauna.

However, as overhead transmission/distribution facilities (lines, poles and conductors) give negative impact on birds, such as electrocution and collision[3], necessary measures should be taken.

Large birds with long wings, particularly raptors and storks, are most vulnerable to electrocution, because they roost and nest on power poles. Even small birds only 25cm in height can be threatened. A threatened bird species, Falco naumanni (Lesser Kestrel) and Scotopelia ussheri (Rufous Fishing – owl) which are believed to have their habitat in Western Area are vulnerable to electrification. In particular, badly designed medium voltage (1kV to 60 kV) power poles pose a risk of electrocution. The best way to avoid electrocution of birds is to use underground cables. But this is costly, so another option is firstly to consider how to attach insulators on power poles, for instance to avoid upright insulators on power poles and use suspended insulators, to use insulting caps, or to insulate power lines with tubing. The second measure is to keep safe distance between power cables and other energized and grounded parts. It is recommended to keep the distance of 140cm between conductors, and 60cm between a perch site and energized elements. The third option is to take measures to stop birds roosting on poles or install platforms for birds to perch on power poles in a safe place. These measures can also prevent bird-caused electrical outages.

Big birds, particularly migratory birds flying at night, are most vulnerable to collision with power lines of all voltages. Although there is no threatened big migratory bird species reported to have their habitat in Western Area, the best way to avoid collision of birds again is underground cables. The next option is to increase power line visibility to birds. It is recommended to conduct a detailed bird survey to know their flying routes to take above measures in necessary areas.

Other animals which are at risk of electrocution are primates, who climb power poles and use the poles as pathways to move in forest. One solution to avoid electrocution is to trim branches giving access to power lines. Next one is to attach some contrivances which prevent primates to climb the poles such as barbed wires. Again, it is recommended to conduct a habitat survey.

Marine cables give adverse impacts on coral reefs. It is reported there are no coral reefs in the planned northern coast of the peninsula. But it is necessary to conduct a survey before installation.

8) Landscape

Transmission/distribution lines should be designed in an environmental conscious manner.

9) Soil Contamination

Oil leaks can be observed in the existing substations. Oil retaining bands or pits should be installed around transformers. And the earth surface should be covered by concrete to avoid penetration of oil to the ground. Then, an adequate operation and maintenance system for substations should be established.

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[3] For details of the negative impacts, refer to "Position Statement on Birds and Power Lines" by BirdLife International. For mitigation measures, refer to Caution: Electrocution- Suggested Practices for Bird Protection on Power Lines" by Dieter Haas & Markus Nipkow, NABU.

10) Waste

There is no regulation on PCB disposal or treatment facilities in Sierra Leone. Thus, the NPA, as a generator of waster, should safely store the old transformers in a properly controlled storage for the time being as a temporary solution, and establish a safety handling procedures to protect NPA staff. And it is desirable to establish a recycling system as recyclable waste will be discharged after renewing the distribution line.

11) Accidents

To avoid electrocution or fires caused by distribution facilities, to keep minimal safety clearance between the line and structures is needed. Also to enhance safety factors of distribution line is needed.

The current safety rules should be followed by the NPA. The NPA should raise awareness of people on potential accidents.

7.6 Stakeholder Consultation

The Study Team held three workshops to listen to opinions from stakeholders and reflect their opinions in this Master Plan. The Study Team explained the expected environmental and social impacts caused by the Master Plan and mitigation measures for the impacts in the workshops. Several opinions raised in the workshops are summarized below. The opinions were examined in the Master Plan.

(1) The First Workshop to Present the Inception Report

This workshop was held on December 3, 2008 with 40 participants. Representatives from the former Ministry of Power and Energy, the NPA, the Ministry of Finance and Economic Development, the National Commission for Privatisation, donors, and the media attended the workshop. Several comments on electricity tariff were offered from the NPA. They understood that the generation costs were high so that it was difficult to make a profit. So they continued that the demand for renewal of the power plant and introduction of another hydro power station was high.

(2) The Second Workshop to Present the Interim Report

This workshop was held on February 5, 2009 with 41 participants. Representatives from the former Ministry of Power and Energy, the NPA, the Ministry of Finance and Economic Development, the Environmental Protection Agency, the Forestry Division under the Ministry of Agriculture and Food Security, donors, the private sector, and NGOs (environment and rural development) attended the workshop. A private bio energy company commented that it was essential to develop capacity of the NPA and the Ministry of Energy and Power. The NPA commented that the Study needed to consider renewable energy, and it wanted to contribute to economic development in rural areas through rural electrification, using money gained from collection of arrears.

(3) The Third Workshop to Present the Draft Final Report

This workshop was held on August 5, 2009 with 50 participants. Representatives from the Ministry of Energy and Water Resources, the NPA, the National Commission for Privatisation, the Freetown City Council, donors, NGO, the private sector, and the media attended. An environmental NGO commented that the NPA should implement the Master Plan while they protect the environment, taking the mitigation measures presented.

In addition to the workshops, the Study Team exchanged information with concerned organizations from time to time. In particular, exchange of information and opinions with the Forestry Division which is in charge of protection of the natural environment and the Ministry of Lands, Country Planning and the Environment which is in charge of land acquisition was often done and the results were referred to in formulating the Master Plan.

7.7 Recommendation for Environmental and Social Considerations in the Future

7.7.1 Important Points in the Next Step of Feasibility Study or Project Implementation

This Master Plan presents the plans of power development and renewal, enforcement and extension of distribution lines from now on. To implement the Master Plan, in the next step, feasibility study or project implementation, it is necessary to consider the following points.

(1) To Avoid Involuntary Resettlement

Involuntary resettlement has to be avoided as much as possible since the financial capacity of the government to pay such costs is very weak. Thus, routes or height and position of pylons and poles for distribution lines need to be carefully considered, and the location of a power plant and dam is also carefully considered.

(2) To Conduct Environmental Survey

There are forest reserves and mangrove swamps in Western Area, and the possibility that endangered species live there is very high. It is necessary to conduct survey on the protected areas and its ecosystem, and then consider mitigation measures again after the current conditions become clear. As for a new dam, it is necessary to start field survey at an early stage and collect basic information as there are no data on the environment in rural areas.

(3) To Have Enough Time and Budget for Study

Unfortunately, there are few reliable data in Sierra Leone. It is not realistic to depend on only the existing data. Data on protected areas and ecosystem for environmental protection are necessary, for example, population data or accurate maps for resettlement. Therefore, it is necessary to have enough time and budget to conduct field survey and collect necessary data.

(4) To Work with the Forestry Division, NGOs, etc. in a Coordinated Manner

The Forestry Division under the Ministry of Agriculture and Food Security is implementing the project to protect WAPF assisted by a donor, and there is a forestation plan in some areas in WAPF. It is necessary to obtain update information before the start of projects in Western Area. Local environmental NGOs have more detailed information on protected areas and ecosystem through their activities than the government. It is worth cooperating with them.

7.7.2 Recommendations to NPA on Environmental and Social Considerations

(1) Current System of Environmental and Social Considerations in the NPA

The NPA does not have an organizational and institutional framework for environmental and social considerations, which are needed before the NPA starts a new project. Nor does the NPA have environmental management system to monitor and manage their activities. There is no department or section to deal with environmental and social issues. A safety specialist under the safety division of the technical department is also assigned as an environmental officer. An acting commercial director under the customer services section of the commercial department is assigned as a social/resettlement officer. Except for these two officers, no one has been involved in environmental and social considerations.

There is no environmental department or division. So when the officers in charge have some problems, they consult with the deputy general manager.

As there is no formal organizational structure to deal with environmental and social issues, no budget is available. When they need budget for their work, they request to the general manager, but the weak financial standing of the NPA hinders allocation of money.

The two officers do not have enough formal background in the field of the environment and social considerations. No training has been organized in the NPA. Therefore, they have been learning through their works and acquire necessary knowledge from practical experiences

As for the environmental officer, he helped an environmental audit study of the Kingtom PowerStation done by a German consulting company funded by the World Bank in 2004, which was his first experience. Then he participated in a study to prepare EIA for 33kV line done by a Ghanaian consultant company under the Power and Water project of the World Bank in 2004. He prepared a simple EIA for a mini hydro dam in 2008. That's all his experience as an environmental officer

As for the social/resettlement officer, he had the first experience when the RAP for 33kV line under the Power and Water Project of the World Bank was prepared in 2004. This was led by the World Bank and international consultants were hired to conduct the study. The RAP was revised and updated in 2007, and he was also involved in the study. And he is now supervising the implementation of the RAP.

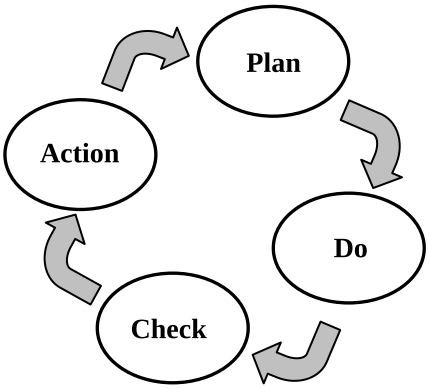
Even though the two of them participated in the projects above, the role of them was still limited because it was not the NPA who took initiative but it was the World Bank and the consultants. The two officers think their knowledge and capacity are not adequate enough to carry out their work. The workload of their main posts makes it difficult for them to concentrate on their secondary posts of the environmental and social/resettlement officers.

In the first place, there are no environmental regulations or standards in Sierra Leone which regulate the activities of the NPA. The NPA does not have an environmental management system or plan. Consequently, environmental monitoring has never been conducted at the only Kingtom power station. No monitoring equipment or budget has been available.

As well, waste management and cleaning of the power station or substations are not carried out. Waste management has not properly been handled, and a harmful waste such as waste oil is discharged without proper treatment to the sea. All kinds of wastes are discharged to the landfills, which have no facilities to separate wastes. The ground of the power plant is contaminated by waste oil or leaked oil. Substations are also contaminated by leaked transformer oil and several types of waste are scattered in the substations.

(2) Recommendation

It is recommended that NPA introduce an environmental management system. The “Plan, Do, Check and Act management cycle” is often used.



[Source] JICA Study Team

Fig. 7.7-1 PDCA Cycle

Table 7.7-1 PDCA Cycle

Plan	To develop environmental policy, set environmental targets and prepare an environmental management plan
Do	To implement the plan to protect the environment
Check	To monitor and evaluate the results of actions regularly
Act	Review the original plan for improvement

[Source] JICA Study Team

To operate this management system, the following steps will be needed.

1) Establish an environmental unit

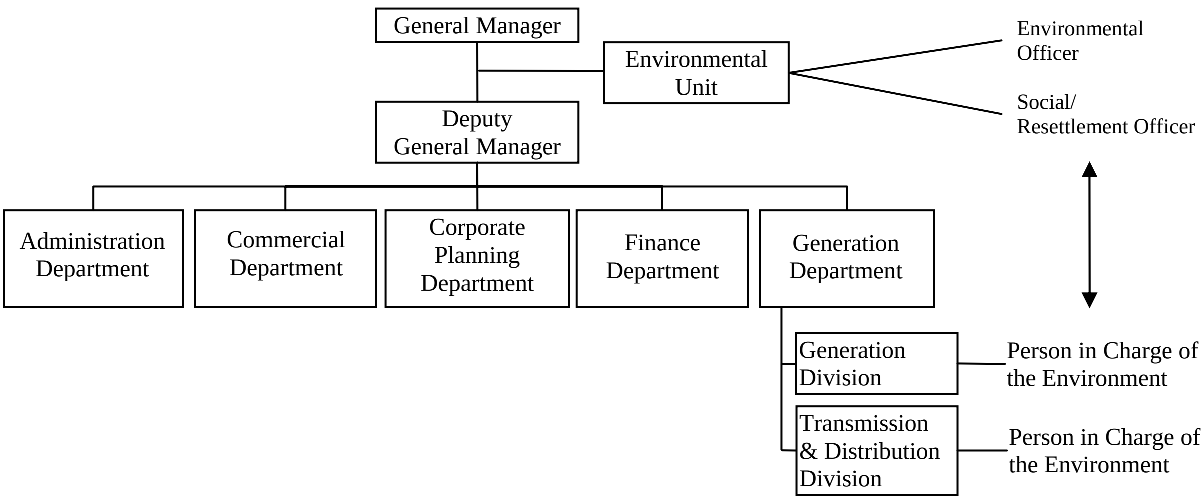
It is ideal to have an environmental department consisting of several qualified staff in the future. But it is not feasible to create this kind of environmental department from the current condition of the NPA. As a first step, it is recommended to create an environmental unit under the direct supervision of the general manager in order to deal with the environmental and social issues seriously as an authority. This unit consists of at least two environmental officers and two social/ resettlement officers. They work with all the other concerned departments. TOR of the officers is as follows. It is encouraged to hire new staff who have basic knowledge and qualifications.

Table 7.7-2 TOR of Officers

	TOR
Environmental officer	・Develop an environmental policy ・Set internal environmental targets ・Prepare an environmental management plan ・Conduct EIA or contract out EIA and supervise it ・Organize training for NPA staff ・Conduct the environmental monitoring ・Analyze the results of the environmental monitoring ・Report the results to the management ・Take necessary counter measures ・Coordinate with concerned ministries and agencies ・Supervise activities of and coordinate with other departments, especially the generation division and transmission & distribution division
Social and resettlement officer	・Develop a land acquisition and resettlement policy ・Conduct EIA or contract out EIA and supervise it ・Prepare a resettlement action plan or contract out the plan to consultants and supervise them ・Coordinate with donors ・Coordinate with concerned ministries and agencies for land acquisition and resettlement ・Give information to the public and negotiate with project affected people ・Report the progress of land acquisition and implementation of a resettlement action plan to the management

[Source] JICA Study Team

One officer each in the transmission and distribution division, generation division and the power stations should be assigned as the person in charge of the environment and supervise their activities in each office.



[Source] JICA Study Team

Fig. 7.7-2 Organization Chart of NPA

2) Develop environmental policy and management plan

The environmental officers in collaboration with the management are expected to develop an environmental policy of the NPA. Then minimal environmental targets will be set and management plan will be developed. Although no national environmental standards are available, the NPA should develop an internal reference by referring to environmental standards of international organizations, developed counties or neighboring countries. It is important to set the feasible targets to the NPA, which has no experience of environmental considerations and monitoring.

The environmental management plan should include environmental pollution control measures for and monitoring plan of power plants, environmental and social monitoring plan for distribution lines, waste management plan and chemical control plan. In the future when the NPA has a hydro plant, it is expected to monitor environmental and social impacts of the hydro plant.

Harmful wastes, such as oil or chemicals, should be collected separately and discharged in a proper manner. Since no landfill or treatment facilities for industrial wastes exist in Sierra Leone, the NPA as the generator of wastes should take adequate measures.

In addition, to develop an EIA guideline to help NPA officers to assess environmental and social impacts of a new project is badly needed since the NPA will implement many new projects in the coming years. It is believed that donors will fund those projects. Thus, it is required to study the guidelines of donors and explain them in the the NPA EIA guideline. In particular, the standards of donors for resettlement are more favorable to project affected people than the national law. This NPA guideline for EIA should include a part for resettlement.

3) Allocate necessary budget

A budget to take action for environmental protection needs to be secured. The budget should include not only recurrent cost of the environmental unit, but also the procurement costs of necessary equipment, costs of environmental monitoring and so on.

As the NPA’s financial status is very weak, it is difficult to allocate budgets. But this is necessary cost that the NPA should bear to protect the environment.

4) Procure monitoring equipment

The NPA does not have any monitoring equipment. So it is recommended to procure monitoring equipment as follows for the thermal plant.

- Gas emission monitoring equipment (NOx, SOx, dust)
- Noise emission monitoring equipment
- Vibration monitoring equipment
- Water quality monitoring equipment

And a laboratory at each power plant is expected to be created for monitoring purposes. When the NPA has a hydro power plant, it is necessary to buy additional monitoring equipment.

5) Participate and organize training

It is required to give a chance to take technical trainings for the environmental officers and social/ resettlement officers to equip advanced knowledge. A seminar or training on EIA or environmental monitoring is recommended for an environmental officer. A seminar or training to learn other cases of resettlement, EIA or social-economic survey is recommended for social/resettlement officers. And environmental education training to all the NPA staffs to raise their awareness should be held.

The current environmental disaster in the power plant is caused partly by poor operation and maintenance practices. To train the workers how to operate and maintain the generating facilities and incidental facilities is also needed.

6) Monitoring, reporting and evaluation

Monitoring according to the environmental management plan should be conducted and reported to the management regularly. Monitoring should cover

1. Gas emission
2. Noise emission
3. Vibration
4. Water quality
5. Waste
6. Soil contamination
7. Ecosystem

In case of a project which needs involuntary resettlement of people, monitoring of the progress of rebuilding of lives of project affected people even after the construction stage is needed.

The results of the monitoring are compared to the targets set by the environmental management plan and evaluated. If the results are not satisfactory, necessary measures should be taken.

Introduction of this environmental management system is to improve the operation structure of the NPA in order to take environmental and social issues into consideration.