8. Financial and Economic Analyses

8.1 Tariff Review

8.1.1 Willingness-to-Pay Survey Results

Willingness-to-pay survey was conducted from November to December in 2008 by Peninsular Group of Companies with support of JICA Team. The results are summarized as follows from the financial viewpoint (the survey aimed at the demand, too).

(1) Domestic Consumers

1) NPA Supply Hours

On average, the NPA supply hours are 9.2 hours ranging from 6 to 12.8 hours by area and 1 to 24 hours by individual household. Therefore, NPA electric power is supplied only for less than 40% within a day.

2) NPA Average Consumption

On average, NPA monthly domestic consumption is 229 kWh ranging from 49 to 543 kWh by area and from 5 to 2,199 kWh by individual household.

3) NPA Payment

Average monthly payment to the NPA is 114,000 leones ranging from 42,000 to 204,000 leones by area and from 7,000 to 740,000 leones by individual household.

4) Cooking Energy

Mostly charcoal (86%) is used for cooking. Secondly, kerosene is used (11%). Thirdly, wood is used (8.6%). Of course, some use multiple energy resources for cooking.

Table 8.1-1 Household Consumers' Energy Use

Area	Supply Hours	Monthly kWh	Payment/ M	Charcoal for	Kerosene for	Wood for Cooking
East 1	6.0	63.4	41,875	75.0%	12.5%	12.5%
East 2	7.2	148.0	110,118	88.9%	0.0%	11.1%
East 3	7.0	161.0	53,513	77.8%	0.0%	22.2%
West 1	11.4	49.3	53,750	75.0%	25.0%	12.5%
West 2	9.4	543.8	193,333	88.9%	11.1%	11.1%
West 3	10.4	222.9	203,715	100.0%	25.0%	0.0%
Central 1	12.8	408.7	115,522	100.0%	0.0%	0.0%
Central 2	8.9	158.9	144,886	77.8%	22.2%	0.0%
Total	9.2	228.8	114,412	85.7%	11.4%	8.6%

[Source] JICA Study Team

5) Lighting Energy

NPA electric power is 100% used for lighting except in Central 2 area. So it is used 97.1% on average. Secondly, self generators are used 60% on average ranging from 40% (Central 1) to 100% (East 3). Thirdly, kerosene is used 56% on average ranging from 25% (West 3) to 89% (Central 2). Of course, most consumers use multiple energy resources for lighting.

6) Willingness to Pay for 24 Hours Supply

Most domestic consumers (97%) have willingness to pay for 24 hours supply of the NPA except 22% of Central 2. On average, consumers think that they can pay 40% more ranging from 23% (West 1) to 111% (West 3) by area and from -15% to 357% by individual household if they can get NPA electric power for 24 hours a day.

Table 8.1-2 Household Consumers' Willingness-to-Pay

Area	NPA for Lighting	Kerosene for	Generator for	Willingness	No Willingness	Payment Increase
East 1	100.0%	50.0%	50.0%	100.0%	0.0%	107%
East 2	100.0%	66.7%	55.6%	100.0%	0.0%	107%
East 3	100.0%	55.6%	100.0%	100.0%	0.0%	96%
West 1	100.0%	50.0%	50.0%	100.0%	0.0%	23%
West 2	100.0%	44.4%	55.6%	100.0%	0.0%	44%
West 3	100.0%	25.0%	75.0%	100.0%	0.0%	111%
Central 1	100.0%	60.0%	40.0%	100.0%	0.0%	78%
Central 2	77.8%	88.9%	55.6%	77.8%	22.2%	41%
Total	97.1%	55.7%	60.0%	97.1%	2.9%	40%

[Source] JICA Study Team

7) Own Generator

60% of the total households have own generators ranging from 40% (Central 1) to 100% (East 3) by area. Consumption of fuel for the generators is 14.3 gallons per month on average ranging from 4.5 to 22 gallons per month by area and from 2 to 60 gallons per month. Average monthly costs including repair and fuel costs for the generators are 206,000 leones. Average investment cost of the generator is 1.6 million leones. Average generator capacity is 1.8 kW ranging from 1.3 (East 2) to 2.6 kW (West 2) by area and from 0.4 to 4.4 kW by individual household.

Table 8.1-3 Household Consumers' Own Generation

Area	Generator	Fuel (gall.) /M	Maint. Cost (Le) /	Fuel Cost (Le)/M	Monthly Costs (Le)	Investment Cost (Le)	Capacity (kW)
East 1	50.0%	4.50	25,000	56,250	81,250	875,000	1.42
East 2	55.6%	10.60	18,000	132,500	150,500	918,300	1.31
East 3	100.0%	15.11	12,222	188,889	201,111	1,388,869	1.77
West 1	50.0%	11.00	23,750	137,500	161,250	1,247,875	1.40
West 2	55.6%	13.40	22,000	167,500	189,500	2,598,132	2.57
West 3	75.0%	20.17	46,667	251,042	297,708	2,089,000	2.18
Central 1	40.0%	13.00	18,750	162,500	181,250	1,552,000	2.10
Central 2	55.6%	22.20	54,000	277,500	331,500	1,587,624	1.63
Total	60.0%	14.33	26,905	179,018	205,923	1,553,657	1.82

[Remarks] 1Le=0.03060JPY
[Source] JICA Study Team

(2) Commercial Consumers

1) NPA Supply Hour

On average, NPA supply hours are 9 hours ranging from 6.2 to 11.9 hours by area and 1 to 24 hours by individual consumer. (This result is almost similar to that of 1. Domestic consumers.) Therefore, NPA electric power is supplied only for less than 40% within a day.

2) NPA Average Consumption

On average, NPA monthly commercial consumption is 215 kWh ranging from 50 to 372 kWh by area and from 11 to 1,445 kWh by individual consumer.

3) NPA Payment

Average monthly payment to NPA is 198,000 leones ranging from 53,000 to 515,000 leones by area and from 5,000 to 3,069,000 leones by individual consumer.

4) Cooking Energy

Charcoal is used for cooking (33%). Secondly, electricity is used (5.7%). Thirdly, gas is used (4.3%). Of course, some use multiple energy resources for cooking.

Table 8.1-4 Commercial Consumers' Energy Use

Area	Supply Hours	Monthly kWh	Payment/ M	Charcoal for	Electricity for	Gas for Cooking	Kerosene for	Wood for
East 1	6.2	98.7	54,375	28.6%	0.0%	0.0%	14.3%	0.0%
East 2	7.3	72.8	52,895	11.1%	0.0%	0.0%	0.0%	0.0%
East 3	8.7	50.0	82,004	88.9%	0.0%	0.0%	0.0%	0.0%
West 1	7.9	153.1	168,269	50.0%	12.5%	0.0%	0.0%	0.0%
West 2	8.8	337.6	203,572	25.0%	0.0%	25.0%	0.0%	0.0%
West 3	10.3	372.1	515,166	16.7%	25.0%	0.0%	0.0%	8.3%
Central 1	11.9	155.8	214,125	11.1%	0.0%	11.1%	11.1%	0.0%
Central 2	10.4	182.1	244,750	37.5%	0.0%	0.0%	0.0%	0.0%
Total	9.0	214.5	197,504	32.9%	5.7%	4.3%	2.9%	1.4%

[Source] JICA Study Team

5) Lighting Energy

NPA electric power is 97% used for lighting. West 3 and Central 1 areas are 92% and 89%, respectively. The other areas are 100%. Secondly, self generators are used 67% on average ranging from 0% (West 2) to 100% (East 3 and Central 2) by area. Thirdly, kerosene is used 11% ranging from 0% to 33% (East 3) by area. Of course, most consumers use multiple energy resources for lighting.

6) Willingness to Pay for 24 Hours Supply

Most commercial consumers (96%) have willingness to pay for 24 hours supply of NPA except 11% of East 2 and 8.3% of West 3. On average, commercial consumers think that they can pay 95% more ranging from 32% (West 3) to 199% (East 1) by area and from -10% to 288% by individual commercial consumer if they can get NPA electric power for 24 hours a day.

Table 8.1-5 Commercial Consumers' Willingness-to-Pay

Area	NPA for Lighting	Kerosene for Lighting	Generator for Lighting	Willingness	No Willingness	Payment Increase
East 1	100.0%	14.3%	14.3%	100.0%	0.0%	199%
East 2	100.0%	22.2%	66.7%	88.9%	11.1%	101%
East 3	100.0%	33.3%	100.0%	100.0%	0.0%	48.3%
West 1	100.0%	12.5%	62.5%	100.0%	0.0%	56.6%
West 2	100.0%	0.0%	0.0%	100.0%	0.0%	85.4%
West 3	91.7%	8.3%	91.7%	91.7%	8.3%	32.4%
Central 1	88.9%	0.0%	77.8%	88.9%	0.0%	60.8%
Central 2	100.0%	0.0%	100.0%	100.0%	0.0%	46.3%
Total	97.1%	11.4%	67.1%	95.7%	2.9%	95.2%

[Source] JICA Study Team

7) Own Generator

76% of the total commercial consumers have own generators raging from 14% (East 1) to 100% (East 3 and Central 2) by area. Consumption of fuel for the generators is 48.5 gallons per month on average ranging from 4 to 94 gallons per month by area and from 4 to 400 gallons per month by individual commercial consumer. Average monthly costs including repair and fuel costs for the generators are 1,303,000 leones. Average investment cost of the generator is 5.4 million leones. Average generator capacity is 6.96 kW ranging from 1.5 (East 2) to 22.9 kW (West 2) by area and from 0.44 to 108 kW by individual commercial consumer.

Table 8.1-6 Commercial Consumers' Own Generation

Area	Generator	Fuel (gall.) /M	Maint. Cost (Le) / M	Fuel Cost (Le)/M	Monthly Costs (Le)	Investment Cost (Le)	Capacity (kW)
East 1	14.3%	4.00	25,000	50,000	75,000	2,600,000	2.72
East 2	66.7%	16.33	14,500	204,167	218,667	1,469,517	1.47
East 3	100.0%	28.11	21,667	351,389	373,056	2,168,246	1.98
West 1	62.5%	24.80	59,000	310,000	369,000	2,348,300	2.96
West 2	75.0%	94.33	1,693,333	4,833,333	6,526,667	10,471,067	22.93
West 3	91.7%	91.55	246,364	1,144,318	1,390,682	11,971,200	12.36
Central 1	77.8%	20.86	66,429	260,714	327,143	3,128,860	2.89
Central 2	100.0%	46.38	135,000	579,688	714,688	3,638,335	3.86
Total	75.7%	48.47	283,340	1,019,575	1,302,915	5,437,568	6.96

[Remarks] 1Le=0.03060JPY
[Source] JICA Study Team

(3) Institutional Consumer

1) Type of Supply

On average, 3x415v is 71% ranging from 50% to 89% by area. 11kv is 29%.

2) Transformer

On average, 97% of institutional consumers have no transformer. Only 2 institutions (3%) in Central 2 have 11kv transformers.

3) Appliances

On average, power of appliances is 10,000 watts per institution ranging from 1,530 to 24,700 watts by area and from 160 to 155,500 watts by individual institution.

Table 8.1-7 Institutional Consumers' Electrical Demand Situation

Area	3x415v	11kv	No Transformer	11kv Transformer	Appliance (W)
East 1	75.0%	25.0%	100.0%	0.0%	2,454
East 2	83.3%	16.7%	100.0%	0.0%	1,527
East 3	50.0%	50.0%	100.0%	0.0%	12,328
West 1	60.0%	40.0%	100.0%	0.0%	2,711
West 2	87.5%	12.5%	100.0%	0.0%	11,108
West 3	83.3%	16.7%	100.0%	0.0%	11,062
Central 1	88.9%	11.1%	100.0%	0.0%	8,954
Central 2	50.0%	50.0%	75.0%	25.0%	24,676
Total	70.8%	29.2%	96.9%	3.1%	10,040

[Source] JICA Study Team

4) Own Generator

72% of institutions have own generators, on average, ranging from 40% (West 1) to 100% (East 3) by area.

Consumption of fuel for the generators is 195 gallons per month on average ranging from 35 to 408 gallons per month by area and from 4 to 1,320 gallons per month by individual institution. Average monthly costs including repair and fuel costs for the generators are 2,772,000 leones. Average investment cost of the generator is 75 million leones. Average generator capacity is 26.7 kW ranging from 3.7 (East 1) to 49.3 kW (West 2) by area and from 1.1 to 200 kW by individual institution.

Table 8.1-8 Institutional Consumers' Own Generation

Area	Generator	Fuel (gall.) /M	Maint. Cost (Le) / M	Fuel Cost (Le)/M	Lubricant Cost (Le)/M	Monthly Costs (Le)	Investment Cost (Le)	Capacity (kW)
East 1	87.5%	34.9	394,286	435,714	315,429	1,145,429	4,682,857	3.7
East 2	66.7%	75.0	52,250	937,500	41,800	1,031,550	43,625,000	11.1
East 3	100.0%	135.3	116,500	1,691,250	93,200	1,900,950	111,672,650	36.4
West 1	40.0%	71.0	162,500	887,500	130,000	1,180,000	13,550,000	6.1
West 2	75.0%	408.3	80,000	5,104,167	64,000	5,248,167	106,883,333	49.3
West 3	83.3%	274.4	190,000	3,430,000	152,000	3,772,000	139,430,000	32.4
Central 1	66.7%	248.0	85,833	3,100,000	68,667	3,254,500	17,236,000	16.4
Central 2	62.5%	337.6	381,000	4,220,000	304,800	4,905,800	141,800,000	47.5
Total	72.3%	195.3	183,702	2,441,223	146,962	2,771,887	75,086,649	26.7

[Remarks] 1Le=0.03060JPY
[Source] JICA Study Team

(4) Industrial Consumer

1) Type of Supply

On average, 3 X 415V is 91% ranging from 67% to 100% by area. 11 kv is 5.5%.

2) Transformer

On average, 75% of industrial consumers have no transformer. 22% of industrial consumers have 11kv transformers.

3) Appliances

On average, power of appliances is 6,400 watts per industrial consumer ranging from 18 to 17,800 watts by area and from 0.3 to 193,545 watts by individual industrial consumer.

Table 8.1-9 Industrial Consumers' Electrical Demand Situation

Area	3x415v	11kv	No Transformer	11kv Transformer	Appliance (kW)
East 1	77.8%	22.2%	77.8%	22.2%	24
East 2	77.8%	0.0%	88.9%	11.1%	33
East 3	100.0%	0.0%	80.0%	20.0%	100
West 1	100.0%	0.0%	0.0%	50.0%	21
West 2	100.0%	0.0%	100.0%	0.0%	43
West 3	100.0%	0.0%	100.0%	0.0%	18
Central 1	66.7%	33.3%	33.3%	66.7%	69
Central 2	100.0%	0.0%	66.7%	27.8%	17,813
Total	90.9%	5.5%	74.5%	21.8%	6,442

[Source] JICA Study Team

4) Own Generator

91% of industrial consumers have own generators, on average, ranging from 50% (West 1) to 100% by area.

Consumption of fuel for the generators is 873 gallons per month on average ranging from 520 to 1,621 gallons per month by area and from 20 to 7,080 gallons per month by individual industrial consumer. Average monthly costs including repair and fuel costs for the generators are 13 million leones. Average investment cost of the generator is 261 million leones. Average generator capacity is 200 kW ranging from 96 (West 2) to 313 kW (East 2) by area and from 4.3 to 1,680 kW by individual industrial consumer.

Table 8.1-10 Industrial Consumers' Own Generation

Area	Fuel (gall.) /M	Fuel Cost (Le) / M	Maint. Cost (Le)/M	Lubricant Cost (Le)/M	Monthly Costs (Le)	Investment Cost (Le)	Capacity (kW)
East 1	726	9,073,214	553,810	703,048	10,330,072	234,221,638	209.2
East 2	1,270	15,876,563	699,583	637,500	17,213,646	493,177,941	312.9
East 3	838	10,470,000	1,040,000	832,000	12,342,000	262,936,856	230.4
West 1	1,621	20,262,500	600,000	4,200,000	25,062,500	874,875,008	160.0
West 2	520	6,500,000	470,000	376,000	7,346,000	90,562,500	96.0
West 3	704	8,796,875	473,250	63,750	9,333,875	41,162,850	141.8
Central 1	1,205	15,066,667	1,313,333	361,667	16,741,667	69,408,000	249.3
Central 2	756	9,451,471	2,343,529	1,396,941	13,191,941	272,921,261	162.1
Total	873	10,917,750	1,266,187	882,007	13,065,943	260,845,701	200.3

[Remarks] 1Le=0.03060JPY
[Source] JICA Study Team

8.1.2 Comparison with NPA's Tariff

Based on the results of the survey, consumers' own generation costs are compared with the NPA's tariffs as follows.

The survey result shows the average monthly fuel cost of each category consumer and assuming 30 US cents/kWh as general generation cost, own generator demand (kWh/month) can be calculated. Then, the average generator investment cost can be exchanged to US dollars and annuitized using the following formula.

$$\frac{\text{Investment cost} \times \text{Discount Rate (10\%)} \times (1+\text{Discount rate})^{\text{Economic Life (year)}}}{(1+\text{Discount Rate})^{\text{Economic Life (year)}}-1}$$

The annuitized investment cost can be divided by 12 and monthly costs can be calculated. The average operation and maintenance cost (including fuel cost) obtained from the survey is added and monthly total own-generator cost can be calculated.
The old and new tariffs of the NPA are applied to each category consumer's average monthly used electricity volume of own generation calculated above and compared with the own generation cost. The result is shown in Table 8.1-11.
Own generation cost is more than NPA charges for domestic, commercial and institutional consumers. However, industrial consumers' own generation cost is less than the NPA charges, even old charges. Therefore, they may use their own generators rather than NPA power as long as the tariff of the NPA for industry is as expensive as the old tariff. The new tariff is, needless to say. The factors other than cost may be noise, air pollution and operation and maintenance work.

Table 8.1-11 Comparison of Own Generation Costs and Corresponding NPA Charges

Category	Fuel Cost	Fuel Cost	Demand	Investment	Annuitized	O&M	Cost	NPA(old)	NPA(new)
	Le/M	UScents/M	kWh/M	US$/Y	US$/M	US$/M	US$/M	US$/M	US$/M
Household	179,018	5,631	188	129	10.7	64.8	75.5	32.1	48.2
Commercial	1,019,575	32,072	1,069	451	37.6	410	447	280	420
Institution	2,441,223	76,790	2,560	6,231	519	872	1,391	629	943
Industry	10,917,750	343,426	11,448	21,645	1,804	4110	5,914	6323	9484

[Remarks] 1Le=0.03060JPY, 1US$=97.28JPY
[Source] JICA Study Team

8.2 Long-run Marginal Cost Calculation

8.2.1 Concept of Long-run Marginal Cost

According to the JBIC's "Power Tariff Theory and Analysis Handbook" (only Japanese version) published in February 2000, since the electrical market is a natural monopoly and there is no competitive pressure, it is necessary to set tariff at the price equal to "marginal cost" politically in order to attain efficient resource allocation. Long-run marginal cost is marginal cost (necessary cost to attain production increase per unit) in the long term as the capital (facility investment) changes (increases and decreases) (in the case of electricity, usually 20 years).

The guideline indicates the causes bringing about the difference of marginal cost as follows.

- Voltage class
  Marginal cost is calculated depending on cost necessary to increase electrical supply and so the marginal cost differs depending on the voltage class at which each user receives electricity. Long-run marginal cost of high voltage users such as factories is cheaper than that of low voltage user households. Generally, different tariffs are imposed on voltage classes based on the marginal costs.

- Peak and off-peak
  Marginal costs at peak and off-peak times differ. In particular, demand increase at peak time causes not only energy cost increase but also facility cost increase because of additional generation facility capacity need and it is the main cause of marginal cost difference between peak and off-peak times. Generally, introduction of tariffs based on the marginal cost difference between 1) peak and off-peak in a day (night time off-peak tariff) and 2) seasonal peak and off-peak in a year (such as summer tariff) is examined.

- Area
  Marginal costs of a densely populated area and a rural dispersed area or areas with very different distances from the generation station differ because necessary facilities differ. If the marginal costs by areas differ very much, it is efficient to impose different tariffs by each area. However, there is a case that a nation adopts a policy to impose national uniform tariffs from the viewpoint of equity and if the uniform tariff policy is prioritized, a cross-subsidy happens.

The calculation methods of long-run marginal cost are different between generation and transmission & distribution. Marginal cost of generation includes energy cost, but that of transmission & distribution is only facility cost excluding loss. Long-run marginal cost is regarded as long-run average increment cost obtained from dividing the least facility investment cost of original investment plan by annual demand increase based on the existing demand forecast. The calculation method is described as follows.

(1) Find A= (Present value sum of investment and O&M costs during a certain period) / (Present value sum of annual peak demand increase during the same period)

(2) Convert A ($/kW) resulting from (1) above to annual value, namely annuitize
$A \times i \times (1+i)^n / ((1+i)^n - 1) = B$ $/kW/year

(3) Convert B in $/kW/year resulting from (2) above to value in $/kWh
B/ 365days/ 24hours / Load Factor (0.65)

Long-run marginal cost of generation requires addition of fuel and variable costs calculation.
It is said that the power industry is one of the plant industries and so initial investment cost is high and past accumulated investment cost becomes great. Therefore, tariffs of power operators to maintain their sound financial balance may tend to be higher than those to cover the future cost (Long-run

marginal cost). In this case, it is necessary to set tariffs higher than Long-run Marginal Cost in order to continue their business.

8.2.2 Application of Long-run Marginal Cost to This Project

An example table to calculate long-run marginal cost is applied to the JICA Study using the power development plan with investment and NPA's existing financial data. The result is shown from Table 8.2-1 to Table 8.2-4.
Long-run marginal costs of generation, transmission (actually, HV&MV in the case of NPA) and distribution are summarized as follows.

Generation (Base Case: Hydro Main):	13.5	US cents/kWh
HV&MV:	3.17	US cents/kWh
Distribution:	0.48	US cents/kWh
Total:	17.2	US cents/kWh

Generation (Alternative: Thermal Main):	15.5	US cents/kWh
HV&MV:	3.17	US cents/kWh
Distribution:	0.48	US cents/kWh
Total:	19.2	US cents/kWh

Table 8.2-1 Long-run Marginal Costs of Original Generation Development Plan (Base Case: Hydropower Main)

Hydro Main Base Case Assumption	
Growth Rate of Peak Demand	6.5%-7.8%
Discount Rate	10%
Plant Cost (Million US$)	
15MW X 0	0
8.28MW X 3	34.9
8.0MW X 6	82.8
1.8MW X 21	17.4
Yiben I	189.6
Yiben II	245.9

	Peak Demand Forecast				
	Year	Peak Demand (MW)	Incremental Demand (MW)	Existing Capacity (MW)	New Construction (MW)
2008	0	17			
2009	1	30.5	0	30.5	
2010	2	46.7	16.2	55.0	24.5
2011	3	50.0	3.3	61.1	6.1
2012	4	53.8	3.8	62.6	1.5
2013	5	58.0	4.2	67.8	5.2
2014	6	62.5	4.5	71.2	3.4
2015	7	67.4	4.9	76.4	5.2
2016	8	72.6	5.2	83.7	7.3
2017	9	78.2	5.6	91.0	7.3
2018	10	84.1	5.9	98.2	7.2
2019	11	90.4	6.3	156.5	58.3
2020	12	97.0	6.6	156.2	0.0
2021	13	104.0	7.0	155.9	0.0
2022	14	111.5	7.5	155.5	0.0
2023	15	119.3	7.8	155.2	0.0
2024	16	127.6	8.3	154.9	0.0
2025	17	136.3	8.7	154.6	0.0
2026	18	145.5	9.2	157.9	3.3
2027	19	155.2	9.7	170.6	12.7
2028	20	165.4	10.2	190.0	19.4
	Total		134.9		
	PV		51.7		

Year	Investment Costs (MUS$)
1	4.7
2	23.4
3	9.3
4	0.8
5	2.5
6	4.4
7	14.6
8	42.2
9	80.2
10	77.4
11	28.4
12	0.0
13	0.0
14	0.0
15	0.0
16	0.0
17	0.0
18	41.3
19	99.6
20	93.8
Total	522.6
PV	173.8

NPV Inc. Demand	NPV Investment
0	4.229090909
13.38842975	19.35371901
2.479338843	6.990232908
2.59545113	0.565535141
2.607869557	1.542368566
2.540132685	2.492716875
2.514474779	7.506476953
2.425838377	19.70387222
2.374946663	33.99269641
2.274705408	29.8383518
2.208111567	9.96699502
2.102963397	0
2.027650658	0
1.974984407	0
1.867257985	0
1.806321827	0
1.721248619	0
1.654700867	7.427376645
1.586027511	16.2815371
1.520624315	13.93985889
51.7	173.8

Marginal Capacity Cost for Generation		
1) Discounted Capital Expenditure for Generation Investment divided by Discounted Incremental Demand	3,364	US$/kW
2) Annuitize 1) above	339.3	US$/kW/year
3) Convert 2) above into US$/kWh assuming 65% load factor	5.96	cents/kWh

Marginal Energy Cost (Fuel + Variable O&M) for Generation		
1) Discounted fuel and variable O&M costs	132.1	Million US$
2) Discounted power purchase cost from Bumbuna Hydro	135.1	Million US$
3) Discounted change (increase) in Peak Demand	51.7	MW
4) 1)+2) above / 3) above	5170.9	US$/kW
5) Sum of discounted generation	3,540,699,665.7	kWh
6) Convert 4) above into US$/kWh assuming 65% load factor	7.55	US cents/kWh

Generation Marginal Costs	US$/kW/year	US cents/kWh
Capacity Cost	339.3	5.96
Energy + O&M Cost + Bumbuna Purchase	5,170.9	7.55
Total	5,510.2	**13.51**

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Table 8.2-2 Long-run Marginal Costs of Original Generation Development Plan (Alternative Case: Thermal Main)

Thermal Main Alternative Case Assumption	
Growth Rate of Peak Demand	6.5%-7.8%
Discount Rate	10%
Economic Life of Distribution System	35
Plant Cost (Million US$)	
15MW X 3	113.85
8.28MW X 3	34.9
8.0MW X10	138.0
1.8MW X 19	15.7

	Peak Demand Forecast				
	Year	Peak Demand (MW)	Incremental Demand (MW)	Existing Capacity (MW)	New Construction (MW)
2008	0	17			
2009	1	30.5	0	30.5	
2010	2	46.7	16.2	55.0	24.5
2011	3	50.0	3.3	61.1	6.1
2012	4	53.8	3.8	62.6	1.5
2013	5	58.0	4.2	67.8	5.2
2014	6	62.5	4.5	71.2	3.4
2015	7	67.4	4.9	76.4	5.2
2016	8	72.6	5.2	83.7	7.3
2017	9	78.2	5.6	91.0	7.3
2018	10	84.1	5.9	98.2	7.2
2019	11	90.4	6.3	101.4	3.2
2020	12	97.0	6.6	110.6	9.2
2021	13	104.0	7.0	124.4	13.8
2022	14	111.5	7.5	125.8	1.4
2023	15	119.3	7.8	136.7	10.9
2024	16	127.6	8.3	145.7	9.0
2025	17	136.3	8.7	159.4	13.7
2026	18	145.5	9.2	166.3	6.9
2027	19	155.2	9.7	179.8	13.5
2028	20	165.4	10.2	190.2	10.4
	Total		134.9		
	NPV		51.7		

Year	Investment Costs (MUS$)
1	4.7
2	23.4
3	9.3
4	0.8
5	2.5
6	4.4
7	14.6
8	13.8
9	13.8
10	11.0
11	4.4
12	21.9
13	30.4
14	4.4
15	17.9
16	21.1
17	33.9
18	18.6
19	33.1
20	107.1
Total	391.3
NPV	118.0

NPV Inc. Demand	NPV Investment
0	4.229090909
13.38842975	19.35371901
2.479338843	6.990232908
2.59545113	0.565535141
2.607869557	1.542368566
2.540132685	2.492716875
2.514474779	7.506476953
2.425838377	6.437801847
2.374946663	5.852547134
2.274705408	4.256397915
2.208111567	1.54778106
2.102963397	6.991397402
2.027650658	8.794210569
1.974984407	1.162870819
1.867257985	4.294693366
1.806321827	4.595021573
1.721248619	6.71643082
1.654700867	3.350769256
1.586027511	5.415384656
1.520624315	15.91861773
51.7	118.0

Marginal Capacity Cost for Distribution		
1) Discounted Capital Expenditure for Generation Investment divided by Discounted Incremental Demand	2283.9	US$/kW
2) Annuitize 1) above	268.3	US$/kW/year
3) Convert 2) above into US$/kWh assuming 65% load factor	4.71	cents/kWh

Marginal Energy Cost (Fuel + Variable O&M) for Generation		
1) Discounted fuel and variable O&M costs	253.1	Million US$
2) Discounted power purchase cost from Bumbuna Hydro	129.0	
3) Discounted change (increase) in Peak Demand	51.7	MW
4) 1)+2) above / 3) above	7395.0	US$/kW
5) Sum of discounted generation	3,540,699,665.7	kWh
6) Convert 4) above into US$/kWh assuming 65% load factor	10.79	US cents/kWh

Generation Marginal Costs	US$/kW/year	US cents/kWh
Capacity Cost	268.3	4.71
Energy + O&M Cost + Bumbuna Purchase	7,395.0	10.79
Total	7,663.2	**15.50**

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Table 8.2-3 Long-run Marginal Cost of Transmission (HV & MV) Development Plan

Assumption	
Growth Rate of Peak Demand	6.5%-7.8%
Discount Rate	10%
Economic Life of Transmission System	20

Peak Demand Forecast at Entry to Transmission System

	Year	Peak Demand (MW)	Incremental Demand (MW)	Existing Capacity (MW)	New Construction (MW)
2008	0	17			
2009	1	30.5	0	35.0	
2010	2	46.7	16.2	51.2	16.2
2011	3	50.0	3.3	54.5	3.3
2012	4	53.8	3.8	58.3	3.8
2013	5	58.0	4.2	62.5	4.2
2014	6	62.5	4.5	67.0	4.5
2015	7	67.4	4.9	71.9	4.9
2016	8	72.6	5.2	77.1	5.2
2017	9	78.2	5.6	82.7	5.6
2018	10	84.1	5.9	88.6	5.9
2019	11	90.4	6.3	94.9	6.3
2020	12	97.0	6.6	101.5	6.6
2021	13	104.0	7.0	108.5	7.0
2022	14	111.5	7.5	116.0	7.5
2023	15	119.3	7.8	123.8	7.8
2024	16	127.6	8.3	132.1	8.3
2025	17	136.3	8.7	140.8	8.7
2026	18	145.5	9.2	150.0	9.2
2027	19	155.2	9.7	159.7	9.7
2028	20	165.4	10.2	169.9	10.2
	Total		134.9		
	PV		51.7		

Year	Inveastment + Fixed O&M Costs (MUS$)
1	0.00
2	3.33
3	11.70
4	19.38
5	19.37
6	21.29
7	17.96
8	18.78
9	10.90
10	7.34
11	4.38
12	3.87
13	4.12
14	4.12
15	
16	
17	
18	
19	
20	
Total	146.5
PV	79.3

Marginal Capacity Cost for Transmission		
1) Discounted Capital Expenditure for Transmission Investment divided by Discounted Incremental Demand	1,535	US$/kW
2) Annuitize 1) above	180.3	US$/kWh/year
3) Convert 2) above into US$/kWh assuming 65% load factor	3.17	cents/kWh

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Table 8.2-4 Long-run Marginal Cost of Distribution Development Plan

Assumption	
Growth Rate of Peak Demand	6.5%-7.8%
Discount Rate	10%
Economic Life of Distribution System	35

Peak Demand Forecast at Entry to Distribution System (e.g. 33kV system)

	Year	Peak Demand (MW)	Incremental Demand (MW)	Existing Capacity (MW)	New Construction (MW)
2008	0	17			
2009	1	30.5	0	35.0	
2010	2	46.7	16.2	51.2	16.2
2011	3	50.0	3.3	54.5	3.3
2012	4	53.8	3.8	58.3	3.8
2013	5	58.0	4.2	62.5	4.2
2014	6	62.5	4.5	67.0	4.5
2015	7	67.4	4.9	71.9	4.9
2016	8	72.6	5.2	77.1	5.2
2017	9	78.2	5.6	82.7	5.6
2018	10	84.1	5.9	88.6	5.9
2019	11	90.4	6.3	94.9	6.3
2020	12	97.0	6.6	101.5	6.6
2021	13	104.0	7.0	108.5	7.0
2022	14	111.5	7.5	116.0	7.5
2023	15	119.3	7.8	123.8	7.8
2024	16	127.6	8.3	132.1	8.3
2025	17	136.3	8.7	140.8	8.7
2026	18	145.5	9.2	150.0	9.2
2027	19	155.2	9.7	159.7	9.7
2028	20	165.4	10.2	169.9	10.2
	Total		134.9		
	NPV		51.7		

Year	Inveastment + Fixed O&M Costs (MUS$)
1	0.0
2	0.0
3	1.0
4	1.5
5	2.0
6	2.0
7	2.0
8	0.4
9	3.1
10	6.3
11	2.2
12	1.5
13	1.0
14	1.0
15	1.1
16	1.1
17	2.1
18	
19	
20	
Total	28.6
NPV	12.0

Marginal Capacity Cost for Distribution		
1) Discounted Capital Expenditure for Distribution Investment divided by Discounted Incremental Demand	231.6	US$/kW
2) Annuitize 1) above	27.2	US$/kWh/year
3) Convert 2) above into US$/kWh assuming 65% load factor	0.48	cents/kWh

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

In these tables, peak and off-peak times are not distinguished because Sierra Leone is in the situation requiring simpler tariffs and cheaper meters (which do not respond to tariffs depending on the peak and off-peak times). Furthermore, it is generally indicated to estimate border prices converted from market prices of costs in order to exclude effects of the national policy distorting economic efficiency, but in this study, most procured equipment and materials are imported from abroad without tax and local cost share is small and so prices are not converted.

The long-run marginal costs calculated cannot be just adopted directly. Financial estimate of NPA in the future is necessary.

8.3 Comparison of NPA Tariffs with International Level

Japan External Trade Organization (JETRO) that is a governmental agency in Japan publishes JETRO Sensor as monthly journal. Its December 2006 special edition shows costs of worldwide cities including electricity cost. It is limited to the household user's viewpoint, but the result is summarized in Table 8.3-1. The costs of the other cities are cheaper than those of Freetown, even the old NPA tariff. JETRO Sensor published newer data as of January 2008 but limited to Asian major cities. The tariffs for domestic users are shown in Table 8.3-2. Tariffs comparable to Freetown's are Tokyo's (15 – 21 cents/kWh), Manila's (19 cents/kWh), Kuala Lumpur's (22 cents/kWh) and Singapore's (16 cents/kWh). Assuming household users in Freetown use 200 kWh a month, the average tariff is 20 cents/kWh as old tariff or 28 cents/kWh as new tariff in Freetown. Therefore, the new tariff of NPA is very expensive.

Table 8.3-1 (Domestic) Electricity Cost in Worldwide Capital Cities

Country	Capital	Cost	Note
Korea	Seoul	2,090	For domestic
China	Beijing	1,380	
Vietnam	Hanoi	1,253	
Thailand	Bangkok	1,788	
Malaysia	Kuala Lumpur	1,341	
Singapore		2,129	For domestic excluding tax
Indonesia	Jakarta	1,458	
Bangladesh	Dhaka	1,890	
India	New Delhi	2,155	Including service charge and tax
Pakistan	Karachi	2,261	
Peru	Lima	2,175	
Brazil	Sao Paulo	3,547	
Chile	Santiago	3,047	For domestic
Argentina	Buenos Aires	939	
Turkey	Istanbul	2,228	
Nigeria	Lagos	480	
South Africa	Johannesburg	1,080	
Sierra Leone	Freetown	3,384	For domestic (old tariff) excluding service charge
	Freetown	5,080	For domestic (new tariff) excluding service charge

[Note] Electricity cost is amount per 200 kWh.
Cost currency is Japanese yen almost equal to US cent in 2009.
Cost is as of 2006 except Sierra Leone
[Source] Modified from JETRO, "JETRO Sensor," December 2006

Table 8.3-2 Domestic Electricity Tariffs in Asian Capital Cities

Country	Capital	Tariff for Household	Remarks
Japan	Tokyo	2.53 - 15.19	Contract current (10A - 60A)
		0.15 - 0.21	Different depending on used kWh
Korea	Seoul	5.50/kW	Contract kW: <1,000kW
		0.07	
China	Beijing	0	
		0.07	
The Philippines	Manila	0.12	Monthly use 201 - 300kWh
		0.19	
Vietnam	Hanoi	0	
		0.034 - 0.11	
Thailand	Bangkok	1.23	Monthly use 150kWh<
		0.05:1-150kWh, 0.08: 151-400kWh, 0.09: 400kWh<	
Malaysia	Kuala Lumpur	0	
		0.22	
Singapore		0	Excluding GST (7%)
		0.1583	
Indonesia	Jakarta	3.21	<2,200VA
		0.05	60kWh<
Bangladesh	Dhaka	0.29-0.87	Including VAT (5%)
		0.04-0.08	Different depending on kWh
India	New Delhi	0.31/kW	5kW<
		0.06-0.12	Different depending on used kWh
Sri Lanka	Colombo	0.55-2.22	Including fuel control tax (20%, =<90kWh) different
		0.028-0.22	depending on used and contract kWhs, VAT exempted
Pakistan	Karachi	0	Different depending on unit number, including sales tax
		0.03-0.14	(15%), additionally 0.14-0.37 for monthly meter rental
Sierra Leone	Freetown	1.67	Old tariff
		0.124: <30kWh, 0.178: 30-150kWh, 0.282: 150kWh<	Minimum US$3.727
		2.5	New tariff
		0.187: <30kWh, 0.267: 30-150kWh, 0.355: 150kWh<	Minimum US$5.59

[Note] The upper row shows the service charge and the lower row shows the charge per kWh.
The currency is US dollar.
Tariffs are as of January 2008 except Sierra Leone

[Source] Modified from JETRO, “Comparison of Investment Related Costs in Asian Major Cities and Regions,” ‘JETRO Sensor,’ June 2008

The JETRO Sensor article displays tariffs for industrial consumers in Table 8.3-3. The tariffs per kWh are expensive in Manila (13 cents/kWh), Singapore (14 cents/kWh), New Delhi (13 cents/kWh) and Colombo (15 – 20 cents/kWh, but in peak time), but the NPA’s are much more expensive (31 cents/kWh as old tariff and 47 cents/kWh as new tariff).

Expensive electricity for industry impedes foreign direct investment and export and weakens international competitiveness of Sierra Leone. Therefore, it is necessary to decrease the NPA’s tariffs for industry.

Table 8.3-3 Electricity Tariffs for Industry in Asian Capital Cities

Country	Capital	Tariff for Industry	Remarks
Japan	Tokyo	14.22	Special high voltage (10kv=< <50kv)
		0.082	0.09 for summer season (from July to September)
Korea	Seoul	4.46/kw	<300kW including VAT
		0.06	From Nov. to Feb. (different depending on the season)
China	Beijing	0	
		0.04 - 0.1	
The Philippines	Manila	23.98+10.42/kW	
		0.13	
Vietnam	Hanoi	0	
		0.049 - 0.056	Depending on the type of industry and used kWh
Thailand	Bangkok	6.88	Additional demand charge 2.24/kW at peak time (9 to
		0.08	22 from Monday to Friday) <64kV
Malaysia	Kuala Lumpur	5.99/kW	
		0.07	
Singapore		4.93/kW	Within the contract kW (7.39/kW for excess),
		0.1417 - 0.1428	excluding GST
Indonesia	Jakarta	3.14	200kVA=< , <350 hours/month
		0.09	
Bangladesh	Dhaka	8.73	Including VAT (5%),
		0.02 - 0.08	Different depending on the used kWh
India	New Delhi	1.28/kW	
		0.13	
Sri Lanka	Colombo	2.22: <10kVA, 4.62: <42kVA, 27.73: 42kVA<	Depending on the max. instanteneous used and
		0.066 - 0.073: off-peak, 0.15 - 0.20: peak	contract kWhs, taxes exempted
Pakistan	Karachi	5.02 - 5.52	Different depending on the used unit number, including
		0.06 - 0.11	sales tax (15%), additionally 0.14-0.37 for monthly
Sierra Leone	Freetown	12.41+0.4827/kW	Old tariff
		0.3137	Minimum 39.43Le
		18.62+0.724/kW	New tariff
		0.4707	Minimum 59.15Le

[Note] The upper row shows the service charge and the lower row shows the charge per kWh.
The currency is US dollar.
Tariffs are as of January 2008 except Sierra Leone

[Source] Modified from JETRO, "Comparison of Investment Related Costs in Asian Major Cities and Regions," 'JETRO Sensor,' June 2008

8.4 Financial Estimate Based on Power Development Plan

8.4.1 Estimate Model Structure

Based on the power development plan, a financial estimate model of the NPA for the future is prepared. It starts from 2009 and continues until 2030. The revenue of the NPA in 2009 is estimated from the sale data from January to April except February. The other income is assumed to be 10% of sale based on the past data. The expenditure is estimated based on the past data, too. Bumbuna hydropower is assumed to begin supply power from December, 2009. The purchase price is set at 7 US cents/kWh, but it can be changed in the model calculation. In addition, the currency used is US dollar. The exchange rate is 3,179.07 Le/US$ according to the rate of Bank of Sierra Leone as of June 3, 2009. The other assumptions are as follows.

- Revenue

  The past tariff (before the raise in December, 2008) of the NPA is set, but increase rate (e.g. 120% shows 120% of the past tariff) can be changed (e.g. 100% is the same as the past tariff). The tariff is multiplied by demand in each consumer category based on the demand forecast except industrial consumer category for which 93.5% is set because the industrial tariff is necessary to be competitive with own generation based on the willingness to pay survey result. Furthermore, institution users are included in commercial users. However, it is assumed that the rates of system loss and collection (namely arrears) are 40% and 70% in 2009 and would be improved to 15% and 95% in 2025 (transmission and distribution investment completion), respectively, improving proportionately between 2009 and 2025.

- Expenditure
  General administration and payroll costs are supposed to change proportionately to the revenue. Operation and maintenance costs for new facilities and fuel cost are based on the power development plan. Income electric generation (payment) will continue until February 2011 and capacity charge (US$ 100,000 per month) will be paid to Income Electric until accumulated monthly payment becomes US$ 12 million

- Depreciation
  The existing asset depreciation is calculated based on the NPA asset data. Lifetimes are as follows.

    Building: 50 or 30 years
    Diesel generator (middle-speed): 20 years
    Transmission and distribution facility: 20 years
    General and office equipment and furniture: 5 years
    Vehicle: 4 years

  Lifetimes of the new investment facilities are as follows.
    Low-speed generator: 30 years
    High-speed generator: 10 years
    Hydropower facilities: 50 years

  Scrap value is null and depreciation is linear.

- Long-term liability
  The existing long-term liabilities such as EU's and IDA's have not been repaid because the NPA has had deficits. When the NPA gets profits, interest payment and repayment of the existing long-term liabilities would be started at once. The conditions are as follows.

    EU: 15 years for repayment and 2% as interest rate
    IDA: 20 years for repayment with 5 years grace period and 7.75% as interest rate
    BADEA and Saudi Fund: 30 years for repayment with 10 years grace period and 1% as interest rate

  New investment in the power development plan of this study is assumed to be funded as follows based on the Bumbuna Hydroelectric Company loan by the AfDB and other donors and Power and Water project loan of the IDA.

    Yiben Hydroelectric Generation: 40 years repayment with 10 years grace period and 2% interest rate
    Other investment (diesel and distribution): 20 years repayment with 5 years grace period and 5% interest rate

- After profit
  Corporate tax is 28%. Dividend is 10%. Commercial bank interests for lending and saving are 15% and 4%, respectively.

The power development plan shows two cases. One is Hydro Dominant Case and the other is Thermal Dominant Case. Therefore, the financial estimate models are prepared for these two cases with the assumptions above. In addition, another model is prepared in the case that Yiben I and II would be constructed and operated by Bumbuna Hydropower Company and their generated power would be purchased by the NPA at the same price of Bumbuna's (Yiben IPP Case).

8.4.2 Model Calculation Results

The model calculation results are shown from Table 8.4.1 to Table 8.4-3.

Table 8.4-1 is Hydro Dominant Case in which Bumbuna price is 7 cents/kWh and NPA tariffs are 130% of the past tariffs (before December 2008), or approximately 27 cents/kWh on average (22.6 cents/kWh for household, 34.1 cents/kWh for commercial users and 27.7 cents/kWh for industrial users). The result shows that Net Present Value (NPV) (discount rate 10%) from 2009 to 2030 is US$ 41 million and DSCR (Debt Service Coverage Ratio)[1] is from 0.43 in 2009, to 116.1 in 2016 at the maximum and to 0.25 in 2030. If Bumbuna price becomes 10 cents/kWh, the NPA tariff increase rate needs to be 165% (32~30 cents/kWh on average, 28.7 cents/kWh for household, 43.2 cents/kWh for commercial users and 27.7 cents/kWh for industrial users) in order to keep DSCR sound (0.46~61.7~0.21). In this case, NPV (discount rate 10%) is US$ 74 million. If Bumbuna price becomes 20 cents/kWh, NPA tariff increase rate needs to be 280% (50~46 cents/kWh on average, 48.7 cents/kWh for household, 73.4 cents/kWh for commercial users and 27.7 cents/kWh for industrial users) in order to keep DSCR sound (0.56~8.33~0.14). NPV becomes US$ 180 million in this case.

Although Bumbuna purchase price is set at 7 cents/kWh, why do the NPA tariffs become expensive like 27 cents/kWh on average? There are several reasons, but what seems most important is system loss and collection rates (arrears). Those are set at 40% and 70% in 2009 and would be improved to 15% and 95% in 2025, respectively. If 40% and 70% in 2009 are changed to 15% and 95%, the NPA tariff change rate can be decreased to 80% (19 cents/kWh on average, 13.9cents/kWh for household, 21 cents/kWh for commercial users and 27.7 cents/kWh for industrial users). In this case, NPV is US$ 5 million. DSCR is 0.43~15.5~0.38. The issue of system loss and collection rates is explained as follows.

If the hydropower generation cost is 7 cents/kWh and system loss and collection rates are 15% and 95%, respectively, tariff to cover the generation cost will become 8.7 cents/kWh (7/(1-0.15)/0.95= 8.7) excluding other costs. However, if the system loss and collection rates are 40% and 70%, respectively, tariff to cover the generation cost will become 16.7 cents/kWh (7/(1-0.4)/0.7= 16.7), more than twice the generation cost. Therefore, the NPA tariffs are critically depending on the purchase price of Bumbuna power, system loss and collection rate (arrears).

If the existing long-term liabilities of the NPA such as EU’s, IDA’s and others are transferred to the government to privatize the NPA, the tariffs will need to be 115% up (24~25 cents/kWh on average, 20.0 cents/kWh for household, 30.1 cents/kWh for commercial users and 27.7 cents/kWh for industrial users). NPV (discount rate 10%) is US$ 1 million and DSCR is 0~1.03~0.29. However, new investment is supposed to be funded by soft loan such as IDA’s in this case.

Table 8-4-2 shows the Thermal Dominant Case result. Although the conditions are similar to those in Table 8-4-1, NPA tariffs need to be 155% up of old tariffs (30 cents/kWh on average, 27.0 cents/kWh for household, 40.6 cents/kWh for commercial users and 27.7 cents/kWh for industrial users), more than that of Hydro Dominant Case, and NPV (10%) is US$ 9 million, less than that of Hydro Dominant Case. DSCR is 0.43~1.97~0.82.

Table 8-4-3 is the result of Yiben IPP Case. The NPA tariff increase rate needs to be 135% (27 cents/kWh on average, 23.5 cents/kWh for household, 35.4 cents/kWh for commercial users and 27.7 cents/kWh for industrial users) and NPV (10%) is US$ 54 million. DSCR is 0.43~11.6~0.26.

[1] Debt Service Coverage Ratio is defined as (annual repayment plus interest payment)/(annual profit). Although it depends on the situation, DSCR=1.2 ~ 1.3 is considered desirable usually.

Table 8.4-1 Financial Estimate of the NPA (Base Case: Hydropower Dominant)

(Unit: US$ 1,000)

US$= Le	3179
Bumbuna c/kWh	7.0
Household c/kWh	22.6
Comm. c/kWh	34.1
Indust. c/kWh	27.7
Indust. c/kW	42.6
Increase rate	130%
Interest: 4.0% (Cash and Cash Equivalent)	
Interest: 15.0% (Short Term Debt)	
Tax Rate: 28.0% (Income Tax)	
Dividend Ratio: 10.0% ((Dividends))	

year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total																						
<Assets>																						
Utility Plant	9,903	51,102	65,501	82,227	96,786	115,905	149,268	173,780	191,893	205,140	380,772	380,439	362,390	353,846	335,652	317,729	306,818	290,551	288,934	275,063	272,839	498,346
Capital Lease																						
Investment & Other Assets																						
Current Assets																						
Accounts Receivables																						
Cash and Cash Equivalent	3,517	536	-1,243	-2,389	-3,755	-5,166	-6,554	-8,142	-10,429	-23,095	-19,122	-12,028	1,705	30,011	60,137	94,227	133,953	173,872	213,473	252,528	285,082	342,664
Total Assets	13,419	51,638	64,257	79,838	93,031	110,740	142,715	165,638	181,465	182,045	361,650	368,411	364,095	383,857	395,789	411,956	440,771	464,423	502,407	527,591	557,921	841,010
<Capital>																						
Capital	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Retained Earnings	5,109	3,737	1,343	-1,289	-5,164	-10,095	-16,167	-24,265	-33,356	-42,704	-22,336	-2,541	19,270	45,452	75,059	108,902	147,591	186,262	225,293	262,840	299,898	361,292
Total	5,110	3,738	1,343	-1,288	-5,163	-10,094	-16,166	-24,265	-33,356	-42,704	-22,335	-2,540	19,270	45,453	75,060	108,902	147,592	186,262	225,294	262,840	299,898	361,293
<Liabilities>																						
Short Term Debt	0	0	1,243	2,389	3,755	5,166	6,554	8,142	10,429	23,095	19,122	12,028	0	0	0	0	0	0	0	0	0	0
Long Term Debt	36,240	59,615	74,793	93,465	110,933	134,073	173,480	205,052	228,014	248,620	436,474	446,327	432,063	425,827	407,986	390,145	380,730	365,546	364,474	351,945	345,191	574,096
Total Capital and Liabilities	41,350	63,353	77,379	94,565	109,524	129,144	163,867	188,929	205,086	229,011	433,261	455,815	451,334	471,280	483,046	499,048	528,322	551,808	589,767	614,785	645,089	935,389
<Profit and Loss>																						
Revenue																						
Sale	21,903	30,792	34,597	38,990	43,937	49,475	55,646	62,494	70,065	78,411	87,587	97,651	108,667	120,704	133,835	148,141	163,708	174,499	185,840	197,760	210,291	223,473
Other	2,190	3,079	3,460	3,899	4,394	4,948	5,565	6,249	7,006	7,841	8,759	9,765	10,867	12,070	13,384	14,814	16,371	17,450	18,584	19,776	21,029	22,347
Total Revenue	24,093	33,871	38,057	42,889	48,330	54,423	61,211	68,743	77,071	86,252	96,346	107,416	119,534	132,775	147,219	162,955	180,078	191,949	204,424	217,536	231,321	245,820
Operation, Maintenance and General Expenses																						
New O & M Expenses	0	1,247	1,490	1,778	2,129	2,516	2,944	3,415	3,948	4,560	1,068	1,089	1,168	1,342	1,581	1,860	2,171	2,562	3,129	3,861	4,706	3,087
Fuel	5,348	7,436	8,478	10,255	12,592	15,149	17,741	20,010	22,784	26,088	14	50	438	1,398	2,746	4,310	6,066	8,381	11,853	16,976	22,559	6,214
A & G Expenses	2,795	3,929	4,415	4,975	5,607	6,313	7,101	7,975	8,941	10,006	11,177	12,461	13,867	15,403	17,079	18,904	20,891	22,268	23,715	25,236	26,835	28,517
Payroll Expenses (Admin. & Gen. And Oper. & Maint.)	3,171	4,458	5,009	5,645	6,361	7,163	8,057	9,048	10,144	11,353	12,681	14,138	15,733	17,476	19,377	21,449	23,702	25,265	26,907	28,633	30,447	32,356
Depreciation and Amortization	824	807	3,031	3,902	4,925	5,936	7,265	9,488	11,188	12,653	13,948	17,632	18,049	18,044	18,194	17,923	17,712	17,922	17,901	18,839	19,336	20,357
Others	2,322	15,459	16,028	16,608	17,126	17,659	18,185	18,711	19,141	19,429	14,726	17,172	20,159	21,397	22,579	23,770	24,165	26,234	27,325	28,169	28,701	14,657
Total Operation, Maintenance and General Expenses	14,460	33,336	38,451	43,164	48,740	54,737	61,293	68,647	76,146	84,089	53,615	62,543	69,415	75,060	81,556	88,215	94,707	102,633	110,829	121,714	132,584	105,188
Operating Profit	9,633	535	-394	-275	-409	-314	-82	96	925	2,164	42,731	44,873	50,120	57,715	65,663	74,740	85,371	89,317	93,595	95,822	98,736	140,632
Other Income and Expenses																						
Other Income																						
Interest Income	0	141	21	0	0	0	0	0	0	0	0	0	0	68	1,200	2,405	3,769	5,358	6,955	8,539	10,101	11,403
Other Income	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	141	21	0	0	0	0	0	0	0	0	0	0	68	1,200	2,405	3,769	5,358	6,955	8,539	10,101	11,403
Other Expenses																						
Interest Expense	1,749	1,632	1,873	2,356	3,466	4,617	5,990	8,195	10,016	11,512	14,442	17,380	16,853	14,404	14,160	13,336	12,629	12,222	11,572	11,651	11,088	11,009
Other Expense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1,749	1,632	1,873	2,356	3,466	4,617	5,990	8,195	10,016	11,512	14,442	17,380	16,853	14,404	14,160	13,336	12,629	12,222	11,572	11,651	11,088	11,009
Net Income before Tax	7,884	-956	-2,245	-2,631	-3,875	-4,931	-6,072	-8,099	-9,091	-9,348	28,289	27,493	33,266	43,379	52,704	63,810	76,511	82,453	88,978	92,710	97,750	141,026
Income Tax	2,208	0	0	0	0	0	0	0	0	0	7,921	7,698	9,315	12,146	14,757	17,867	21,423	23,087	24,914	25,959	27,370	39,487
Net Income after Tax	5,677	-956	-2,245	-2,631	-3,875	-4,931	-6,072	-8,099	-9,091	-9,348	20,368	19,795	23,952	31,233	37,947	45,943	55,088	59,366	64,064	66,751	70,380	101,538
Retained Earnings at Beginning	0	5,109	3,737	1,343	-1,289	-5,164	-10,095	-16,167	-24,265	-33,356	-42,704	-22,336	-2,541	19,270	45,452	75,059	108,902	147,591	186,262	225,293	262,840	299,898
(Dividends)	568	415	149	0	0	0	0	0	0	0	0	0	2,141	5,050	8,340	12,100	16,399	20,696	25,033	29,204	33,322	40,144
Retained Earnings at End	5,109	3,737	1,343	-1,289	-5,164	-10,095	-16,167	-24,265	-33,356	-42,704	-22,336	-2,541	19,270	45,452	75,059	108,902	147,591	186,262	225,293	262,840	299,898	361,292
<Cashflow>																						
Cashflow from Operating Activities																						
Net Income	5,677	-956	-2,245	-2,631	-3,875	-4,931	-6,072	-8,099	-9,091	-9,348	20,368	19,795	23,952	31,233	37,947	45,943	55,088	59,366	64,064	66,751	70,380	101,538
Depreciation	824	807	3,031	3,902	4,925	5,936	7,265	9,488	11,188	12,653	13,948	17,632	18,049	18,044	18,194	17,923	17,712	17,922	17,901	18,839	19,336	20,357
Operating Assets (Increase)/Decrease		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cashflow from Investing Activities																						
Construction Expenditures/Sales of Assets	-4,652	-29,199	-28,128	-22,928	-23,584	-27,016	-36,228	-64,337	-97,253	-93,493	-44,537	-15,200	-13,600	-9,600	-2,100	-2,100	-2,000	-4,416	-50,404	-93,781	-100,405	-36,880
Cashflow from Financing Activities																						
Long-term Borrowing	4,652	29,199	28,128	22,928	23,584	27,016	36,228	64,337	97,253	93,493	44,537	15,200	13,600	9,600	2,100	2,100	2,000	4,416	50,404	93,781	100,405	36,880
Repayment	-2,416	-2,416	-2,416	-2,416	-2,416	-2,416	-2,582	-2,978	-4,383	-15,972	-30,343	-30,334	-26,126	-15,921	-17,675	-17,675	-16,674	-16,674	-17,331	-17,331	-23,840	-24,169
Capital/Grant																						
Dividend	-568	-415	-149	0	0	0	0	0	0	0	0	0	-2,141	-5,050	-8,340	-12,100	-16,399	-20,696	-25,033	-29,204	-33,322	-40,144
Net Increase (Decrease)	3,517	-2,981	-1,780	-1,145	-1,366	-1,411	-1,388	-1,589	-2,286	-12,667	3,973	7,094	13,734	28,306	30,126	34,090	39,727	39,918	39,601	39,055	32,554	57,583
Cash at Beginning		3,517	536	-1,243	-2,389	-3,755	-5,166	-6,554	-8,142	-10,429	-23,095	-19,122	-12,028	1,705	30,011	60,137	94,227	133,953	173,872	213,473	252,528	285,082
Cash at End	3,517	536	-1,243	-2,389	-3,755	-5,166	-6,554	-8,142	-10,429	-23,095	-19,122	-12,028	1,705	30,011	60,137	94,227	133,953	173,872	213,473	252,528	285,082	342,664
IRR (22years) 12.1% Cashflow	5,805	-27,857	-25,491	-19,301	-19,068	-21,394	-29,045	-54,753	-85,140	-78,676	12,142	47,306	54,568	66,158	81,757	90,563	101,083	102,823	61,092	20,880	17,668	622,455
NPV 10.0% 41,393	5,805	-24,850	-20,285	-13,701	-12,075	-12,085	-14,636	-24,613	-34,142	-28,145	3,875	13,466	13,857	14,987	16,521	16,326	16,255	14,750	7,818	2,384	1,799	56,544
DSCR	0.43	7.57	-10.89	-17.34	-14.37	-22.39	-104.53	116.10	15.56	12.70	1.05	1.06	0.86	0.53	0.48	0.41	0.34	0.32	0.31	0.30	0.35	0.25
Turnover :				42,889	48,330	54,423	61,211	68,743	77,071	86,252	96,346	107,416	119,534	132,775	147,219	162,955	180,078	191,949	204,424	217,536	231,321	245,820
Gross Int. Cov. :				5.5%	7.2%	8.5%	9.8%	11.9%	13.0%	13.3%	15.0%	16.2%	14.1%	10.8%	9.6%	8.2%	7.0%	6.4%	5.7%	5.4%	4.8%	4.5%
Fixed Charges Cov. :				(0.1)	(0.1)	(0.1)	(0.0)	0.0	0.1	0.2	3.0	2.6	3.0	4.0	4.7	5.8	7.1	7.7	8.7	9.0	9.8	13.8
RCF % TD :				1.3%	0.9%	0.7%	0.7%	0.7%	0.9%	1.2%	7.5%	8.2%	9.2%	10.4%	11.7%	13.3%	14.8%	15.5%	15.6%	16.0%	16.3%	14.2%
Op. Margin :				-0.6%	-0.8%	-0.6%	-0.1%	0.1%	1.2%	2.5%	44.4%	41.8%	41.9%	43.5%	44.6%	45.9%	47.4%	46.5%	45.8%	44.0%	42.7%	57.2%
EBITDA Cov. :				1.5	1.3	1.2	1.2	1.2	1.2	1.3	3.9	3.6	4.0	5.3	6.0	7.1	8.5	9.2	10.2	10.6	11.6	15.7
EBIT % Capital :				-0.3%	-0.4%	-0.2%	-0.1%	0.1%	0.5%	0.9%	9.9%	9.8%	11.1%	12.3%	13.8%	15.5%	16.9%	17.2%	17.0%	17.0%	16.9%	16.3%
ROA % after Tax :				-3.7%	-4.5%	-4.8%	-4.8%	-5.3%	-5.2%	-5.1%	7.5%	5.4%	6.5%	8.4%	9.7%	11.4%	12.9%	13.1%	13.3%	13.0%	13.0%	14.5%
ROE % after Tax :				-9502.6%	120.1%	64.6%	46.2%	40.1%	31.6%	24.6%	-62.6%	-159.2%	286.3%	96.5%	63.0%	49.9%	43.0%	35.6%	31.1%	27.3%	25.0%	30.7%
Pretax Int. Cov. :				(0.1)	(0.1)	(0.1)	(0.0)	0.0	0.1	0.2	3.0	2.6	3.0	4.0	4.7	5.8	7.1	7.7	8.7	9.0	9.8	13.8
RCF % Invest. Activities :				6%	4%	4%	3%	2%	2%	4%	77%	246%	293%	461%	2276%	2465%	2820%	1282%	113%	60%	56%	222%
Invest. Activities % Cap. :				24.2%	21.5%	20.9%	22.1%	34.1%	47.4%	40.8%	10.3%	3.3%	3.0%	2.0%	0.4%	0.4%	0.4%	0.8%	8.5%	15.3%	15.6%	3.9%
Dividend Payout :				0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.9%	16.2%	22.0%	26.3%	29.8%	34.9%	39.1%	43.8%	47.3%	39.5%
TD % Cap. :				101.4%	104.7%	107.8%	109.9%	112.8%	116.3%	118.6%	105.2%	100.6%	95.7%	90.4%	84.5%	78.2%	72.1%	66.2%	61.8%	57.2%	53.5%	61.4%
Equity % Cap. :				-1.4%	-4.7%	-7.8%	-9.9%	-12.8%	-16.3%	-18.6%	-5.2%	-0.6%	4.3%	9.6%	15.5%	21.8%	27.9%	33.8%	38.2%	42.8%	46.5%	38.6%
Tot. Cap. :				94,565	109,524	129,144	163,867	188,929	205,086	229,011	433,261	455,815	451,334	471,280	483,046	499,048	528,322	551,808	589,767	614,785	645,089	935,389
Total Demand (GWh)	249	266	285	307	330	356	384	413	445	479	514	552	592	635	679	726	776	828	884	942	1,003	1,068
Average Rate (UScents/kWh)		27.6	27.6	27.6	27.5	27.5	27.5	27.5	27.4	27.4	27.3	27.3	27.3	27.2	27.2	27.1	27.1	26.1	26.0	26.0	26.0	25.9

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Table 8.4-2 Financial Estimate of the NPA (Alternative Case: Thermal Power Dominant)

(Unit: US$ 1,000)

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
US$= Le 3179	Total																						
Bumbuna c/kWh 7.0	<Assets>																						
Household c/kWh 27.0	Utility Plant	9,903	51,102	65,501	82,227	96,786	115,905	149,268	173,780	191,893	205,140	192,848	213,253	235,759	230,211	231,131	229,562	262,232	255,610	272,636	265,902	260,796	278,074
Comm. c/kWh 40.6	Capital Lease																						
Indust. c/kWh 27.7	Investment & Other Assets																						
Indust. c/kW 42.6	Current Assets																						
Increase rate 155%	Accounts Receivables																						
Interest: 4.0%	Cash and Cash Equivalent	3,517	2,736	3,578	5,506	8,092	11,567	16,110	21,927	28,369	35,964	44,147	52,025	60,433	69,162	79,579	93,610	112,535	128,936	146,510	162,423	178,156	193,032
	Total Assets	13,419	53,838	69,079	87,732	104,878	127,473	165,378	195,707	220,262	241,104	236,995	265,278	296,192	299,373	310,710	323,172	374,767	384,546	419,146	428,324	438,952	471,107
	<Capital>																						
	Capital	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Retained Earnings	5,109	5,937	6,164	6,606	6,683	6,638	6,497	5,804	5,441	5,926	7,409	12,493	19,554	27,500	38,573	52,536	70,816	87,285	105,192	121,377	137,623	155,013
	Total	5,110	5,938	6,165	6,606	6,684	6,639	6,498	5,805	5,442	5,927	7,409	12,493	19,555	27,500	38,573	52,536	70,817	87,286	105,193	121,378	137,624	155,014
	<Liabilities>																						
Interest: 15.0%	Short Term Debt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Long Term Debt	36,240	59,615	74,793	93,465	110,933	134,073	173,480	205,052	228,014	248,620	242,863	269,967	294,033	289,453	289,692	288,165	316,647	309,931	327,046	320,014	314,371	329,558
	Total Capital and Liabilities	41,350	65,553	80,957	100,071	117,617	140,711	179,978	210,857	233,456	254,546	250,272	282,461	313,589	316,953	328,265	340,702	387,464	397,217	432,239	441,392	451,995	484,571
	<Profit and Loss>																						
	Revenue																						
	Sale	21,903	34,928	39,215	44,157	49,727	55,967	62,922	70,642	79,181	88,597	98,952	110,312	122,752	136,349	151,188	167,362	184,970	197,195	210,052	223,578	237,813	252,801
	Other	2,190	3,493	3,921	4,416	4,973	5,597	6,292	7,064	7,918	8,860	9,895	11,031	12,275	13,635	15,119	16,736	18,497	19,719	21,005	22,358	23,781	25,280
	Total Revenue	24,093	38,421	43,136	48,572	54,700	61,563	69,214	77,706	87,099	97,457	108,847	121,344	135,027	149,984	166,307	184,098	203,468	216,914	231,058	245,936	261,594	278,081
	Operation, Maintenance and General Expenses																						
	New O & M Expenses	0	1,247	1,490	1,778	2,129	2,516	2,944	3,415	3,948	4,560	5,212	5,927	6,746	7,594	8,498	9,446	10,452	11,497	12,613	13,780	15,014	16,319
	Fuel	5,348	7,440	8,480	10,261	12,600	15,176	17,771	20,032	22,802	26,104	30,594	34,641	37,758	43,515	48,987	54,760	59,166	65,616	70,806	78,189	86,171	92,800
	A & G Expenses	2,795	4,457	5,004	5,635	6,346	7,142	8,029	9,015	10,104	11,306	12,627	14,077	15,664	17,399	19,293	21,357	23,604	25,164	26,805	28,531	30,347	32,260
	Payroll Expenses (Admin. & Gen. And Oper. & Maint.)	3,171	5,057	5,678	6,393	7,200	8,103	9,110	10,228	11,464	12,828	14,327	15,972	17,773	19,741	21,890	24,232	26,781	28,551	30,413	32,371	34,432	36,602
	Depreciation and Amortization	824	807	3,031	3,902	4,925	5,936	7,265	9,488	11,188	12,653	13,948	14,006	15,444	16,704	17,020	17,852	18,580	20,422	20,925	22,190	23,046	23,984
	Others	2,322	15,856	16,423	16,944	17,474	17,999	18,535	19,009	19,339	19,606	19,397	18,809	18,809	18,809	18,809	18,809	18,809	18,809	18,809	18,809	18,809	18,809
	Total Operation, Maintenance and General Expenses	14,460	34,863	40,106	44,913	50,673	56,872	63,655	71,187	78,845	87,056	96,106	103,432	112,194	123,762	134,497	146,456	157,392	170,060	180,370	193,870	207,818	220,773
	Operating Profit	9,633	3,558	3,030	3,659	4,027	4,691	5,559	6,519	8,254	10,400	12,741	17,912	22,834	26,222	31,810	37,643	46,075	46,855	50,687	52,066	53,776	57,307
	Other Income and Expenses																						
	Other Income																						
	Interest Income	0	141	109	143	220	324	463	644	877	1,135	1,439	1,766	2,081	2,417	2,766	3,183	3,744	4,501	5,157	5,860	6,497	7,126
	Other Income	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	141	109	143	220	324	463	644	877	1,135	1,439	1,766	2,081	2,417	2,766	3,183	3,744	4,501	5,157	5,860	6,497	7,126
	Other Expenses																						
	Interest Expense	1,749	1,632	1,873	2,170	3,108	4,054	5,215	7,212	8,795	9,947	10,977	10,689	12,089	13,360	13,245	13,325	13,502	15,012	14,740	16,717	16,471	16,359
	Other Expense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	1,749	1,632	1,873	2,170	3,108	4,054	5,215	7,212	8,795	9,947	10,977	10,689	12,089	13,360	13,245	13,325	13,502	15,012	14,740	16,717	16,471	16,359
	Net Income before Tax	7,884	2,066	1,267	1,633	1,139	961	807	-48	336	1,588	3,202	8,989	12,826	15,279	21,331	27,501	36,318	36,344	41,104	41,210	43,802	48,074
Tax Rate: 28.0%	Income Tax	2,208	579	355	457	319	269	226	0	94	445	897	2,517	3,591	4,278	5,973	7,700	10,169	10,176	11,509	11,539	12,264	13,461
	Net Income after Tax	5,677	1,488	912	1,175	820	692	581	-48	242	1,143	2,306	6,472	9,235	11,001	15,359	19,801	26,149	26,168	29,595	29,671	31,537	34,613
	Retained Earnings at Beginning	0	5,109	5,937	6,164	6,606	6,683	6,638	6,497	5,804	5,441	5,926	7,409	12,493	19,554	27,500	38,573	52,536	70,816	87,285	105,192	121,377	137,623
Dividend Ratio: 10.0%	(Dividends)	568	660	685	734	743	738	722	645	605	658	823	1,388	2,173	3,056	4,286	5,837	7,868	9,698	11,688	13,486	15,291	17,224
	Retained Earnings at End	5,109	5,937	6,164	6,606	6,683	6,638	6,497	5,804	5,441	5,926	7,409	12,493	19,554	27,500	38,573	52,536	70,816	87,285	105,192	121,377	137,623	155,013
	<Cashflow>																						
	Cashflow from Operating Activities																						
	Net Income	5,677	1,488	912	1,175	820	692	581	-48	242	1,143	2,306	6,472	9,235	11,001	15,359	19,801	26,149	26,168	29,595	29,671	31,537	34,613
	Depreciation	824	807	3,031	3,902	4,925	5,936	7,265	9,488	11,188	12,653	13,948	14,006	15,444	16,704	17,020	17,852	18,580	20,422	20,925	22,190	23,046	23,984
	Operating Assets (Increase)/Decrease		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cashflow from Investing Activities																						
	Construction Expenditures/Sales of Assets	-4,652	-29,199	-28,128	-22,928	-23,584	-27,016	-36,228	-35,900	-30,900	-27,140	-20,516	-37,142	-43,960	-14,016	-20,040	-23,214	-35,948	-18,630	-33,120	-15,456	-22,770	-33,672
	Cashflow from Financing Activities																						
	Borrowing	4,652	29,199	28,128	22,928	23,584	27,016	36,228	35,900	30,900	27,140	20,516	37,142	43,960	14,016	20,040	23,214	35,948	18,630	33,120	15,456	22,770	33,672
	Repayment	-2,416	-2,416	-2,416	-2,416	-2,416	-2,416	-2,582	-2,978	-4,383	-5,543	-7,247	-11,212	-14,098	-15,921	-17,675	-17,786	-17,935	-20,490	-21,257	-22,463	-23,558	-26,498
	Capital/Grant																						
	Dividend	-568	-660	-685	-734	-743	-738	-722	-645	-605	-658	-823	-1,388	-2,173	-3,056	-4,286	-5,837	-7,868	-9,698	-11,688	-13,486	-15,291	-17,224
	Net Increase (Decrease)	3,517	-781	842	1,928	2,587	3,475	4,543	5,817	6,442	7,594	8,183	7,878	8,408	8,728	10,418	14,030	18,925	16,401	17,574	15,912	15,734	14,876
	Cash at Beginning		3,517	2,736	3,578	5,506	8,092	11,567	16,110	21,927	28,369	35,964	44,147	52,025	60,433	69,162	79,579	93,610	112,535	128,936	146,510	162,423	178,156
	Cash at End	3,517	2,736	3,578	5,506	8,092	11,567	16,110	21,927	28,369	35,964	44,147	52,025	60,433	69,162	79,579	93,610	112,535	128,936	146,510	162,423	178,156	193,032
	IRR (22years) 10.7% Cashflow	5,805	-24,834	-22,067	-15,367	-14,632	-16,389	-23,404	-19,893	-11,458	-4,087	6,173	-5,224	-5,682	28,910	28,790	32,281	28,707	48,647	38,492	58,800	54,052	325,694
	NPV (10%) 8,778	5,805	-22,576	-18,237	-11,545	-9,994	-10,176	-13,211	-10,208	-5,345	-1,733	2,380	-1,831	-1,811	8,374	7,581	7,728	6,248	9,625	6,923	9,614	8,034	44,011
	DSCR	0.43	1.14	1.42	1.25	1.37	1.38	1.40	1.56	1.60	1.49	1.43	1.22	1.15	1.12	0.97	0.83	0.68	0.76	0.71	0.75	0.74	0.75
	Turnover :				48,572	54,700	61,563	69,214	77,706	87,099	97,457	108,847	121,344	135,027	149,984	166,307	184,098	203,468	216,914	231,058	245,936	261,594	278,081
	Gross Int. Cov. :				4.5%	5.7%	6.6%	7.5%	9.3%	10.1%	10.2%	10.1%	8.8%	9.0%	8.9%	8.0%	7.2%	6.6%	6.9%	6.4%	6.8%	6.3%	5.9%
	Fixed Charges Cov. :				1.8	1.4	1.2	1.2	1.0	1.0	1.2	1.3	1.8	2.1	2.1	2.6	3.1	3.7	3.4	3.8	3.5	3.7	3.9
	RCF % TD :				4.6%	4.5%	4.4%	4.1%	4.3%	4.7%	5.3%	6.4%	7.1%	7.7%	8.5%	9.7%	11.0%	11.6%	11.9%	11.9%	12.0%	12.5%	12.6%
	Op. Margin :				7.5%	7.4%	7.6%	8.0%	8.4%	9.5%	10.7%	11.7%	14.8%	16.9%	17.5%	19.1%	20.4%	22.6%	21.6%	21.9%	21.2%	20.6%	20.6%
	EBITDA Cov. :				3.6	3.0	2.7	2.5	2.3	2.3	2.4	2.6	3.2	3.3	3.4	3.9	4.4	5.1	4.8	5.2	4.8	5.1	5.4
	EBIT % Capital :				3.8%	3.6%	3.6%	3.3%	3.4%	3.9%	4.5%	5.7%	7.0%	7.9%	9.0%	10.5%	12.0%	12.9%	12.9%	12.9%	13.1%	13.3%	13.3%
	ROA % after Tax :				1.5%	0.9%	0.6%	0.4%	0.0%	0.1%	0.5%	1.0%	2.6%	3.3%	3.7%	5.0%	6.2%	7.5%	6.9%	7.4%	7.0%	7.3%	7.6%
	ROE % after Tax :				18.4%	12.3%	10.4%	8.8%	-0.8%	4.3%	20.1%	34.6%	65.0%	57.6%	46.8%	46.5%	43.5%	42.4%	33.1%	30.8%	26.2%	24.4%	23.7%
	Pretax Int. Cov. :				1.8	1.4	1.2	1.2	1.0	1.0	1.2	1.3	1.8	2.1	2.1	2.6	3.1	3.7	3.4	3.8	3.5	3.7	3.9
	RCF % Invest. Activities :				19%	21%	22%	20%	24%	35%	48%	75%	51%	51%	176%	140%	137%	103%	198%	117%	248%	173%	123%
	Invest. Activities % Cap. :				22.9%	20.1%	19.2%	20.1%	17.0%	13.2%	10.7%	8.2%	13.1%	14.0%	4.4%	6.1%	6.8%	9.3%	4.7%	7.7%	3.5%	5.0%	6.9%
	Dividend Payout :				62.4%	90.5%	106.6%	124.2%	-1332.9%	249.8%	57.6%	35.7%	21.4%	23.5%	27.8%	27.9%	29.5%	30.1%	37.1%	39.5%	45.5%	48.5%	49.8%
	TD % Cap. :				93.4%	94.3%	95.3%	96.4%	97.2%	97.7%	97.7%	97.0%	95.6%	93.8%	91.3%	88.2%	84.6%	81.7%	78.0%	75.7%	72.5%	69.6%	68.0%
	Equity % Cap. :				6.6%	5.7%	4.7%	3.6%	2.8%	2.3%	2.3%	3.0%	4.4%	6.2%	8.7%	11.8%	15.4%	18.3%	22.0%	24.3%	27.5%	30.4%	32.0%
	Tot. Cap. :				100,071	117,617	140,711	179,978	210,857	233,456	254,546	250,272	282,461	313,589	316,953	328,265	340,702	387,464	397,217	432,239	441,392	451,995	484,571
	Total Demand (GWh)	249	266	285	307	330	356	384	413	445	479	514	552	592	635	679	726	776	828	884	942	1,003	1,068
	Average Rate (UScents/kWh)		29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.7	29.7	29.7	29.7	29.6	29.6	29.6	29.6	29.5	29.5	29.4	29.4	29.3	29.3

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Table 8.4-3 Financial Estimate of the NPA (Yiben IPP Case)

(Unit: US$ 1,000)

US$= Le	3179
Bumbuna c/kWh	7.0
Household c/kWh	23.5
Comm. c/kWh	35.4
Indust. c/kWh	27.7
Indust. c/kW	42.6
Increase rate	135%
Interest:	4.0%
Interest:	15.0%
Tax Rate:	28.0%
Dividend Ratio:	10.0%

year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total											
<Assets>											
Utility Plant	9,903	51,102	65,501	82,227	96,786	115,905	149,268	173,780	191,893	205,140	191,192
Capital Lease											
Investment & Other Assets											
Current Assets											
Accounts Receivables											
Cash and Cash Equivalent	3,517	1,152	21	-183	-261	-73	508	1,271	1,766	2,848	18,527
Total Assets	13,419	52,254	65,522	82,043	96,525	115,833	149,776	175,051	193,659	207,989	209,719
<Capital>											
Capital	1	1	1	1	1	1	1	1	1	1	1
Retained Earnings	5,109	4,354	2,607	917	-1,669	-5,002	-9,105	-14,852	-21,162	-27,189	-18,211
Total	5,110	4,354	2,608	917	-1,669	-5,001	-9,105	-14,851	-21,161	-27,188	-18,210
<Liabilities>											
Short Term Debt	0	0	0	183	261	73	0	0	0	0	0
Long Term Debt	36,240	59,615	74,793	93,465	110,933	134,073	173,480	205,052	228,014	248,620	241,207
Total Capital and Liabilities	41,350	63,969	77,400	94,565	109,524	129,144	164,375	190,201	206,852	221,431	222,996
<Profit and Loss>											
Revenue											
Sale	21,903	31,619	35,521	40,023	45,095	50,773	57,101	64,123	71,888	80,448	89,860
Other	2,190	3,162	3,552	4,002	4,509	5,077	5,710	6,412	7,189	8,045	8,986
Total Revenue	24,093	34,781	39,073	44,025	49,604	55,851	62,811	70,536	79,077	88,493	98,846
Operation, Maintenance and General Expenses											
New O & M Expenses	0	1,247	1,490	1,778	2,129	2,516	2,944	3,415	3,948	4,560	183
Fuel	5,348	7,436	8,478	10,255	12,592	15,149	17,741	20,010	22,784	26,088	14
A & G Expenses	2,795	4,035	4,533	5,107	5,755	6,479	7,287	8,183	9,174	10,266	11,467
Payroll Expenses (Admin. & Gen. And Oper. & Maint.)	3,171	4,578	5,143	5,795	6,529	7,351	8,267	9,284	10,408	11,648	13,010
Depreciation and Amortization	824	807	3,031	3,902	4,925	5,936	7,265	9,488	11,188	12,653	13,948
Others	2,322	15,459	16,028	16,608	17,126	17,659	18,185	18,711	19,141	19,429	36,891
Total Operation, Maintenance and General Expenses	14,460	33,561	38,703	43,445	49,055	55,090	61,689	69,091	76,643	84,644	75,513
Operating Profit	9,633	1,220	370	580	549	760	1,122	1,445	2,434	3,850	23,333
Other Income and Expenses											
Other Income											
Interest Income	0	141	46	1	0	0	0	20	51	71	114
Other Income	0	0	0	0	0	0	0	0	0	0	0
Total	0	141	46	1	0	0	0	20	51	71	114
Other Expenses											
Interest Expense	1,749	1,632	1,873	2,170	3,135	4,093	5,226	7,212	8,795	9,947	10,977
Other Expense	0	0	0	0	0	0	0	0	0	0	0
Total	1,749	1,632	1,873	2,170	3,135	4,093	5,226	7,212	8,795	9,947	10,977
Net Income before Tax	7,884	-272	-1,457	-1,589	-2,586	-3,332	-4,103	-5,747	-6,310	-6,027	12,469
Income Tax	2,208	0	0	0	0	0	0	0	0	0	3,491
Net Income after Tax	5,677	-272	-1,457	-1,589	-2,586	-3,332	-4,103	-5,747	-6,310	-6,027	8,978
Retained Earnings at Beginning	0	5,109	4,354	2,607	917	-1,669	-5,002	-9,105	-14,852	-21,162	-27,189
(Dividends)	568	484	290	102	0	0	0	0	0	0	0
Retained Earnings at End	5,109	4,354	2,607	917	-1,669	-5,002	-9,105	-14,852	-21,162	-27,189	-18,211
<Cashflow>											
Cashflow from Operating Activities											
Net Income	5,677	-272	-1,457	-1,589	-2,586	-3,332	-4,103	-5,747	-6,310	-6,027	8,978
Depreciation	824	807	3,031	3,902	4,925	5,936	7,265	9,488	11,188	12,653	13,948
Operating Assets (Increase)/Decrease		0	0	0	0	0	0	0	0	0	0
Cashflow from Investing Activities											
Construction Expenditures/Sales of Assets	-4,652	-29,199	-28,128	-22,928	-23,584	-27,016	-36,228	-35,900	-30,900	-27,140	-16,100
Cashflow from Financing Activities											
Long-term Borrowing	4,652	29,199	28,128	22,928	23,584	27,016	36,228	35,900	30,900	27,140	16,100
Repayment	-2,416	-2,416	-2,416	-2,416	-2,416	-2,416	-2,582	-2,978	-4,383	-5,543	-7,247
Capital/Grant											
Dividend	-568	-484	-290	-102	0	0	0	0	0	0	0
Net Increase (Decrease)	3,517	-2,364	-1,131	-205	-77	188	580	764	495	1,082	15,679
Cash at Beginning		3,517	1,152	21	-183	-261	-73	508	1,271	1,766	2,848
Cash at End	3,517	1,152	21	-183	-261	-73	508	1,271	1,766	2,848	18,527
IRR (22years) 13.8% Cashflow	5,805	-27,172	-24,727	-18,446	-18,110	-20,319	-27,841	-24,967	-17,278	-10,637	21,181
NPV (10%) 53,663	5,805	-24,239	-19,677	-13,094	-11,468	-11,478	-14,030	-11,223	-6,929	-3,805	6,759
DSCR	0.43	3.32	11.58	7.91	10.11	8.56	6.96	7.05	5.41	4.02	0.78
Turnover :				44,025	49,604	55,851	62,811	70,536	79,077	88,493	98,846
Gross Int. Cov. :				4.9%	6.3%	7.3%	8.3%	10.2%	11.1%	11.2%	11.1%
Fixed Charges Cov. :				0.3	0.2	0.2	0.2	0.2	0.3	0.4	2.1
RCF % TD :				2.4%	2.1%	1.9%	1.8%	1.8%	2.1%	2.7%	9.5%
Op. Margin :				1.3%	1.1%	1.4%	1.8%	2.0%	3.1%	4.4%	23.6%
EBITDA Cov. :				2.1	1.7	1.6	1.6	1.5	1.6	1.7	3.4
EBIT % Capital :				0.6%	0.5%	0.6%	0.7%	0.8%	1.2%	1.8%	10.5%
ROA % after Tax :				-2.2%	-2.9%	-3.1%	-3.1%	-3.5%	-3.4%	-3.0%	4.3%
ROE % after Tax :				-90.1%	688.2%	99.9%	58.2%	48.0%	35.0%	24.9%	-39.6%
Pretax Int. Cov. :				0.3	0.2	0.2	0.2	0.2	0.3	0.4	2.1
RCF % Invest. Activities :				10%	10%	10%	9%	10%	16%	24%	142%
Invest. Activities % Cap. :				24.2%	21.5%	20.9%	22.0%	18.9%	14.9%	12.3%	7.2%
Dividend Payout :				-6.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TD % Cap. :				99.0%	101.5%	103.9%	105.5%	107.8%	110.2%	112.3%	108.2%
Equity % Cap. :				1.0%	-1.5%	-3.9%	-5.5%	-7.8%	-10.2%	-12.3%	-8.2%
Tot. Cap. :				94,565	109,524	129,144	164,375	190,201	206,852	221,431	222,996
Total Demand (GWh)	249	266	285	307	330	356	384	413	445	479	514
Average Rate (UScents/kWh)		27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0

year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total											
<Assets>											
Utility Plant	194,650	180,393	175,641	161,238	147,107	145,659	132,901	134,792	124,429	125,713	108,863
Capital Lease											
Investment & Other Assets											
Current Assets											
Accounts Receivables											
Cash and Cash Equivalent	35,623	53,079	72,182	92,859	117,271	146,572	176,567	206,265	235,527	264,811	302,570
Total Assets	230,274	233,472	247,823	254,097	264,378	292,232	309,467	341,057	359,955	390,524	411,433
<Capital>											
Capital	1	1	1	1	1	1	1	1	1	1	1
Retained Earnings	-3,744	13,552	34,324	58,273	86,230	118,285	150,540	183,177	214,438	245,226	283,795
Total	-3,743	13,553	34,325	58,274	86,230	118,286	150,540	183,177	214,438	245,226	283,796
<Liabilities>											
Short Term Debt	0	0	0	0	0	0	0	0	0	0	0
Long Term Debt	251,059	236,796	230,560	212,719	194,878	185,463	170,279	169,206	156,677	156,433	138,607
Total Capital and Liabilities	247,316	250,349	264,885	270,993	281,108	303,749	320,819	352,384	371,116	401,659	422,403
<Profit and Loss>											
Revenue											
Sale	100,183	111,484	123,833	137,306	151,985	167,960	179,039	190,683	202,924	215,796	229,338
Other	10,018	11,148	12,383	13,731	15,199	16,796	17,904	19,068	20,292	21,580	22,934
Total Revenue	110,202	122,633	136,217	151,037	167,184	184,756	196,942	209,751	223,216	237,375	252,272
Operation, Maintenance and General Expenses											
New O & M Expenses	203	282	456	696	974	1,285	1,677	2,243	2,976	3,820	1,308
Fuel	50	438	1,398	2,746	4,310	6,066	8,381	11,853	16,976	22,559	6,214
A & G Expenses	12,784	14,226	15,802	17,522	19,395	21,433	22,847	24,333	25,895	27,538	29,266
Payroll Expenses (Admin. & Gen. And Oper. & Maint.)	14,505	16,141	17,929	19,880	22,005	24,318	25,922	27,608	29,380	31,244	33,205
Depreciation and Amortization	13,841	14,257	14,252	14,403	14,131	13,920	14,414	14,393	15,331	15,828	16,849
Others	38,860	41,455	43,856	46,169	48,517	50,925	53,218	55,120	56,652	58,021	71,424
Total Operation, Maintenance and General Expenses	80,243	86,801	93,694	101,414	109,332	117,948	126,460	135,550	147,211	159,009	158,266
Operating Profit	29,959	35,832	42,523	49,623	57,852	66,808	70,483	74,201	76,005	78,366	94,007
Other Income and Expenses											
Other Income											
Interest Income	741	1,425	2,123	2,887	3,714	4,691	5,863	7,063	8,251	9,421	10,592
Other Income	0	0	0	0	0	0	0	0	0	0	0
Total	741	1,425	2,123	2,887	3,714	4,691	5,863	7,063	8,251	9,421	10,592
Other Expenses											
Interest Expense	10,606	11,144	10,499	10,255	9,431	8,723	8,316	7,667	7,745	7,183	7,234
Other Expense	0	0	0	0	0	0	0	0	0	0	0
Total	10,606	11,144	10,499	10,255	9,431	8,723	8,316	7,667	7,745	7,183	7,234
Net Income before Tax	20,094	26,113	34,147	42,255	52,136	62,776	68,029	73,597	76,510	80,604	97,365
Income Tax	5,626	7,312	9,561	11,831	14,598	17,577	19,048	20,607	21,423	22,569	27,262
Net Income after Tax	14,467	18,802	24,586	30,424	37,538	45,198	48,981	52,990	55,088	58,035	70,103
Retained Earnings at Beginning	-18,211	-3,744	13,552	34,324	58,273	86,230	118,285	150,540	183,177	214,438	245,226
(Dividends)	0	1,506	3,814	6,475	9,581	13,143	16,727	20,353	23,826	27,247	31,533
Retained Earnings at End	-3,744	13,552	34,324	58,273	86,230	118,285	150,540	183,177	214,438	245,226	283,795
<Cashflow>											
Cashflow from Operating Activities											
Net Income	14,467	18,802	24,586	30,424	37,538	45,198	48,981	52,990	55,088	58,035	70,103
Depreciation	13,841	14,257	14,252	14,403	14,131	13,920	14,414	14,393	15,331	15,828	16,849
Operating Assets (Increase)/Decrease	0	0	0	0	0	0	0	0	0	0	0
Cashflow from Investing Activities											
Construction Expenditures/Sales of Assets	-15,200	-13,600	-9,600	-2,100	-2,100	-2,000	-4,416	-13,524	-7,728	-14,352	0
Cashflow from Financing Activities											
Long-term Borrowing	15,200	13,600	9,600	2,100	2,100	2,000	4,416	13,524	7,728	14,352	0
Repayment	-11,212	-14,098	-15,921	-17,675	-17,675	-16,674	-16,674	-17,331	-17,331	-17,331	-17,661
Capital/Grant											
Dividend	0	-1,506	-3,814	-6,475	-9,581	-13,143	-16,727	-20,353	-23,826	-27,247	-31,533
Net Increase (Decrease)	17,096	17,455	19,103	20,676	24,412	29,301	29,994	29,699	29,261	29,285	37,759
Cash at Beginning	18,527	35,623	53,079	72,182	92,859	117,271	146,572	176,567	206,265	235,527	264,811
Cash at End	35,623	53,079	72,182	92,859	117,271	146,572	176,567	206,265	235,527	264,811	302,570
IRR (22years) 13.8% Cashflow	28,599	36,489	47,175	61,925	69,883	78,728	80,481	75,070	83,608	79,842	219,719
NPV (10%) 53,663	8,141	9,266	10,687	12,514	12,598	12,660	11,545	9,607	9,544	8,131	19,960
DSCR	0.73	0.70	0.62	0.56	0.47	0.38	0.35	0.34	0.33	0.31	0.26
Turnover :	110,202	122,633	136,217	151,037	167,184	184,756	196,942	209,751	223,216	237,375	252,272
Gross Int. Cov. :	9.6%	9.1%	7.7%	6.8%	5.6%	4.7%	4.2%	3.7%	3.5%	3.0%	2.9%
Fixed Charges Cov. :	2.9	3.3	4.3	5.1	6.5	8.2	9.2	10.6	10.9	12.2	14.5
RCF % TD :	11.3%	13.3%	15.2%	18.0%	21.6%	24.8%	27.4%	27.8%	29.7%	29.8%	40.0%
Op. Margin :	27.2%	29.2%	31.2%	32.9%	34.6%	36.2%	35.8%	35.4%	34.1%	33.0%	37.3%
EBITDA Cov. :	4.2	4.6	5.6	6.5	8.0	9.8	10.9	12.5	12.9	14.4	16.8
EBIT % Capital :	12.4%	14.9%	16.9%	19.4%	21.9%	23.5%	23.8%	23.1%	22.7%	21.9%	24.8%
ROA % after Tax :	6.6%	8.1%	10.2%	12.1%	14.5%	16.2%	16.3%	16.3%	15.7%	15.5%	17.5%
ROE % after Tax :	-131.8%	383.3%	102.7%	65.7%	52.0%	44.2%	36.4%	31.8%	27.7%	25.3%	26.5%
Pretax Int. Cov. :	2.9	3.3	4.3	5.1	6.5	8.2	9.2	10.6	10.9	12.2	14.5
RCF % Invest. Activities :	186%	232%	365%	1826%	2004%	2299%	1057%	348%	603%	325%	#DIV/0!
Invest. Activities % Cap. :	6.1%	5.4%	3.6%	0.8%	0.7%	0.7%	1.4%	3.8%	2.1%	3.6%	0.0%
Dividend Payout :	0.0%	8.0%	15.5%	21.3%	25.5%	29.1%	34.1%	38.4%	43.3%	46.9%	45.0%
TD % Cap. :	101.5%	94.6%	87.0%	78.5%	69.3%	61.1%	53.1%	48.0%	42.2%	38.9%	32.8%
Equity % Cap. :	-1.5%	5.4%	13.0%	21.5%	30.7%	38.9%	46.9%	52.0%	57.8%	61.1%	67.2%
Tot. Cap. :	247,316	250,349	264,885	270,993	281,108	303,749	320,819	352,384	371,116	401,659	422,403
Total Demand (GWh)	552	592	635	679	726	776	828	884	942	1,003	1,068
Average Rate (UScents/kWh)	27.0	26.9	26.9	26.9	26.8	26.8	26.8	26.7	26.7	26.6	26.6

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Those financial estimate model calculation results can be summarized in Table 8-4-4.

Table 8.4-4 Financial Estimate Model Calculation Results

Case	Bumbuna price	System loss 09	Collection rate 09	Long-term liability	Tariff					NPV (10%) Mill. US$	DSCR
					Increase	Average	Domestic	Commercial	Industrial		
Hydro main	7 c/kWh	40%	70%	Existing	130%	27 c/kWh	23 c/kWh	34 c/kWh	28 c/kWh	41	0.25~116
	10 c/kWh	40%	70%	Existing	165%	31 c/kWh	29 c/kWh	43 c/kWh	28 c/kWh	74	0.21~62
	20 c/kWh	40%	70%	Existing	280%	48 c/kWh	49 c/kWh	73 c/kWh	28 c/kWh	180	0.14~8.3
	7 c/kWh	15%	95%	Existing	80%	19 c/kWh	14 c/kWh	21 c/kWh	28 c/kWh	5	0.38~16
	7 c/kWh	40%	70%	Transferred	115%	25 c/kWh	20 c/kWh	30 c/kWh	28 c/kWh	1	0~1.03
Thermal	7 c/kWh	40%	70%	Existing	155%	30 c/kWh	27 c/kWh	41 c/kWh	28 c/kWh	9	0.43~2.0
Yiben IPP	7 c/kWh	40%	70%	Existing	135%	27 c/kWh	24 c/kWh	35 c/kWh	28 c/kWh	54	0.26~11.6

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Thus, the Base Case is most desirable from the financial viewpoint. However, if Yiben is to be developed as IPP and purchase price can be as cheap as possible, Yiben IPP Case can be considered although tariff is 135% up and NPV (10%) is US$ 54 million.

8.4.3 Consideration of Long-run Marginal Cost

Long-run marginal costs of this project described above are much less than NPA tariffs which enable NPA to continue to manage financially as estimated above. Therefore, long-run marginal cost is different from financial needs. However, most industrial consumers use higher voltage than other consumers and industrial tariffs should reflect the less cost for high and middle voltage users than other users who should bear the distribution costs in long-run marginal cost calculation (8.2.2). (But, this is not necessarily concluded through calculation of long-run marginal cost.) However, the domestic users are poor in Sierra Leone and so the tariff structure is shifted to industrial consumers. Therefore, it is desirable that in the future industrial tariffs should be equal to or less than domestic user's although industrial tariffs are more expensive than other user's at present. In addition, recent study of the World Bank insists that the government subsidy to the NPA for households (NPA's deficits are covered by the government and so it is a kind of subsidy) is not necessarily useful for poor households but rich domestic users who use more electricity receive benefits.

8.5 Financial and Economic Analyses of Distribution Projects

The impacts of power development plan on NPA's finance were analyzed in relation to the tariffs in 8.4, but this section focuses on the distribution projects to which donors will pay attention instead of the whole power development plan and financial and economic effects are analyzed for each of the packaged projects of distribution development as follows.

8.5.1 Preconditions for Packaged Distribution Project Analysis

Packaged distribution projects were described in the distribution plan previously. Key indexes such as system loss, outage time, electrification rate and general household number and investment amounts by each package are described previously as well. In addition to these, preconditions necessary to calculate power demand of each package for financial and economic analyses are shown as follows.

a) Power demand of each project shows estimated annual electricity demand in the target year.
b) Household demand share on the whole is supposed to be 50% based on the 2008 record and average annual demand is used for each household's demand and new household demand as well.
c) A new 33 kV transformer substation is supposed to contribute to power demand at 50% of

peak demand in each distribution district.

d) Calculated power demand is annual.
e) Average annual increase of power demand is supposed to be 3~5% taking into account the Sierra Leone situation.
f) Transformers for distribution are supposed to renew low loss transformers of 25.8MVA within the whole 91.3MVA based on the record at the end of 2008 and distribution loss improvement is assumed 2% of the demand in each year.
g) Extension of 60/80MVA transformers at Freetown transformer substation in Phase-II-2 is considered to contribute to reducing outage time accompanied with reliability improvement, but it is not decided to consider the improvement because the estimated outage time is short at this point.
h) It is expected that extension of 33kV distribution line between Goderich and York town will contribute to electrification of some villages along the line so that it is decided that 20% of Goderich peak power demand is contribution to rural electrification.
i) Number of houses subject to the rural electrification (Phase-II-1 and Phase-III) is supposed to be 3,000 for each and new demand households by the extension are not included.
j) 3,000 new demand households are considered in the renewal of Goderich and Jui Districts in Phase-I-3.
k) Estimated annual power demand of each project is just for the completed year.

Furthermore, O&M costs of distribution and transformation are supposed to be 3% of initial investment amount. Based on these, power demand in each project completed year is shown in Table 8.5-1 Energy Consumption by Project. However, after the completed year, power demand is supposed to be proportional to economic growth rate.

8.5.2 Financial Analysis of Distribution Projects

The distribution projects are limited part of NPA projects and financial analysis separating generation has only limited meaning because it is not entire profit and loss. The entire account was analyzed in 8.4 previously and so financial analysis in this section shows the profit and loss extent of distribution projects, in particular, packaged projects in the total accounts.

The revenues of distribution are calculated multiplying the total revenues by distribution cost share (50.7%)[2] which can be derived from tentative calculation in the model and sharing the total distribution revenues among the projects with the shares of project power demand to the whole demand. Concerning costs, O&M costs are supposed to be 3% of initial investment costs and others such as administration costs of distribution in the model are divided with the shares of project power demand to the whole demand.

Construction time period of each project is supposed to be one year and cash flow is calculated for 20 years from the construction year so that IRR (Internal Rate of Return) can be obtained. Since the account is partial, it may be minus (loss) or IRR cannot be calculated. In addition, 20 years may be beyond 2030 which is the final year of the model depending on the construction year. In that case, increase rates of 2030 are used to extend the revenues and expenditures.

The average tariff, 27 cents/kWh (22.6 cents/kWh for household, 34.1 cents/kWh for commercial users and 27.7 cents/kWh for industrial users), that is 130% increase of the old tariffs, in the standard hydro main case with 7cents/kWh as purchase price from Bumbuna hydro power is used as income.
Based on these conditions, the calculated results are shown in Table 8.5-2. Cash flows of all the distribution projects are minus and IRRs cannot be obtained.

[2] Bumbuna power purchase cost is calculated on the generation side in the long-run marginal cost calculation, but it is calculated on the distribution side in this section.

8.5.3 Economic Analysis of Distribution Projects

While the costs in the benefit/ cost analysis of each distribution project are the same as those in 8.5.2, namely investment cost and expenditures, the benefits are not revenues but economic benefits. Considering what the economic benefit of distribution project is, it is defined as satisfaction or utility of users obtaining electricity in this section. Concretely, the benefit is considered to be the cost which users pay

Table 8.5-1 Energy Consumption by Project

No.	Title of the Project	Major Components	Funded by	Target Year	Cost (10^6US$)	Expected Energy Consumption at Target Year [GWh]
A:	**Phase-I (from 2010 to 2015)**					
1	Rehabilitation of 11 kV and Improvement of 33 kV System	1) Improvement of 33 kV system of Kingtom P/S 2) Improvement of 33 kV system from Kingtom to Blackhall Road P/S 3) Construction of Falconbridge S/S 4) Rehabilitation of 11 kV system		2012	25.6	**28.7**
2	Improvement of 33 kV System in Goderich and Jui Area	1) Installation of 33 kV line (about 20 km) 2) Construction of Goderich and Jui S/S 3) Improvement of 11 kV existing lines		2014	35.4	**9.4**
3	Improvement of 11 kV Distribution Facil	1) Replacement of 11 kV transformer more than 40 years 2) Replacement of 11 kV transformers more than 30 years 3) Rehabilitation of existing 11 kV system 4) Electrification around Goderich and Jui S/S		2015	32.0	**2.3**
3		**Sub-total**			**93.0**	
B:	**Phase-II (from 2016 to 2020)**					
1	Improvement of 33 kV System	1) Construction of 33 kV line (about 32 km) 2) Construction of Lumpa and Tombo S/S 3) Rural electrification around Lumpa and Tombo S/S		2017	33.7	**7.2**
2	Expansion of 33 kV System and Improvement of Network	1) 1-161/33 kV Trf. (60/80 MVA, OLTC with AVR) 2) 33 kV line from Goderich S/S to York town (29 km) 3) Rehabilitation of trunk lines and rural electrification		2020	31.4	**4.1**
2		**Sub-total**			**65.1**	
C:	**Phase-III (from 2021 to 2025)**					
1	Improvement of Distribution Network	1) Expansion of 33 kV system 2) Rural electrification 3) Power Purchase Agreement to the neighboring country		2025	16.3	**0.9**
1		**Sub-total**			**16.3**	
		Grand Total			**174.4**	

Table 8.5-2 Financial Analysis Result of Distribution Projects

(Unit: US$ 1,000)

Phase I-1	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Investment cost	25,600																			
	Revenue		2,036	2,295	2,584	2,906	3,264	3,659	4,095	4,574	5,100	5,675	6,304	6,990	7,737	8,550	9,113	9,706	10,328	10,982	11,671
	Expenditure		2,963	3,106	3,262	3,429	3,609	3,795	3,981	3,759	4,244	4,734	5,080	5,442	5,827	6,162	6,562	6,882	7,189	7,478	6,415
	Cash flow	-25,600	-927	-811	-678	-523	-346	-135	114	815	856	941	1,223	1,547	1,909	2,387	2,551	2,824	3,140	3,504	5,256
	IRR	-																			
Phase I-2	Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
	Investment cost	35,400																			
	Revenue		729	820	920	1,032	1,155	1,290	1,438	1,600	1,778	1,971	2,182	2,411	2,570	2,737	2,912	3,097	3,291	3,497	3,717
	Expenditure		1,765	1,812	1,863	1,915	1,968	1,905	2,042	2,180	2,278	2,380	2,489	2,583	2,696	2,786	2,873	2,954	2,654	2,730	2,808
	Cash flow	-35,400	-1,037	-993	-943	-884	-813	-616	-604	-580	-500	-409	-307	-172	-126	-49	40	143	637	767	909
	IRR	-																			
Phase I-3	Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
	Investment cost	32,000																			
	Revenue		186	209	234	262	293	326	363	404	447	495	547	583	621	661	703	747	794	844	897
	Expenditure		1,130	1,142	1,154	1,166	1,151	1,183	1,214	1,236	1,259	1,284	1,305	1,331	1,351	1,371	1,390	1,322	1,339	1,358	1,376
	Cash flow	-32,000	-944	-933	-920	-904	-859	-856	-851	-833	-812	-789	-758	-748	-730	-710	-686	-574	-545	-514	-479
	IRR	-																			
Phase II-1	Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	Investment cost	33,700																			
	Revenue		632	708	790	881	981	1,089	1,208	1,337	1,477	1,575	1,677	1,784	1,898	2,016	2,143	2,277	2,420	2,572	2,733
	Expenditure		1,534	1,566	1,528	1,612	1,696	1,756	1,819	1,885	1,943	2,012	2,067	2,120	2,170	1,987	2,034	2,082	2,131	2,181	2,232
	Cash flow	-33,700	-902	-859	-737	-730	-716	-667	-611	-548	-466	-438	-390	-336	-273	30	109	196	289	391	500
	IRR	-																			
Phase II-2	Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Investment cost	31,400																			
	Revenue		404	450	500	554	613	678	722	769	819	871	925	983	1,045	1,110	1,180	1,254	1,332	1,416	1,505
	Expenditure		1,218	1,256	1,284	1,313	1,343	1,370	1,401	1,427	1,451	1,474	1,390	1,412	1,434	1,457	1,480	1,503	1,527	1,551	1,576
	Cash flow	-31,400	-813	-807	-784	-758	-730	-692	-679	-657	-632	-603	-464	-428	-389	-346	-300	-249	-194	-135	-71
	IRR	-																			
Phase III	Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
	Investment cost	16,300																			
	Revenue		106	113	120	128	136	145	154	163	173	184	196	208	221	235	250	265	282	300	319
	Expenditure		556	561	565	569	572	559	562	566	570	573	577	580	584	588	591	595	599	603	607
	Cash flow	-16,300	-450	-448	-445	-441	-436	-414	-409	-403	-396	-389	-381	-372	-363	-353	-342	-330	-317	-303	-288
	IRR	-																			

actually or think reasonable to pay for obtaining electricity.

The willingness-to-pay survey from November to December in 2008 described in 8.1.1 clarifies payments which users will pay and actual costs of their own generation. There is a method to calculate benefits by clarifying economic tariff based on amounts which users pay for alternative electricity actually or intended to pay and calculating benefits.[3] It is explained as follows.

The part "ABFC" shown in Fig. 8.5-1 is called consumer's surplus and calculated by the following formula.

$(ABFC)= (P'_E-P_E) \times Q_E \times R$ ----------- (1)

Here, the definitions are as follows.

P_E: existing electricity tariff, P'_E: upper limit of willing-to-pay
P''_E: economic electricity tariff
Q_E: electricity demand at electricity price P_E
R: ratio of area ABFC to area of rectangle (ABO'C)

P''_E is electricity tariff P_E converted from consumer surplus and so area of rectangle (ADO"C) is equal to area of ABFC. Therefore, ABFC is expressed in the following formula.

$(ABFC) = (ADO''C) = (P''_E-PE) \times Q_E$ ----------- (2)

Based on (1) and (2) formulae,

$(P'_E - P_E) \times Q_E \times R= (P''_E-P_E) \times Q_E$
$P''_E = P_E + (P'_E - P_E) \times R$

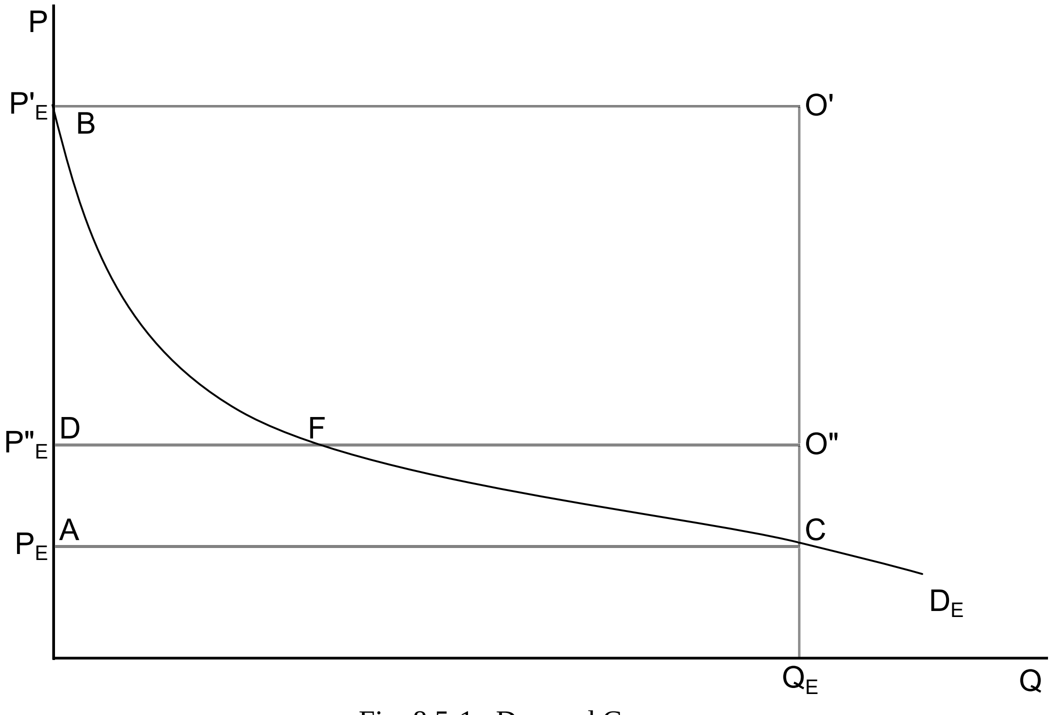


Fig. 8.5-1 Demand Curve

Both the willingness-to pay amounts and own independent generation costs are surveyed in the willingness-to-pay survey of this Master Plan Study and the result shows that the own generation cost

3 Desai, N., Economic Analysis of Power Projects: Asian Development Bank Economic Staff Paper No.24, Asian Development Bank, 1985

is more expensive than the willing-to-pay amount. Therefore, the own generation cost is used. The survey was conducted for three categories: household, commercial and industrial users. Concerning household and commercial users, the tariff units, which are costs divided by electricity volumes, of own generation are more expensive than the tariffs of the NPA. However, it is the contrary concerning industrial users and the industrial own generation unit cost is used as economic tariff. Concerning household and commercial users, economic tariffs are calculated by the method above. Those economic tariffs including generation are separated to distribution by use of the distribution cost share in the financial analysis model. The resultant economic distribution tariffs for household, commercial and industrial users are multiplied by the total electricity demands of household, commercial and industrial users, respectively. Then, the three multiplied numbers are summed up and distribution project share of electricity demand is used to obtain the project benefit. In addition, system loss improvement effects by the distribution projects are considered using total economic tariffs because it is effective to not only distribution but also generation.

For example, the household economic tariff is calculated as follows.
Using monthly fuel volumes and costs for own generation and monthly investment costs which result from dividing annuitized investment costs with five years lifetime and 10% discount rate by 12 according to the household samples of the willingness-to pay survey, own generation costs per kWh can be calculated dividing the monthly costs by monthly own generated electricity in kWh. The generation maintenance cost data exceeding 1,000 leones/kWh are supposed to have required a lot of repair costs and excluded from the calculation. In addition, generation facilities with very low use rates (less than 3%) are also excluded similarly because fixed cost shares in own generation costs are too many. The resultant own generation costs per kWh of the samples are assumed distribution of demand curve and 2,819 leones/kWh, the maximum among them, is defined as P'_E. The distribution curve is shown in Fig. 8.5-2.

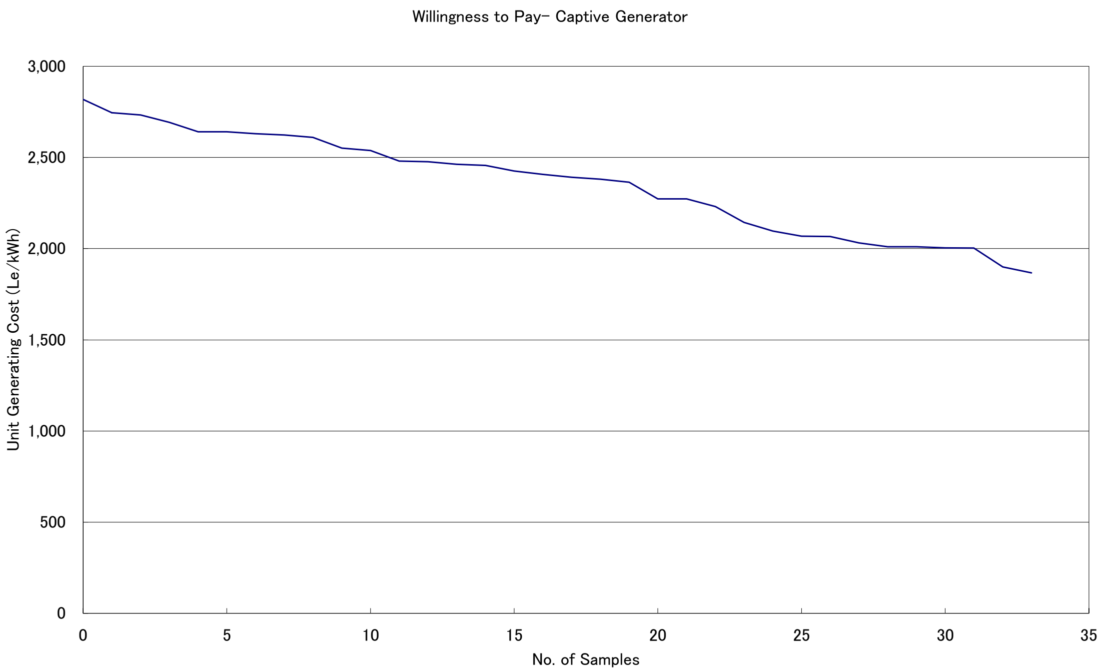


Fig. 8.5-2 Sample Distribution Curve of Own Generation Costs

On the other hand, the NPA's tariffs at the survey time are as shown in Table 8.5-3. Using these and 0.73 as standard conversion factor (SCF)[4] derived from export and import and others in Sierra Leone

[4] SCF: used to exclude national policy effects distorting economic efficiency concerning investment costs and estimate to convert the costs from market prices to economic costs (border costs)

$$SCF = (M + X) / ((M + Tm) + (X – Tx – SB))$$

Where M: import (CIF), Tm: import duty, X: export (FOB), Tx: export tax, SB: export subsidy and assumed consumer surplus 25%, the economic electricity tariff is shown in Table 8.5-4.

Table 8.5-3 NPA's Tariffs for Household

Old Tariff	Le/kWh	cents/kWh
0-30 kWh	373	11.7
31-150 kWh	533	16.8
above 150 kWh	709	22.3

Note: 1USD=3,179Le

Table 8.5-4 Economic Tariffs for Household

Economic Tariff	Le/kWh	cents/kWh
0-30 kWh	**719**	**22.6**
31-150 kWh	**806**	**25.4**
above 150 kWh	**903**	**28.4**

According to the willingness-to pay survey, general household's average monthly NPA and own generation electricity demands are 228.8kWh and 107.2 kWh, respectively, and the sum is 336 kWh. This is applied to the economic tariffs and 22.6 × 30 + 120 × 25.4 + 186 x 28.4 = US$9,008.4. The average is 9,008.4 / 336 = 26.8 cents/kWh. The distribution part is its 50.7% and it is multiplied by annual household power demand and the benefit is obtained.

Similarly the commercial user benefits are calculated. The commercial users' economic tariffs calculated are shown in Table 8.5-6. Commercial user's average monthly NPA and own generation electricity demands are 214.5 kWh and 341.35 kWh, respectively, according to the willingness-to pay survey and the sum is 555.85 kWh. This is applied to the economic tariffs and the average is 16,666.8 / 555.85 = 30.0 cents/kWh.

Table 8.5-5 NPA's Tariffs for Commercial Users

Old Tariff	Le/kWh
0-30 kWh	651
31-150 kWh	781
above 150 kWh	846

Table 8.5-6 Economic Tariffs for Commercial Users

Economic Tariff	Le/kWh	cents/kWh
0-30 kWh	**861**	**27.1**
31-150 kWh	**932**	**29.3**
above 150 kWh	**968**	**30.4**

Concerning industrial users, own generation unit cost, 27.7 cent/kWh, is multiplied by SCF 27.7 × 0.73 = 20.2 cent/kWh and it is used as economic tariff.

The results of benefit / cost analyses are shown in Table 8.5-7. IRR of Phase I-1 is 6.7%, but cash flows of the other projects are minus and so IRR cannot be calculated.

8.5.4 Consideration of Financial and Economic Analyses of Distribution Projects

Financial analyses of the distribution projects result in worse account than the whole electricity development plan including generation. This shows that revenues of the distribution projects are smaller and cannot cover the costs. It means that the demand increase by the distribution project implementation is smaller proportionally to the whole plan and the revenues cannot cover the investment and expenditures and so the other existing demand contributes much more financially.

Economic analyses are similar, but barely IRR of Phase I-1 is 6.7% and the other distribution projects show that the benefits cannot cover the costs (including investment). This is also because of small proportion of demand increase by the distribution project implementation to the whole. As the phases progress, distribution network is extended to the areas with low demand density and demand increase by the project implementation is smaller so that financial and economic balances become worse.

However, the whole plan can avoid financial loss and so the projects can be implemented. After Bumbuna hydro power begins to generate and expansion of Kingtom generation station and construction of Blackhall Road are completed, generation capacity responding to the most urgent demand can be ensured. Nevertheless, power supply situation in Western Area cannot be improved unless the transmission and distribution network supplying power to the end users is improved. Namely, effects of generation facility investment cannot be realized. Networking of distribution brings about effects which cannot be calculated and included in the economic benefits such as stabilization of power supply. They become the existing user’s benefits, too. In addition, the Hydro Dominant Case has economic effects on greenhouse gas reduction which are not included in the benefits. Furthermore, the projects have effects on reduction of air pollution and noise caused by own generation. These economic effects are difficult to quantify so that they are not calculated, but they exist absolutely.

Since there are benefits which cannot be expressed simply in numbers such as IRR above and an electricity supply system has characteristics that it functions as a total system and if part of it is missing, electricity supply is impeded, implementation of the distribution projects in this Master Plan is meaningful enough to improve electricity supply in Western Area.

Table 8.5-7 Benefit/ Cost Analysis Result of Distribution Projects

(Unit: US$ 1,000)

Phase I-1	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Investment cost	25,600																			
	Benefit		3,852	4,146	4,466	4,810	5,178	5,572	5,991	6,437	6,908	7,407	7,935	8,492	9,079	9,700	10,354	11,045	11,774	12,544	13,358
	Expenditure		2,963	3,106	3,262	3,429	3,609	3,795	3,981	3,759	4,244	4,734	5,080	5,442	5,827	6,162	6,562	6,882	7,189	7,478	6,415
	Cash flow	-25,600	890	1,040	1,204	1,380	1,569	1,778	2,010	2,678	2,664	2,673	2,854	3,049	3,252	3,537	3,792	4,163	4,586	5,066	6,943
	IRR	6.7%																			
Phase I-2	Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
	Investment cost	35,400																			
	Benefit		1,463	1,575	1,696	1,825	1,962	2,108	2,263	2,426	2,599	2,781	2,974	3,177	3,391	3,618	3,856	4,109	4,375	4,659	4,961
	Expenditure		1,765	1,812	1,863	1,915	1,968	1,905	2,042	2,180	2,278	2,380	2,489	2,583	2,696	2,786	2,873	2,954	2,654	2,730	2,808
	Cash flow	-35,400	-303	-237	-167	-90	-6	203	220	246	321	401	485	594	695	832	984	1,154	1,721	1,929	2,154
	IRR	-																			
Phase I-3	Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
	Investment cost	32,000																			
	Benefit		385	415	447	480	516	554	594	636	681	728	777	830	885	944	1,005	1,071	1,140	1,214	1,293
	Expenditure		1,130	1,142	1,154	1,166	1,151	1,183	1,214	1,236	1,259	1,284	1,305	1,331	1,351	1,371	1,390	1,322	1,339	1,358	1,376
	Cash flow	-32,000	-745	-727	-707	-686	-636	-629	-620	-600	-579	-556	-528	-501	-466	-427	-384	-251	-199	-144	-83
	IRR	-																			
Phase II-1	Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	Investment cost	33,700																			
	Benefit		1,398	1,503	1,615	1,733	1,858	1,991	2,130	2,278	2,433	2,598	2,771	2,954	3,147	3,351	3,569	3,800	4,047	4,309	4,589
	Expenditure		1,534	1,566	1,528	1,612	1,696	1,756	1,819	1,885	1,943	2,012	2,067	2,120	2,170	1,987	2,034	2,082	2,131	2,181	2,232
	Cash flow	-33,700	-136	-63	87	122	162	234	312	393	490	585	704	833	977	1,365	1,535	1,719	1,916	2,128	2,357
	IRR	-																			
Phase II-2	Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Investment cost	31,400																			
	Benefit		987	1,058	1,134	1,213	1,297	1,386	1,479	1,578	1,682	1,792	1,908	2,032	2,164	2,304	2,454	2,613	2,783	2,963	3,156
	Expenditure		1,218	1,256	1,284	1,313	1,343	1,370	1,401	1,427	1,451	1,474	1,390	1,412	1,434	1,457	1,480	1,503	1,527	1,551	1,576
	Cash flow	-31,400	-231	-198	-150	-99	-46	16	78	151	231	318	519	621	730	848	974	1,110	1,256	1,412	1,580
	IRR	-																			
Phase III	Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
	Investment cost	16,300																			
	Benefit		304	325	346	369	393	419	446	475	506	539	574	611	651	693	738	786	837	891	949
	Expenditure		556	561	565	569	572	559	562	566	570	573	577	580	584	588	591	595	599	603	607
	Cash flow	-16,300	-252	-236	-218	-199	-179	-140	-116	-91	-64	-34	-3	30	66	105	146	190	238	288	342
	IRR	-																			

9. Capacity Building

In this chapter, capacity building for technical staffs of the Generation Division, and the Transmission and Distribution Division of the NPA has been planned as follows:

Firstly, standard services are described as Operation and Maintenance Guidelines which the NPA technical staffs shall acquire to operate and maintain the diesel engine generators, and transmission and distribution network. Secondly, current knowledge and skills of technical staffs of Generation Division, and Transmission and Distribution Division, Technical Department, NPA are described who actually conduct the operation and maintenance of these facilities in the Republic of Sierra Leone. Lastly, the technical items which shall be transferred and capacity development schedule are planned in consideration of the distance between knowledge and skills which the NPA technical staffs shall possess and actually possess.

9.1 Operation and Maintenance Guidelines for Power Supply Facilities

Power system is composed of generation facilities, and transmission and distribution network including transformation equipment.

Concerning generation equipment, operation and maintenance guidelines for diesel engine generator are described. In consideration of the situation that the diesel engine generators (two sets of 5 MW Rated Output) are the only generators the NPA will operate and maintain by themselves which will be procured under the Project, "Urgent Improvement of Electric Power in Freetown" of Japan's Grant Aid, Operation and Maintenance Guidelines for the diesel engine generators are featured. It is shown as "Operation and Maintenance Guidelines for Diesel Engine Generator" in Appendices 2.

On the other hand, concerning transmission and distribution network, the equipment currently operated by the NPA is so decrepit that the Transmission and Distribution Division is forced to handle a huge number of repair works. In consideration of the situation, it is difficult to operate and maintain the current equipment in accordance with Operation and Maintenance Guidelines. Load Dispatching Procedures, Patrol Procedures and Inspection Procedures are shown as Operation and Maintenance Guidelines in assumption that, in future, the equipment will be improved and dispatch of power will be in stable condition. It is shown as "Operation and Maintenance Guidelines for Transmission and Distribution Network" in Appendices 2.

9.2 Current Situation and Problems of Technical Staffs in the NPA

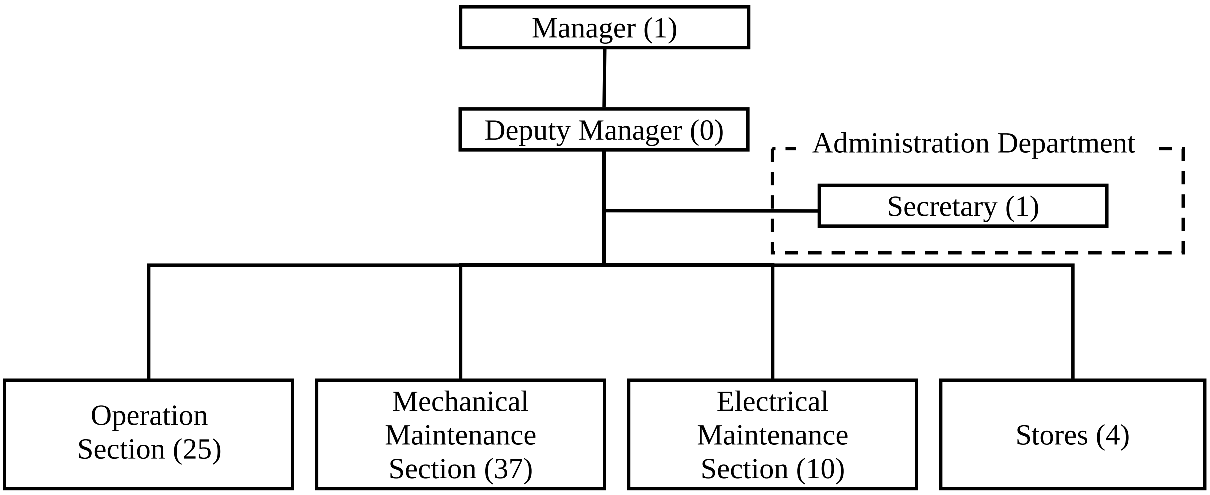
Operation and maintenance for generation facilities and power system of the NPA are conducted by Generation Division, and Transmission and Distribution Division, Technical Department (Refer to Fig. 3.2-1). The current situations and problems of these two divisions are shown below. Both divisions are forced to operate and maintain the facilities under the situation far from sound status and the organization for stable and qualitative power supply becomes weak. Requirement for capacity development of technical staffs is clearly confirmed.

9.2.1 Organization of Generation Division and Transmission and Distribution Division

The organization of the Generation Division is shown in Fig. 9.2-1. The numbers in the brackets in the figure show the numbers of the staffs belonging to each group. The post of Deputy Manager is vacant and Operation Manager currently holds the post. There are 77 staffs in the Generation Division as of May 2009 (Secretary, who belong to Administration Department, is not counted as a staff of the Generation Division). The Division is composed of four Sections, Operation Section, Mechanical Maintenance Section, Electrical Maintenance Section and Stores.

At present, the generation equipment of NPA is out of service because of deterioration and critical damages, and operation and maintenance of equipment necessarily stopped from the end of 2006. Therefore, the organization for operation and maintenance is as obscure as the staffs who belong to plural sections. Though 16 (4 staffs * 4 groups) out of total 25 staffs in Operation Section are in charge of shift work, after resumption of operation and maintenance of their equipment, the number of staffs in charge will be increased.

At the beginning of 2010, concerning two sets of 5 MW diesel engine generators procured under the Project of Japan's Grant Aid, the organization shall be reconstructed. In addition, two sets of 8.26 MW diesel engine are planned for installation in the area of Blackhall Road Substation in August 2010 and, moreover, one set is planned to be added there in 2011. As total three sets are operated and maintained in Blackhall Road, additional technical staffs shall be secured in the near future. The composition of staffs in the Generation Section is shown in Table 9.2-1.



Total Number of Official Staff: **77**

As of May, 2009
[Source] Generation Division, NPA

Fig. 9.2-1 Organization Chart of the Generation Division

Table 9.2-1 Number of Technicians of Each Section in Generation Division

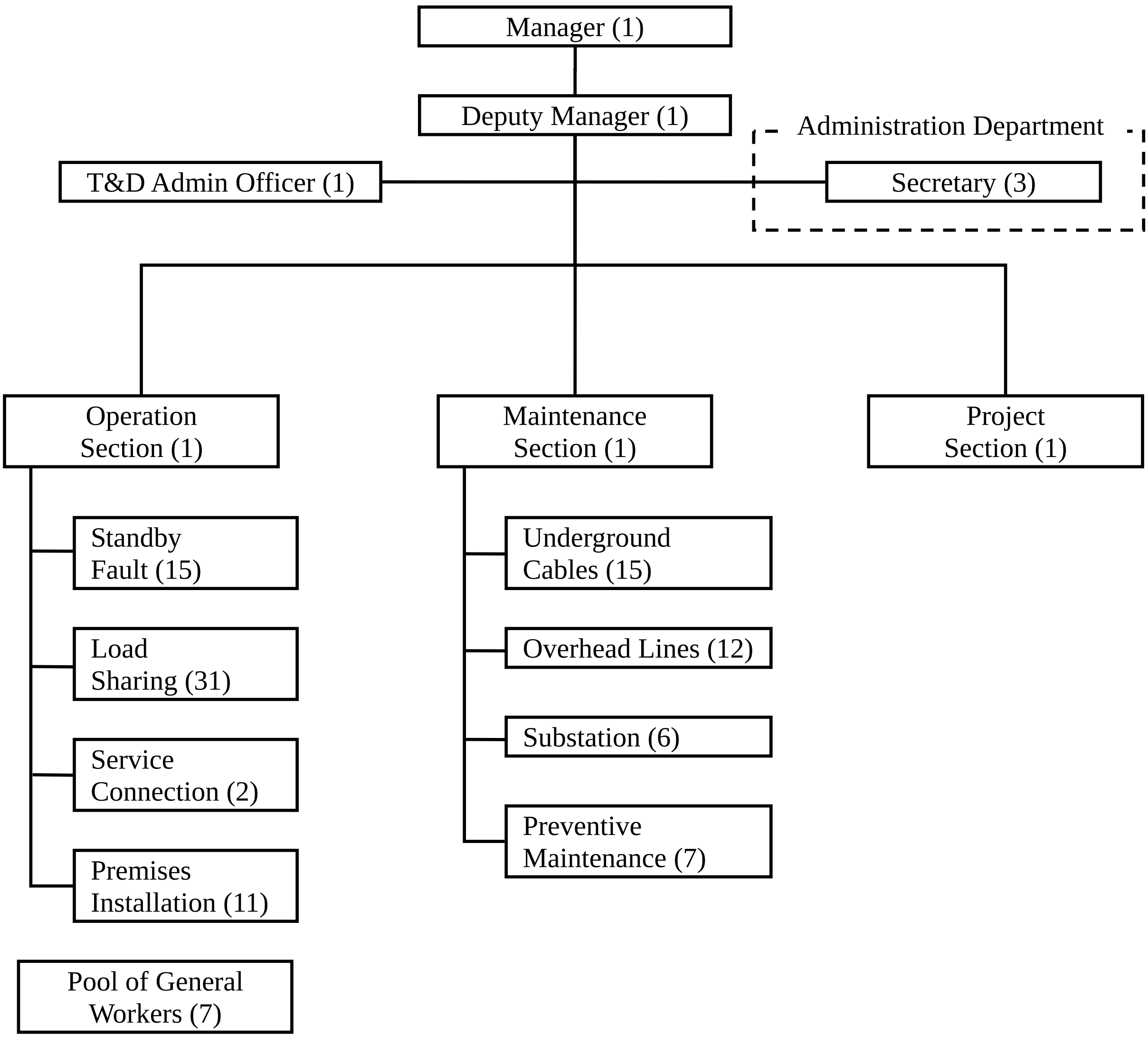
	Operation Section	Mechanical Maintenance Section	Electrical Maintenance Section	Stores
Section Manager	1	1		
Chief Superintendent		1	1	
Senior Superintendent		1	2	
Superintendent	5	3		
Assistant Superintendent	3	2	1	
Senior. Engine Attendant	8			
Senior. Shift Supervisor	2			
Senior. Switch Board Attendant	1			
Senior. Fitter	4	8		
Fitter	1	3		
Senior. Plumber		1		
Tools Keeper		1		
Electrician			6	
Storekeeper				2
Data Processing Clerk				1
Stores Support Staff				1
General Worker		16		
Total	**25**	**37**	**10**	**4**

As of May 2009
[Source] Generation Division, NPA

The organization of the Transmission and Distribution Division is shown in Fig. 9.2-2. There are 112 staffs as of May 2009 (Secretary is not counted as a staff of the Transmission and Distribution Division). The Division is composed of three Sections, i.e. the Operation Section, Maintenance Section and Project Section. The Standby Fault Party under Operation Section is in charge of fist aid action for faults and the actual repair work for faults is executed by parties under the Maintenance Section. As the Project Section has only just been established in May 2009 and the actual staffs for planning have not been secured, general workers do not belong to a particular section and engage in general works of three sections.

In addition to the situation where the Transmission and Distribution Division is forced to handle a huge number of repair works for faults, they lack such necessary goods and equipment for work as cars for patrol and computers.

Technical staffs who have basic knowledge for electrical equipment exist in the section and it is a issue of the section to train these staffs as chief engineers by the Capacity Development Plan. The composition of staffs in the Transmission and Distribution Division is shown in Table 9.2-2.



Total: **112**

As of May 2009
[Source] T&D Division, NPA

Fig. 9.2-2 Organization Chart of Transmission and Distribution Division

Table 9.2-2 Number of Technicians of Each Section in T&D Division

	Operation Section				Maintenance Section				Project Section	Pool of General Workers
	Standby Fault	Load Sharing	Service Connection	Premises Installation	Underground Cables	Overhead Lines	Substation	Preventive Maintenance		
Section Manager	1				1				1	
Chief Superintendent							2			
Senior Superintendent		2	1							
Superintendent	1	2		2	4	3	1	2		
Assistant Superintendent	2	6			2	2	1			
Senior Electrician	2	2		3						
Electrician	1	14		4						
Senior Technician		1					1			
Technician		2			1	1	1	1		
Senior Linesman	2							1		1
Linesman	4			1		3		3		1
Linesman Mate						1				
Senior Cable Jointer					1					
Cable Jointer					4					
Senor Fitter		1								
Fitter		1								
Lift Maintenance Technician				1						
Telephone Operator	3									
General Worker			1		3	2				5
Total	**15**	**31**	**2**	**11**	**15**	**12**	**6**	**7**	**1**	**7**

As of May, 2009
[Source] T&D Division, NPA

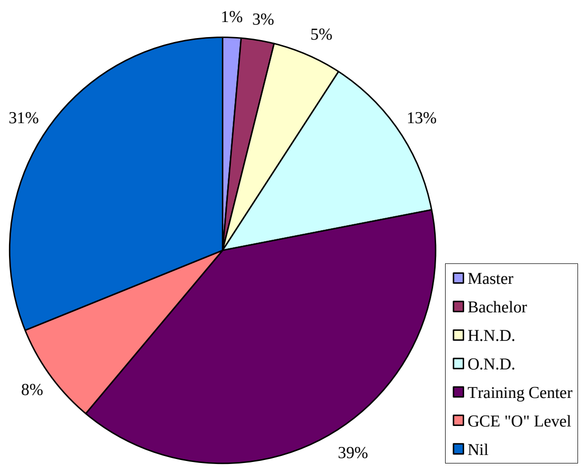
9.2.2 Technical Level and Problems in the Generation Division and Transmission and Distribution Division

Technical knowledge and skills of technical staffs are acquired via technical education and trainings and mastered through the practice. The current problems in technical capacity are clarified through confirmation of technical education and trainings which the staffs of Generation Division and Transmission and Distribution Division have received in the past.

(1) Academic backgrounds of technical staffs, NPA

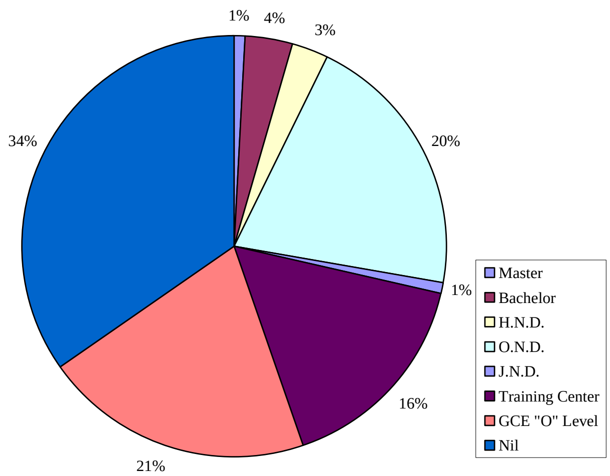
The education system has been transferred to the new system, composed of 6 years of primary, 3 years of junior secondary, 3 years of senior secondary and 4 years of university education since 1993. Before 1993, education was conducted in the system shown in Fig. 9.2-5. Recently, the NPA has not hired new employees (2 new employees in 2007 and 2008 for each year) and most of its technical staffs received their education according to the system shown in Fig. 9.2-5. One example of Technical Center in the figure is NPA Training Center in Kingtom Power Plant. Fourah Bay University is the only national one which has engineering faculty in Sierra Leone. In Technical Institute, higher education can be received than Technical Center. G.C.E. “O” Level is the same level as graduation of high school.

As is shown in 9.2.1, the number of staffs in the Generation Division and the Transmission and Distribution Division are respectively 77 and 112. Compositions of their academic background are shown in Fig. 9.2-3 and Fig. 9.2-4. The numbers of graduates from university, who possess capability to be trained as chief engineers are three in Generation Division and five in Transmission and Distribution Division. And the numbers of graduates from Technical Institute, who possess capability to be trained as chief technicians are 14 in Generation Division and 27 in Transmission and Distribution Division. Though academic backgrounds of staffs are one of the most reliable indicators which show the potential to grow as chief engineers and chief technicians, final decision on selection of trainees for the capacity development plan shall be made with consideration of such items as business experience and vocation after the careful discussion with managers of each division.



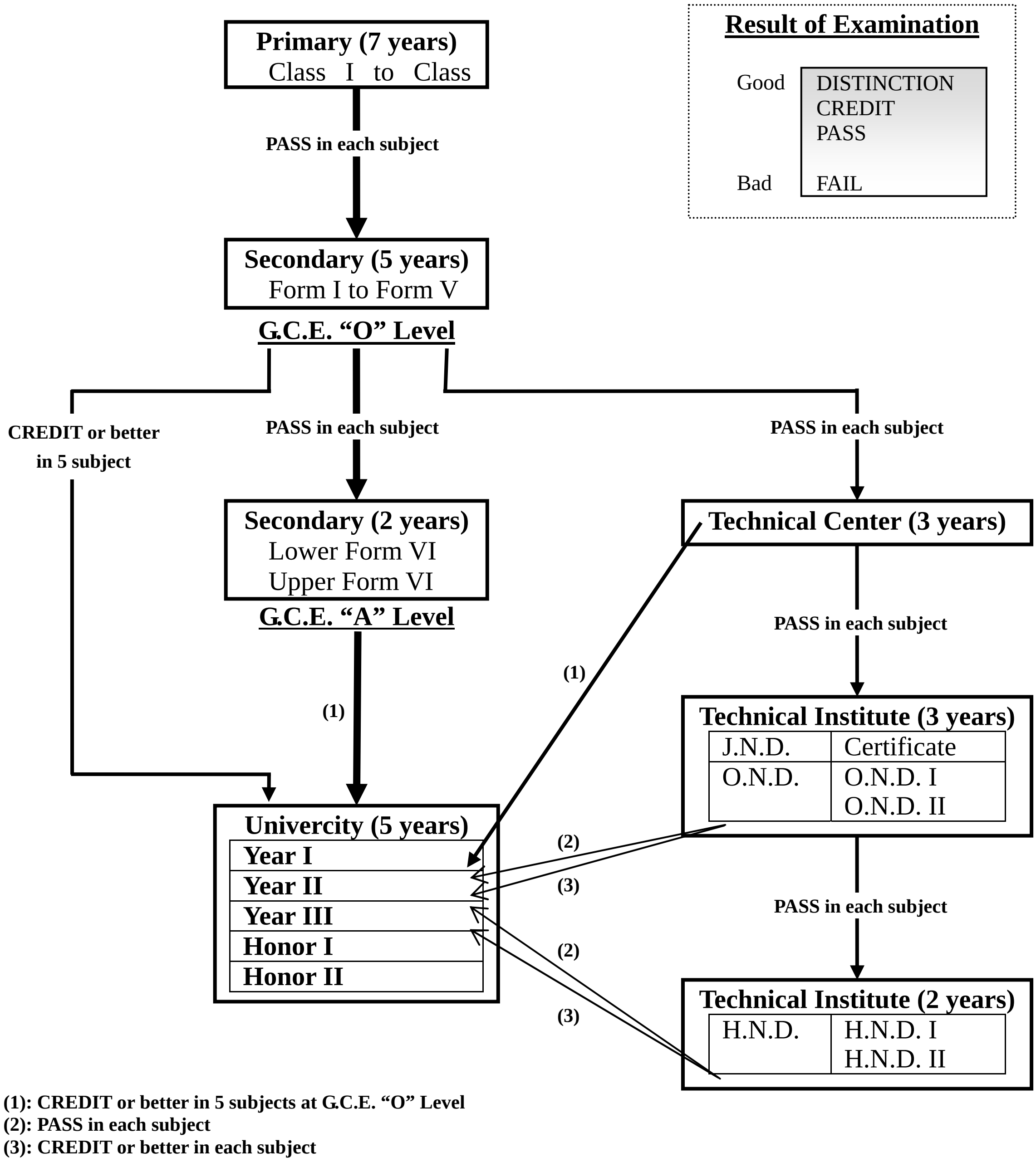
[Source] JICA Study Team

Fig. 9.2-3 Academic Background of staffs in Generation Division



[Source] JICA Study Team

Fig. 9.2-4 Academic Background of staffs in Transmission and Distribution Division



G.C.E. "O" Level: General Certificate of Education at Ordinary Level
G.C.E. "A" Level: General Certificate of Education at Advanced Level
J.N.D.: Junior National Diploma
O.N.D.: Ordinary National Diploma
H.N.D.: Higher National Diploma

[Source] JICA STUDY TEAM

Fig. 9.2-5 Education Structure in Old System

(2) Technical level achieved in the NPA Technical Center

Though the NPA Training Center is located in the area of Kingtom Power Plant, currently, it is not the training center for NPA staffs. It is a technical school for general students who graduate from senior secondary school. At present, as the NPA hardly hires new employees, there is no student who enters the NPA after graduation of the NPA Training Center. From 1985 to 1993, as it was in charge as the training center of the NPA, the technical staffs who passed G.C.E. “O” Level and entered the NPA were trained in the training center. The training center has two technical courses, which are Electrical Course and Mechanical (Fitter General) Course. The curriculums of them are shown in Table 9.2-3 and Table 9.2-4. Both courses are composed of 30% theoretical training and 70% practical training. The subjects specializing in power equipment are not confirmed in both courses. From the viewpoint that they are the training for technical staffs who operate and maintain the national power system, there is concern that they are not sufficient.

Concerning Electrical Course, practice for simple work of cable and overhead lines is only conducted and such knowledge and skills as structure of power system, protection method of power system, pole assembling practice and termination and jointing of cables, which are basic for electricians, are not trained.

Concerning Mechanical Courses, practice for disassembling and maintenance of small and simple diesel engines which are used in each household at the time of blackouts is only conducted. There is concern that it is impossible to operate and maintain the thermal power plants which are in charge of national power supply and are composed of such utility facilities as fuel oil system, cooling water system and lubricating oil system, only based on trained techniques in the training center. The situation of the NPA Training Center is shown in Table 9.2.3-5.

Table 9.2-3 Curriculum of Electrical Course

Category	Contents
Theory	Electrical Calculations Electrical Technology Electro-Technical Drawing Electronics Protection and Regulation
Practice	Basic Metal Work Installation Control Circuit Lines and Cable Network Winding Electrical Appliance Repairs Project Work

[Source] NPA Training Center

Table 9.2-4 Curriculum of Mechanical Courses

Category	Contents
Theory	Technical Mathematics Workshop Technology Technical Drawing Diesel Technology Basic Electricity
Practice	Bench Work Gas and Arc Welding Diesel Fitting Machining Pipe Fitting Project Work

[Source] NPA Training Center

Table 9.2-5 Conditions in the NPA Training Center

	
Electrical Circuits Practice 1 (Electrical)	Machine for Processing 1 (Mechanical)
	
Electrical Circuits Practice 2 (Electrical)	Machine for Processing 2 (Mechanical)
	
Lecture Room (Electrical)	Wielding Practice (Mechanical)
	
Relay Board Practice Material (Electrical)	Manufactured Material (Mechanical)

(3) Technical level achieved in Faculty Engineering, Fourah Bay University

At the time of transformation of the education system in 1993, education of university was changed to four-year education from five-year education. But, because of the relic of old system, even now, curriculums of university have five- year education and some students spend five years in university to finish the curriculums. The curriculum of Electrical Modules and Mechanical Modules, Faculty Engineering, Fourah Bay University are shown in Table 9.2-6.

Though the number of technical subjects is relatively less, such significant subjects as dynamics and material engineering are included and it is considered that basic knowledge as an engineer is achieved from the curriculums. But the achievement in universities is only basic knowledge and it is necessary in case of technical staffs who operate and maintain power equipment to also acquire technical knowledge and skills such as operation and maintenance procedures of equipment, protection system and planning of power system. Especially, in case of developing countries, as it is hard to secure the maintenance service providers, all the maintenance works such as disassembling, inspection and reassembling have to be done autonomously. Therefore, the additional systematic trainings to university education for operation and maintenance are indispensable.

Table 9.2-6 Curriculum of FBC

		Electrical Modules		Mechanical Modules		Term
		Power Engineering	Light Current	Mechanical	Maintenance	
Year 1	First & Second	Mathmatics	Same as on the left	Same as on the left	Same as on the left	26 weeks
	Semester	Physics				
		Chemistry				
		Workshop Technology				
		Engineering Drawing				
		Foundamation Course				
Year 2		Electronics	Same as on the left	Same as on the left	Same as on the left	26 weeks
		Applied Electricity				
		Mechnics of Fluids				
		Thermo Dynamics				
		Material and Structures				
		Applied Mathmatics				
		Workshop Technology				
		Engineering Drawing				
Year 3	First Semester	Electronics	Same as on the left	Applied Mechanics	Same as on the left	13 weeks
		Electric Circuits		Manufacturing Processes		
		Communications		Mechanics of Fluids		
		Digital Systems		Plant Component and System		
		Microcomputer Engineering		Energy Conversion		
		Power Engineering		Applied Mathematics & Calculus		
		Applied Mathematics & Calculus				
	Second Semester	Electronics	Same as on the left	Applied Mechanics	Same as on the left	13 weeks
		Communications		Manufacturing Processes		
		Digital Systems		Thermodynamics		
		Microcomputer Engineering		Industrial Engineering		
		Field Theory		Energy Studies		
		Partial Differential Equations		Partial Differential Equation		
		and Laplace Transform		and Laplace Transform		
Year 4	First Semester	Signal Analysis	Same as on the left	Mechanics of Machines & Controls	Mechanics of Machines & Controls	13 weeks
		Controls Systems		Mechanics of Solids	Mechanics of Solids	
		Power Engineering		Mechanics of Fluids	Statistics & Operational Research	
		Digital Systems		Engineer Thermodynamics	Maintenance Procedure & Organizing	
		Communications		Industrial Economics & Management	Engineering Management	
		Engineers-in-Society		Design Engineering	Design Engineering	
				Engineer – in – Society	Engineer – in – Society	
	Second Semester	Data Processing	Same as on the left	Ditto	Ditto	13 weeks
		Control Systems				
		Power Engineering(Power Electronics)				
		Digital Systems				
		Engineers-in-Society				
		Projects and Mini Project				
		Communications				
Year 5	First Semester	Industrial Attachment for 5months	Same as on the left	Same as on the left	Same as on the left	13 weeks
	Second Semester	Industrial Electronics	Industrial Electronics	Mechanics of Machines & Controls	Electronic Instrumentation	13 weeks
		Power Electronics	Power Electronics	Thermodynamics	Mechanics of Machines & Controls	
		Control Systems	Control Systems	Material Science	Material Science	
		Electrical Machines	Computer Aided Design (CAD)	Production Engineering	Maintenance Procedure & Organization	
		Electrical Power System	Communications	Introduction in Chemical Engineering	Instrumentation, Quality Control & Reliability	
		Field Projects	Field Projects	Dissertation / Project	Dissertation / Project	

(4) Practice and Problems of Technical Training in the NPA

In the NPA, staffs hired after the graduation of engineering faculty of universities, are engaged in three-year training as pupil engineers. During this period, they are assigned to Technical Department, Commercial Department, Administration Department and so on, and on-the-job training is conducted. The purpose of this training is for understanding of outline of power industry, not for transferring technical knowledge and skills for operation and maintenance of power equipment. At present, the NPA conducts no technical training for staffs and they operate and maintain the equipment by knowledge only achieved in school education. Though, at the time of execution of the project by foreign donors, on-the-job training was conducted, the NPA currently lacks systematically planned technical training.

In consideration of commissioning of 5 MW diesel engine generators procured under Japan’s Grant Aid and connection Bumbuna System in the near future, it is an urgent issue of Generation Division and the Transmission and Distribution Division to transfer and improve technical knowledge and skills for operation and maintenance of power system based on the Operation and Maintenance Guidelines described in 9.1. In addition, as most of the technical staffs of the NPA digressed from school education long before, it is suggested to supplement programs with basic theory concerning electrical and mechanical engineering in case of technical transfer.

9.3 Capacity Development Plan for the NPA

Firstly, in consideration of “Operation and Maintenance Guidelines for Power Supply Facilities” described in 9.1 and “Current Situation and Problems of Technical Staffs in the NPA” described in 9.2, technical items to be transferred to technical staffs in the NPA are identified in this section.

At the beginning of 2010, coinciding with the start of operation and maintenance of two sets of 5 MW diesel engine generators procured under the Project of Japan’s Grant Aid, capacity of operation and maintenance for the equipment shall be established urgently. Therefore the transfer of the technical items shall be scheduled through the practice of operation and maintenance of the equipment.

9.3.1 Technical Items to be Transferred

As described in 9.2.2, technical staffs in the Generation Division do not have the experience of systematic technical training programs. In addition, from the end of 2006, the practice of operation and maintenance of generation facilities stopped. Therefore, there is concern that technical works shown in Operation and Maintenance Guidelines shall be transferred from the basic steps for development of certain capacity. As diesel engines are operated in such severe conditions as high pressure, high temperature and high speed, early breakdown of engine cannot be avoided without appropriate operation and maintenance. Based on Operation and Maintenance Guidelines for Diesel Engine Generators, technical items to be transferred are shown in Table 9.3-1.

Table 9.3-1 Capacity Development for Lead Engineers of Generation Facility Operation and Maintenance

Section	Items to be trained	Contents
Operation	Operation	Start-up/Stop Procedure
		Mechanical Protection System of Diesel Engine
		Fitting and Adjustment Operation
		Emergency Shutdown and the conditions
		Preparation for Dormant State
		Operation Management of Engine
		Operation Management of Fuel Oil System
		Operation Management of Lubricating Oil System
		Operation Management of Cooling Water System
		Operation Management of Start-up Air System
		Operation Management of Waste Oil Disporsal Facility
	Management of Operation Data	Preparation of Check Lists and Reports
	Management of Recirculating Flow	Management of Fuel Oil, Lubricating Oil and Cooling Water
		Stock Management
		Management of Discharged Water, and Waste (Residual Ash)
	Combustion Management	Adjustment of Injection Timing
		Adjustment of Fuel Injection Pump Rack
	Preparation of Operation Manuals	Preparation of Manuals
	Preparation of Waste Management Manuals	Preparation of Manuals
	Trouble Shooting for Failures	Trouble Shooting Procedures
	Budgetary Planning for Operation	Estimation Procedure of Budget
Maintenance and Planning	Planning and Implementation of Periodical Overhauls	Planning and Implementation Procedures of Periodical Overhauls
	Arrangement/Rearrangement Works for Periodical Overhauls	B Overhaul
		D1 Overhaul
		D2 Overhaul
		D3 Overhaul
		E2 Overhaul
		Stock Management of Spare Parts Management
	Implementation Procedures for Periodical Overhauls	Fitting and Inspection Procedure of Intake/Exhaust Valve
		Overhaul Procedures of Fuel Injection Valve and Pump
		Inspection Procedure of Cylinder Liner
		Disassembling and Inspection Procedure of Piston and Connection Rod
		Disassembling and Inspection Procedure of Rocker Arm and Cam Function
		Replacement Procedure of Main Bearing
		Inspection Procedure of Crank Shaft
		Inspection Procedure of Gears
		Overhaul Procedure of Turbocharger
		Overhaul Procedure of Torsion Vibration Damper
		Overhaul Procedure of Governor
		Overhaul Procedure of Other Accessory Equipment
	Overhaul Procedures of Auxiliary Equipment	Overhaul Procedures of Filtering Equipment
		Overhaul Procedures of Purifiers
		Overhaul Procedures of Pumps
		Overhaul Procedure of Compressor
		Overhaul Procedures of Measurement Instruments
	Preparation of Overhaul Manuals of Engine	Preparation of Manuals
	Preparation of Overhaul Manuals of Auxiliary Equipment	Preparation of Manuals

	Budgetary Planning for Maintenance	Estimation Procedure of Budget
	Trouble Shooting for Failures	Trouble Shooting Procedures
Common Item for、Operation, Maintenance and Planning	Theory	Theory of Diesel Cycle
		Sequence Control System
		Preventive Maintenance
		Non-Destructive Inspection
		Automatic Control of Generation Facilities
		Control Systems of Generation Facilities
	Others	Structure and Function of Governor
		Principle of Function of Purifiers
Electrical Facility	Theory	Voltage and Frequency Management
		Sequence Control System
		Protection Coordination and Setting
		Automatic Voltage Regulator
	Operation Management	Sequence Control of Generation Facilities
		Control Systems of Generation Facilities
		Protection Relays and Setting of Generation Facilities
		Synchronous Running of Generation Facilities
		Operation Management of Generation Facilities
		Voltage and Frequency Management
	Management of Operation Data	Preparation of Check Lists and Reports
	Maintenance Management	Overhaul Procedure of Synchronous Generator
		Overhaul Procedure of Switchgears
		Overhaul Procedure of Control Panel and Synchronizing Panel
		Overhaul Procedure of Station Transformers
		Overhaul Procedure of MCC
		Overhaul Procedure of DC Supply Panel
		Performance Test of Protection Relays
	Trouble Shooting for Failures	Trouble Shooting Procedures
	Applications of Tools and Instruments	Purpose and Method of Usage
	Others	Structure and Operation of Governor
Common	Outline of Generation Facility	Outline of Engine
		Outline of Fuel System
		Outline of Lubricating Oil System
		Outline of Cooling Water System
		Outline of Start-up Air System

[Source] JICA Study Team

Technical staff in the Transmission and Distribution Division also do not have the experience of systematic technical training programs. Therefore, there is concern that the technical works shown in Operation and Maintenance Guidelines shall be transferred from the basic steps for development of certain capacity. After the commissioning of Bumbuna Hydraulic Power Plant, such policies as protection coordination and demand and supply planning shall fundamentally be revised. In addition, as the Transmission and Distribution Division is forced to conduct a huge number of repair works for faults, the appropriate and efficient procedures for repair work shall also be transferred. Based on Operation and Maintenance Guidelines, technical items to be transferred are shown in Table 9.3-2.

Table 9.3-2 Capacity Development for Lead Engineers of Power Distribution Facility Operation and Maintenance

Section	Items to be trained	Contents
Operation	Operation Management	Formulation of Observation Framework
		Start-up/Stop/Switching Operation Procedures of Power System
		Emergency Operation Procedures at Failures
		Commissioning/Recommissioning Procedures of Power System
		Improvement of Power Factor
		Load Shedding
	Protections of Power System	Main and Back-up Protections
		Protection Coordination and Setting
		Performance Tests of Protection Relays
		Functional Tests of Switchgears
	Management of Operation Data	Preparation of Check Lists and Reports
	Planning of Demand and Supply	Analysis of Operation Data
		Analysis of Time Schedule Periodical Overhauls
		Analysis of Reservoir Utilization Plan
	Management of Power System	Voltage and Frequency Management
		Improvement of Power Factor
	Preparation of Operation Manuals	Preparation of Manuals
	Trouble Shooting for Failures	Trouble Shooting Procedures
	Applications of Tools and Instruments	Purpose and Method of Usage
Maintenance and Planning	Maintenance Management	Overhaul Procedure of Transformer
		Inspection of Overhead Lines
		Inspection of Underground Cables
		Overhaul Procedure of Switchgears
		Overhaul Procedure of DC Supply Panels
		Performance Test of Protection Relays
		Overhaul Procedure of Auto Reclosers
		Overhaul Procedure of Arresters
	Repair Work	Overhead Lines
		Underground Cables
	Patrol and Inspection Procedure	Overhead Lines
		Underground Cables
		Transformation Equipment
		Preparation of Patrol and Inspection Check List
	Budgetary Planning for Operation and Maintennce	Estimation Procedure of Budget
	Trouble Shooting for Failures	Trouble Shooting Procedures
Common	Theory	Voltage and Frequency Management
		Sequence Control Systems
		Calculation for Failures
		Protection Coordination and Setting

		Automatic Voltage Regulator
		Power System and Stability
	Applications of Tools and Instruments	Purpose and Method of Usage

[Source] JICA Study Team

Though services concerning the power system planning are conducted in the System Planning Section of the Corporate Planning Department presently, the NPA depends on assistance from the foreign donors and the staff capable of planning the future system do not exist in the NPA. Even in case of reception of assistances from foreign donors, the NPA shall be able to coordinate consistency of each project from technical viewpoints. In the near future, system planning engineers who can plan and evaluate power system development projects shall be secured in the NPA. Especially, concerning the low voltage distribution network, essential problems for stable and reliable power supply are caused not only by lack of knowledge and skills for operation and maintenance in technical staff but also deterioration and overload of equipment. As the distribution network is composed of huge numbers of equipment, it is difficult for foreign donors to assist improvement of the distribution networkt in limited term projects. From this viewpoint, the existence of system planning engineers is necessary. Technical items to be transferred for power system planning are shown in Table 9.3-3.

Table 9.3-3 Capacity Development for Lead Engineers of Power System Planning

Section	Items to be trained	Contents
Power Distribution Facility Planning	Present Data Analysis	Preparation of Single-Line Diagram for 11kV Distribution Line
		Preparation of Single-Line Diagram for Low Voltage Distribution Line
		Preparation of Route Map for 11kV Distribution Line
		Preparation of Route Map for Low Voltage Distribution Line
		Analysis of Load Characteristic
		Analysis of Operation Data
		Analysis of Voltage Drop and Power Loss
		Confirmation of Projects by Foreign Donors
	Demand Forecast	Macro Demand Forecast
		Micro Demand Forecast
	Distribution Network Planning	Planning for Renewal of Distribution Line
		Planning for Empowerment of Distribution Line
		Planning for Extension of Distribution Line
		Designing Procedure for Distribution Network
		Evaluation of Profitability of Projects
		Planning for Reduction of Voltage Drop and Power Loss
		Planning for Introduction of Power Factor Improvement Equipment
	Power System Analysis	Calculation of Power Flow
		Calculation of Short-circuit Capacity
		Calculation for Failures
		Evaluation of Stability of Power System
Power Development Planning	Analysis of Existing Generation Facility	Evaluation of Current Performance and Life Duration of Existing Generation Facility
		Analysis of Load Characteristic
		Confirmation of Projects by Foreign Donors
	Demand Forecast	Macro Demand Forecast
	Evaluation for Potential of Power Development	Feasibility Study for Hydroelectric Power Plant
		Feasibility Study for Thermal Power Plant
		Analysis of Characteristics of each Power Source Type
	Formulate and Evaluation of Power	Evaluation of Initial Costs and Running Costs of Each

	Development Planning	Development Plan
		Study for Best Mix of Power Development (Screening Method)
		Evaluation of Flexibility for Operation
		Study for Optimal Layout of Power Source
		Study for Construction Period
		Evaluation of Flexibility of Development Plan

[Source] JICA Study Team

9.3.2 Schedule of Capacity Development

Though i the capacity for operation and maintenance of generation facilities has declined since the practice stopped from the end of 2006, the new facilities will be commissioned from 2010. Therefore, the capacity for operation and maintenance for the facilities shall be developed as soon as possible. On the other hand, it is necessary to develop synthetically such basic capacity for independently and continuously reliable power supply as operation, maintenance and planning of power generation facilities and power system.
In consideration of these situations, the Capacity Development Plan for the NPA is scheduled shown in Table 9.3-4.

(1) Urgency of Capacity Development for Operation of Diesel Engine Generators

The management techniques for operation and maintenance of diesel engine generators cannot be accomplished in short time and needs deep understanding and experience of the equipment. In case of Generation Division, NPA, capacity development for and the practice of operation and maintenance shall be conducted at the same time, as operation of the new facilities will start from the beginning of 2010. In Table 9.3-4, the time schedule of the practice of operation and maintenance is shown at the top of the table and Capacity Development Plan is established according to the schedule. As capacity development for operation and maintenance is an urgent issue, a long-term expert for “Operation Planning for Generation Facilities” shall be dispatched as fiscal year 2010 starts. The red bars in Table 9.3-4 are processes for urgent capacity development for operation and maintenance of diesel engine generators. The deep red-colored bars show the terms of personnel dispatching.

In case of such developing countries as Sierra Leone, it is difficult to consign maintenance work to maintenance service providers. Therefore, the NPA shall maintain the equipment by itself. Technical staffs for diesel engine generators shall achieve knowledge and skills for such difficult procedures as the internal inspections at major overhauls which require deep understanding and experience of operation and maintenance. In consideration of the current situation of the Generation Division, NPA, it is regarded that it is the first step to master knowledge and skills for operation, before learning knowledge and skills for maintenance. To master operation through dry seasons and rainy seasons, technical transfer for operation shall be scheduled in the first year. But, even in the first year, as 4,000-hour and 8,000-hour overhauls shall be implemented as shown in Table 9.3-4, a short-term expert “Maintenance Planning for Overhauls” shall assist the practice of maintenance work in the term. In addition, as the generation facilities include such electrical equipment as synchronous generators and switchgears, a short-term expert for “Operation and Maintenance Planning for Electrical Equipment” shall be dispatched as shown in Table 9.3-4.

(2) Necessity of Synthetic Capacity Development for Operation, Maintenance and Planning of Generation Facilities and Power Systems

In the NPA, no synthetic technical training program is conducted and technical staffs fundamentally lack technical knowledge and skills for operation, maintenance and planning of the power system. It is necessary to implement technical cooperation for synthetic capacity building for such basic knowledge and skills for independently and continuously reliable power supply. Such synthetic technical cooperation processes are shown by blue bars in Table 9.3-4. In the table, deep blue-colored bars show the terms of personnel dispatching.

1) Capacity Development for Maintenance of Diesel Engine Generators

Maintenance management requires deep understanding of internal combustion engines and running conditions at each part of engines. From the situation of the Generation Division, NPA, a lot of problems are observed for proper maintenance management. Periodical overhauls are the main services of maintenance work of diesel engine generators. Periodical overhauls are composed of such works which require high management techniques as disengaging of cylinder heads, extraction of pistons and connection rods and replacement of main bearings. As equipment and instruments such as overhead crane and hydraulic pump are used in these works, safety control measures shall also be transferred step by step. Therefore, it is predicted that relatively long period is necessary to transfer proper management. As is shown in Table 9.3-4, dispatching of an expert for “Training of Chief Engineer for Engine Maintenance is scheduled along with implementation of periodical overhauls.

But the knowledge and skills achieved through the overhauls implemented a few times in a year are limited. Therefore, it is recommended to transfer knowledge and skills for maintenance effectively at such locations as the manufacturer’s factory in Japan or a garage of a maintenance work provider in a third country by dispatching the staffs of the NPA after their capacity is improved by training in Sierra Leone. Such technical transfers are scheduled before the first 16,000-hour overhaul, 24,000-hour overhaul and 32,000-hour (four years) overhauls in Table 9.3-4, which include important and complicated contents. It is shown in yellow-colored bars in Table 9.3-4. One cycle of the periodical maintenance of the diesel engine generators is four years. To train the whole steps of the periodical maintenance, the capacity development plan shall be scheduled for more than four years.

2) Capacity Development for Operation and Maintenance of Power System

As operation of Bumbuna 161 kV Line will start in near future, the present management for the power system shall be reviewed after commissioning. As improving the current operation conditions for the power system, it is necessary to make control and protection systems conform with new conditions. In addition, as transmission and distribution network of the NPA suffers from a lot of failures caused of deterioration, the technical knowledge and skills for proper repair procedures shall be transferred. For the purpose, personnel for “Training of Chief Engineers for Power System Operation” and “Training of Chief Engineers for Power System Maintenance” are as shown in Table 9.3-4. As the size of the power system in Sierra Leone is not so huge, it is strongly recommended to transfer knowledge and skills for planning as soon as possible after capacity for operation and maintenance of the power system are improved at an early stage.

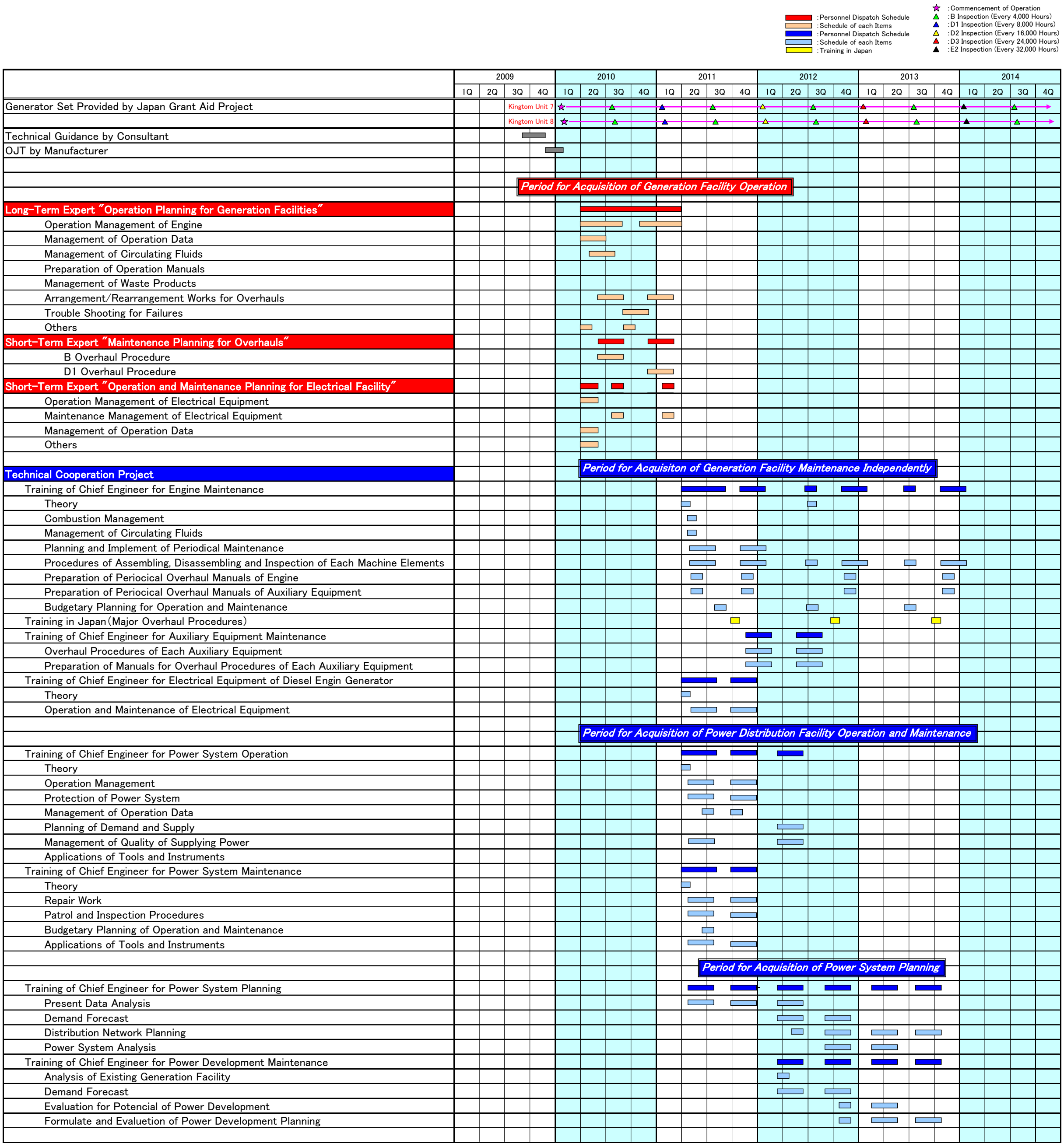
3) Capacity Development for Planning of Generation Facilities and Power Systems

For capacity building for planning, dispatching of personnel for “Training of Chief Engineer for Power System Planning” and “Training of Chief Engineer for Power Development Planning” is scheduled as shown in Table 9.3-4. Concerning Training of Chief Engineer for Power System Planning, so many problems such as deterioration, voltage drop and overload exist in transmission and distribution network of the NPA, especially in low-voltage network. Though it is necessary to start identifying areas of severe voltage drop and overload, a relatively long term will be required for identification as the low-voltage network is composed of huge numbers of equipment.

Even after commissioning of Bumbuna Hydraulic Power Plant which has enough rated output to meet the demand in supply area, additional power plants for dry season will be required. As the technical transfer for maintenance of diesel engine progresses, technical transfer for power development planning shall be scheduled. Though it is recommended to transfer knowledge and skills for power development planning form the early stage, capacity building for maintenance management of diesel engine generators shall be prioritized, as the numbers of technical staffs who have capability to be trained as chief engineers and chief technicians are limited. In the NPA, power system in the future is planned in System Planning Section, Corporate Planning Department. As planning is so significant service for improvement of current situation of the NPA, it is necessary to select carefully superior personnel who are trained as planning engineers from the whole NPA without persisting in staff existing presently in the System Planning Section.

Though consistency of details of technical points such as control systems and protection systems between each generation facility shall be examined by the NPA, as power development planning is a large-scale project, it is necessary that the Ministry of Energy and Water Resources (MEWR) shall control the project. To control the project, technical knowledge shown in Table 9.3-3 shall also be imparted to the concerned staffs of MEWR, as such controls require understanding such technical points as load-frequency characteristics, generator-frequency characteristics and evaluation of existing generation facilities.

Table 9.3-4 Capacity Development Plan for the NPA



[Source] JICA Study Team

9.3.3 Third Country Training

Load dispatching facilities are composed of transformation equipment which shall be reliable and huge numbers of transmission and distribution lines and supports. The technical staffs in charge of the service shall acquire appropriate knowledge and skills for operation and maintenance. Especially, as power companies in developing countries, like the NPA, cannot consign maintenance works such as repair works to maintenance work providers, technical staffs shall acquire properly not only knowledge but also skills for them. For deep understanding of practice procedures, it is effective to acquire knowledge and skills from systematic training programs held in training centers in power companies which have good facilities and programs. To confirm the feasibility of training for technical staffs in neighboring countries around Sierra Leone, the Training Center of Electricity Company of Ghana (hereinafter referred to as ECG) was visited.

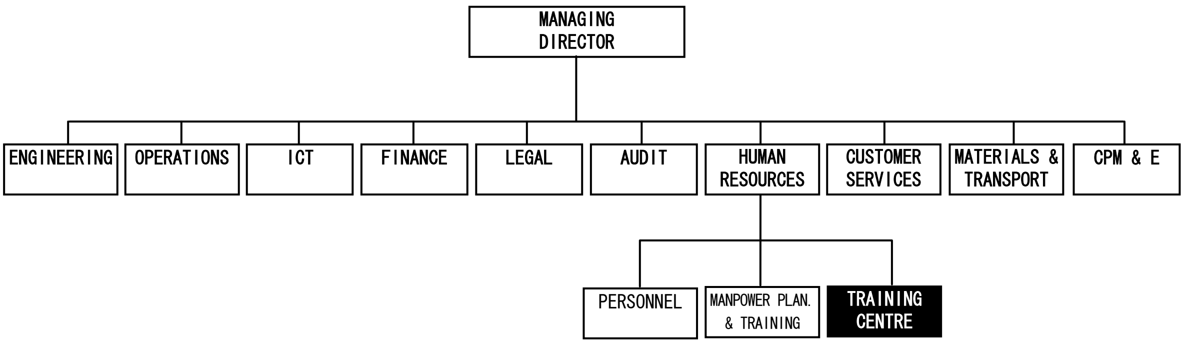
The power system in Ghana is operated and maintained in the formation shown in Table 9.3-5. As the voltage classes of the ECG systems are 33 kV, 11 kV and low voltage, i.e. the same as the NPA, it can be said that ECG Training Center is an appropriate training facility for the NPA.

Table 9.3-5 Framework of Power Companies in Ghana

Department	Entities	Voltage class
Generation	Volta River Authority: VRA	-
Transmission	Ghana Grid Company: GRIDCO	161 kV, 69kV
Distribution	Electricity Company of Ghana: ECG Nothern Electricity Department: NED	33 kV, 11kV and low voltage

[Source] JICA Study Team

The organization chart of ECG is shown in Fig. 9.3-1 and Training Center under Human Resources Department is in charge of practice of capacity building of technical staffs.



[Source] JICA Study Team

Fig. 9.3-1 Organization Chart of ECG

In the center, there are seven full-time instructors. The academic backgrounds and business experiences of the instructors and their subjects are shown in Table 9.3-6. From the table, it is confirmed that the instructors have enough capacity to transfer knowledge and skills for operation and maintenance of power system. Though the number of full-time instructors is seven, in case of lack of instructors, part-time instructors shall be provided from the Engineering Department or Operation Department. The education system in Ghana is shown in Table 9.3-7.

Table 9.3-6 Technical Level of Instructors in ECG

No.	Items	Contents
1.	Academic Background	Master of Electrical Engineering
	Length of Business Experience	19 years
	Subjects to take charge of	Power System Engineering, Power System Simulation
2.	Academic Background	Polytechnical School Part IV Full Technical Certificate
	Length of Business Experience	9 years
	Subjects to take charge of	Operation of Distribution Network
3.	Academic Background	Polytechnical School Part IV Full Technical Certificate
	Length of Business Experience	11 years
	Subjects to take charge of	Distribution Technology
4.	Academic Background	Polytechnical School Part II Electricals
	Length of Business Experience	17 years
	Subjects to take charge of	Safety Measure
5.	Academic Background	Polytechnical School Part IV Full Technical Certificate
	Length of Business Experience	9 years
	Subjects to take charge of	Installation and Maintenance of Substation Equipment
6.	Academic Background	Polytechnical School Part III Electricals
	Length of Business Experience	9 years
	Subjects to take charge of	Installation and Maintenance of Overhead Lines and Cables
7.	Academic Background	High National Diploma
	Length of Business Experience	4 years
	Subjects to take charge of	Installation and Maintenance of Overhead Lines

[Source] ECG Training Center

Table 9.3-7 Education System in Ghana

University Education	Polytechnical Education
Elementary School	
Junior Secondary School	
Secondary School	
University	Polytechnical School Part I Part II Part III Part IV Full Technological Certificate
Graduate School	

[Source] JICA Study Team

The only training program actually implemented in the center is shown in Table 9.3-8. It is the program for new employees in charge as technicians of the Transmission and Distribution Division, ECG. It lasts ten months, then the trainees engage in on-the-job training after training in the center for twelve months, and then, lastly, they go back to the center for evaluation of achievement for two months. Concerning graduates form universities, there is no specified training program.

Table 9.3-8 Contents of Training in ECG Training Center

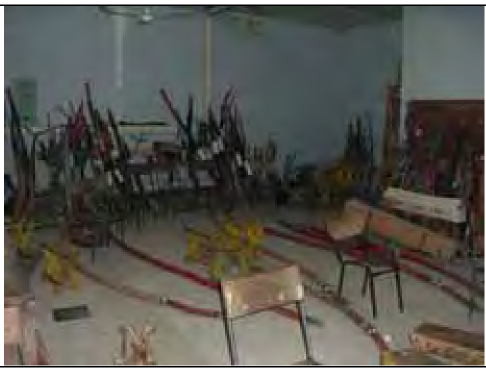
Classification	Subjects
Theory	Overhead Line Construction Procedures Underground Line Construction Procedures Operation and Maintenance of Transformers Operation of Distribution Network Machine Works Distribution Technology
Practice	Low Voltage Cable Jointing 11 kV Cable Jointing and Termination 33 kV Cable Jointing and Termination Basic Substation Maintenance Basic Operation of Distribution Network Meter Installation Construction of Overhead Line Transformer Erection and Maintenance Safety Measure for Construction of Overhead Line Pole Erection Techniques

[Source] ECG Training Center

The photographs of the center are shown in Table 9.3-9. Such efficient equipment for understanding of structures and protection of power system as operation simulator are confirmed. Though such equipment as transformation practice equipment, cable joint and termination practice materials are deteriorated, they have enough functions for technical staffs, but the NPA does not have experience of systematic and basic technical training in the past. Though the program is finished for ten months in ECG, the program shall be finished within the effective schedule for technical staffs. It will be achieved by the conditions that, for example, cable jointers shall be trained with focus on works concerning cable jointing and termination, and linesmen shall be trained with focus on works concerning overhead lines. The rainy season, which includes many system failures, shall be avoided as the time of the training. It shall be held in dry seasons from January to April.

From the viewpoint of technical level of instructors and facilities in the center, though it is not enough for personnel who graduate from electrical engineering courses of university and shall be trained as chief engineers, it is suitable for technicians who shall be trained as chief engineers and do not have experience of systematic and basic trainings.

Table 9.3-9 Conditions of ECG Training Center

	
Entrance Sign	Support Assembling Yard
	
Practice Rooms	Lecture Rooms
	
Cable Practice Room	Lecture Room (Middle Size)
	
Power System Simulator	Dormitory for Trainees

10. Conclusions and Recommendations

10.1 Conclusions

In order to meet the growing power demand in the future and to supply stable and reliable power in Western Area, the power supply system rehabilitation and expansion projects described in the following section 10.1.1 and 10.1.2 are recommended to be completed by 2025. Revision of electricity tariff explained in section 10.1.3 is recommended in order for the NPA to manage investment for the development of power supply system and to be an independent and sustainable entity.

10.1.1 Power Development Planning

High-speed and middle-speed diesel engine generators and Yiben-I hydroelectric power plant are to be developed in line with the schedule indicating completion year and capacity as shown in Table 10.1-1. Investment cost for such power development is described in Table10.1-2 and total investment requires approximately US$268 million.

Table 10.1-1 Power Development Plan (Hydro Dominant Scenario)

Unit: MW

Year	High-speed Diesel (MW) (1.8MW/unit)	Mid-speed Diesel (MW) (8.0MW/unit)	Yiben-I Hydro (MW) (20.5MW/unit)	Annual Total (MW)
2010	5.4			5.4
2011		8.28		8.3
2012	1.8			1.8
2013	5.4			5.4
2014	3.6			3.6
2015	1.8	8.0		9.8
2016		8.0		8.0
2017		8.0		8.0
2018		8.0		8.0
2019	(-18.0)		61.5	61.5
2020				0.0
2021				0.0
2022				0.0
2023				0.0
2024				0.0
2025				0.0
Total	**18.0**	**40.3**	**61.5**	**119.8**

Table 10.1-2 Investment for Power Development

Unit：US$million, expressed in Y2009 price

Year	High-speed Diesel (1.8MW/unit)	Mid-speed Diesel (8.0MW/unit)	Yiben-I Hydro (20.5MW/unit)	Annual Investment Cost	Cumulative Investment Cost
2010	2.48	3.01		5.49	5.49
2011	0.00	12.03		12.03	17.52
2012	0.83	0.00		0.83	18.35
2013	2.48	0.00		2.48	20.83
2014	1.66	2.76		4.42	25.25
2015	0.83	13.80		14.63	39.87
2016	0.00	13.80	28.44	42.24	82.11
2017	0.00	13.80	66.35	80.15	162.26
2018	0.00	11.04	66.35	77.39	239.66
2019	0.00	0.00	28.44	28.44	268.09
2020	0.00	0.00		0.00	268.09
2021	0.00	0.00		0.00	268.09
2022	0.00	0.00		0.00	268.09
2023	0.00	0.00		0.00	268.09
2024	0.00	0.00		0.00	268.09
2025	0.00	0.00		0.00	268.09
Total	**8.28**	**70.23**	**189.58**	**268.09**	

10.1.2 Improvement of Distribution System

Rehabilitation, enhancement and expansion of distribution network until 2025 as shown in Table 10.1-3 shall be implemented by dividing the planning period by 5 year-windows. The total investment costs approximately US$172 million. Even though this Master Plan does not take interconnection of WAPP and national grid into consideration, in case when these transmission lines are realized and connected to the Western Area power system, the following distribution rehabilitation, enhancement and expansion projects should be reviewed and revised based on power system analysis on new network configuration.

Table 10.1-3 Distribution Rehabilitation, Enhancement and Expansion Plans

No.	Project Packages	Major Components	Target Year	Cost (10^6US$)
Phase-I (from 2010 to 2015)				
1	Rehabilitation of 11 kV and Improvement of 33 kV System	1) Improvement of 33 kV system at Kingtom P/S	2012	25.6
		2) Construction of 33 kV line from Kingtom to Falcon Bridge S/S (about 2 km)		
		3) Construction of 33 kV line from Kingtom to Blackhall Road P/S (about 4 km)		
		4) Construction of 11/33kV Substation at Falconbridge S/S		
		5) Rehabilitation of 11 kV switchgears		
2	Construction of 33 kV System in Goderich and Jui Area	1) Construction of 33 kV line from Wilberforce S/S to Goderich S/S (about 7 km)	2014	35.4
		2) Construction of 33 kV line from Wellington S/S to Jui S/S (about 13 km)		
		3) Construction of Goderich and Jui S/S		
		4) Improvement of 11 kV lines and extension of LV system		
3	Improvement of 11 kV Distribution Facilities	1) Replacement of old 11 kV transformers (more than 40 years)	2015	30.0
		2) Replacement of old 11 kV transformers (more than 30 years)		
		3) Rehabilitation of existing 11 kV facilities		
		4) Promote new customer connections around Goderich and Jui S/S		
		Sub-total		**91.0**
Phase-II (from 2016 to 2020)				
1	Construction of 33 kV System in Lumpa and Tombo Area	1) Construction of Lumpa S/S and 33 kV line from Jui S/S to Lumpa S/S (about 15 km)	2017	33.7
		2) Construction of Tombo S/S and 33 kV line from Lumpa to Tombo S/S (about 17 km)		
		3) Electrification around Lumpa and Tombo S/S		
2	Expansion of 33 kV System and Improvement of Network	1) Installation of 161/33 kV transformer (60/80 MVA, OLTC with AVR) at Freetown S/S	2020	31.4
		2) Construction of 33 kV line from Goderich S/S to York town (29 km)		
		3) Rehabilitation of 11kV trunk lines and electrification		
		Sub-total		**65.1**
Phase-III (from 2021 to 2025)				
1	Expansion of Distribution Network	1) Construction of 33 kV line from Lumpa S/S to Fogbo town (about 16 km)	2025	16.3
		2) Construction of 33 kV lines from York S/S to Tombo S/S (about 20 km)		
		3) Extension of 11kV lines and electrification		
		Sub-total		**16.3**
		Grand Total		**172.4**

10.1.3 Revision of Electricity Tariffs

In the case where the power development scenario is the hydro dominant case and the Bumbuna hydro power purchase price is 7 cents/kWh, it is necessary for the NPA to set the average tariff at 27 cents/kWh shown in Table 10.1-4 for the purpose of enabling the NPA to sustain financially with investment of facilities planned by the Master Plan.

Table 10.1-4 Revised Tariff Plan

Category	Subcategory	Old tariff (before Dec. 2008)		Proposed tariff
		Le/kWh	US cents/kWh	US cents/kWh
Household	0-30 kWh	373	11.7	23
	31-150 kWh	533	16.8	
	Above 150 kWh	709	22.3	
Commercial	0-30 kWh	651	20.5	34
	31-150 kWh	781	24.6	
	Above 150 kWh	846	26.6	
Industrial	All units	941	29.6	28
Average	—	816	25.7	27

[Note] US$1 = 3,179 Le

Preconditions of proposed tariff calculation

- Power development scenario: hydro main case
- Power purchase price from Bumbuna: 7 cents/kWh
- System loss: improved from 40% in 2009 to 15% in 2025
- Collection rate: improved from 70% in 2009 to 95% in 2025
- Long-term liability: repayment by the NPA supposed to continue

10.2 Recommendations

10.2.1 Recommendations concerning PPP (Public-Private Partnership) Introduction into Power Development

It is difficult for the Government of Sierra Leone with financial difficulties to give funds to power facility investment even if facilities belong to the electricity sector with high priority. In addition, donor support is not sufficient to invest in the power sector in which demand is increasing. Furthermore, there are no funds and time for the NPA to attain worldwide levels of technical knowhow and efficient management quickly. Therefore, it is very necessary to introduce private activities in order to realize the power development plan in this Master Plan. Concretely, private entry including foreign companies is a theme on the occasion of IPP introduction and NPA participation. However, the NPA is suffering from chronic deficiency and needs the government support and technical capacity building so that it has a lot of issues to solve before the privatization which seems a long way off in the future although the privatization of the NPA is included in the long-term strategy of NCP.

While private generation companies have participated in urgent generation (rental power) already, it is necessary to introduce private company activities from now on. It requires establishment of the following conditions to introduce private activities in future Sierra Leone smoothly.

- Establishment of legal institutions
  It is necessary to establish laws and regulations arranging investment conditions to introduce the private sector without problems so that the private sector can participate without anxiety. Undoubtedly, since it will be a problem only if the situation changes from public monopoly to private monopoly, the laws and regulations of the process below based on the competition policies are necessary. Contracts, implementation, penalties, etc. are prescribed.
- Establishment of transparent and fair introduction process
  It is necessary to establish transparent processes such as public participation invitation and tender which can ensure fair competition. In addition, it is essential to establish an independent regulating organization to monitor and supervise these processes.
- Clarification of roles and risks born by the public and private sectors
  Share of the roles, in particular, risks, between the government and private sector should be designed appropriately in order to complete the project successfully without cancellation or

suspension. Treating the private sector too well may cause too much government burden, whereas pushing too many risks onto the private sector may cause no entry so that balance is necessary. Study on the past best practices and suitable adviser's consultation are necessary.

- Investment promotion policies
  Private investment promotion policies such as government's guarantee of power projects which the private sector enters, incentive tax systems and abolition of foreign investment restriction should be implemented. Since Sierra Leone Investment and Export Promotion Agency (SLIEPA) established in May 2007 is attracting investors and doing publicity work in Sierra Leone, it is desirable that the Ministry of Finance and Economic Development, Ministry of Energy and Water Resources and SLIEPA cooperate to promote investment in the power sector much more.

A standard process of PPP introduction as an example of private introduction into public works is shown in Fig. 10.2-1.

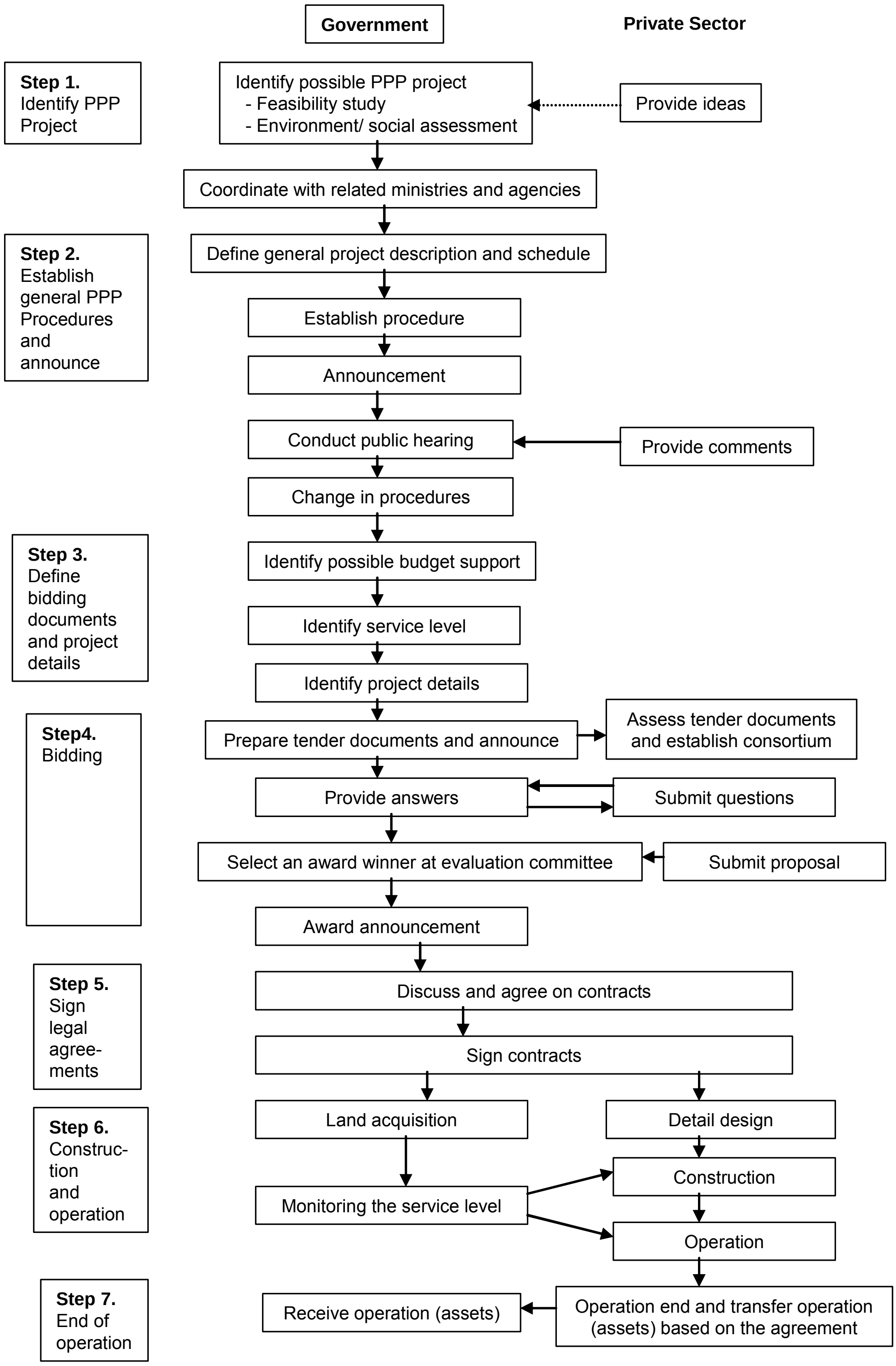
On the other hand, private introduction requires attention. There has already been an example where rental power introduction brought about high costs because of the free contract. Therefore, the competitive process described above is necessary. Indonesia and the Philippines had problems after IPP introduction. For instance, the government introduced IPP responding to lack of power supply in the 1990s in the Philippines. However, high price agreements have made the National Power Corporation (NPC) and later the liquidation organization (Power Sector Assets and Liabilities Management Corporation established by the government to dispose NPC's stranded liabilities and stranded IPP contract costs before the unbundling and privatization of NPC) suffer from huge liabilities and annual adverse income/costs of IPP are still continuing now. Therefore, universal charge imposed on electricity consumers may be increased so that the burden is transferred to the consumers.

In the case of a project close to a monopoly such as electricity supply business, there is a case where tariff negotiation between the government and electricity company is decided with the following formula.

Tariff increase rate = CPI (Consumer Price Index) – alpha

Here, alpha is a productivity improvement goal which is negotiated between the government and operator so that appropriate tariffs can be attained.

Privatization of the NPA is a long-term future matter and it is necessary to attain profits financially and train the staff so that they can operate and maintain technically before the privatization. After the NPA becomes an independent public corporation, it will be necessary to re-examine the privatization and unbundling. At present, NCP has a long-term strategy to unbundle the NPA to generation, transmission and distribution and privatize each, but it should reconsider how to privatize the NPA when it can become independent. It will be necessary to examine desirable aspects of power sector in Sierra Leone because international competitiveness may be necessary when West Africa Power Pool (WAPP) is established. There are some examples of electricity companies without unbundling in the world and it is not necessary to decide how to privatize the NPA at present in a hasty way.



[Source] JICA, "Public-private Partnership (PPP) Program for Cairo Urban Toll Expressway Network Development," March 2006

Fig. 10.2-1 Standard PPP Introduction Process

10.2.2 Recommendations concerning Transmission and Distribution System

(1) 161 kV Bumbuna Transmission Line

In the future, power supply to Western Area will largely depend on hydroelectric power plants such as Bumbuna, Yiben, etc. However, the only transmission line that sends electricity from those hydro power plants to the capital region is 161kV-single circuit Bumbuna line. Therefore, system load must be reduced to the level that is equal to diesel generators' capacity connected to the Kingtom's bus bar on that occasion if an accident occurs on the Bumbuna line, as explained in section 6.4 6) power frequency calculation and 7) stability analysis. The Bumbuna line has the length of approximately 205 km and there is a high possibility of line accident and shut down. If such situation happens, the functions of the capital region will be heavily impeded. In order to avoid such catastrophe, it is highly recommended to implement the following countermeasures.

1) The Western Area power system should be interconnected with cross-border transmission link. The desirable location of new substation will be such that;
   - Power supply is hampered when the existing 161 kV line is out,
   - A load dispatch center can be easily constructed in the future, and
   - No negative impact on the environment is anticipated.

   One of the recommended nominal 230 kV transmission line routes is Mano-Kenema-Bo-Makongo-Lumpa but final decision shall be made through the comprehensive examination on future road plan, demand forecast and conservation areas.

2) Diesel generators which are connected to the Western Area power system might be disconnected if fast load cut back is impossible in case of Bumbuna line outage. This will lead to the collapse of whole Western Area power system. In order to minimize blackout area, it is necessary to cut back system load as soon as possible. To do so, preliminary system flow monitoring, transmission of accident information on Bumbuna line, calculation of the amount of load cut back after an accident happens, and automated load cut back systems should be equipped. In addition, prioritization of feeders at each substation should be defined beforehand.

(2) Operation of Loop System

In the Western Area power system, system configuration that is suitable for loop system operation is preferred and actually the system is composed of complicated multi-loops. A loop system has an advantage in that blackout can be avoided by sending power from a normal path in case an N-1 accident happens. On the other hand, a loop system has the disadvantage that it is difficult to monitor power flow and system operators and planners are required to have higher skills compared with radius network.

In order to maximize the advantages of loop system, it is necessary to establish a distribution network which can cater to change of power flow in case of an accident. Careful system analyses on trunk distribution lines and the selection of configuration of network which will meet various load patterns should be conducted in advance. In addition, loop system operation should be accompanied with the modification of the existing system (adoption of frequency relays, etc.). Furthermore, training for system operators and planners and the introduction of supporting system on system operation and planning would be necessary.

10.2.3 Recommendation for Environmental and Social Considerations in the Future

10.2.3.1 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 the 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 their ecosystems, 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 is 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. As with the population data or accurate maps for resettlement, the information on protected areas and ecosystem for environmental protection are necessary. Therefore, it is required 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 ecosystems through their activities than the government. It is worth cooperating with them.

10.2.3.2 Recommendations to NPA on Environmental and Social Considerations

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

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 an environmental management system to monitor and manage 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 Power Station 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 33 kV 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 33 kV line under the power and water project of the World Bank were 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.

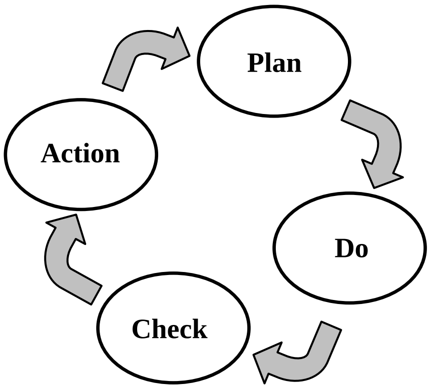
Even though the two of them participated in the projects above, the role of them was still limited. Because, it was not the NPA that took initiative but it was the World Bank and the consultants. The two officers think their knowledge and capacity are not adequate enough to carry out their work. The 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.

In addition, 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. 10.2-2 PDCA Cycle

Table 10.2-1 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, following steps will be needed.

1) Establish an environmental unit

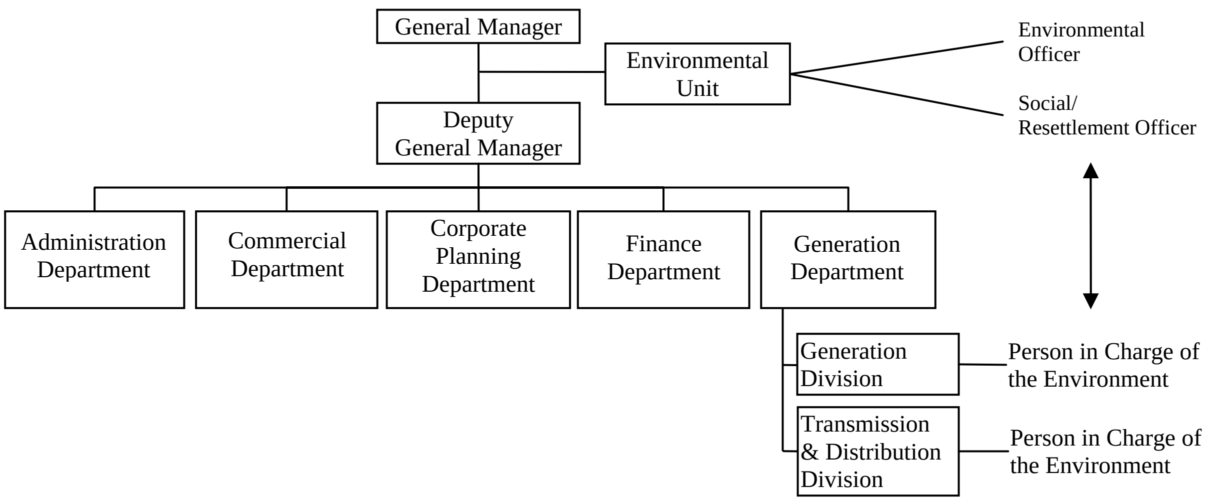
It is ideal to have an environmental department consisting of several qualified staff in the future. But it is not feasible to create this kind of environmental department from the current condition of the NPA. As a first step, it is recommended to create an environmental unit under the direct supervision 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. The TOR of the officers is as follows. It is encouraged to hire new staff members who have basic knowledge and qualifications.

Table 10.2-2 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. 10.2-3 Organization Chart of the NPA

2) Develop environmental policy and management plan

The environmental officers with 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 a generator of wastes should take adequate measures.

In addition, development of an EIA guideline to help the NPA officers assess environmental and social impacts of a new project is highly 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 NPA EIA guideline. In particular, the standards of donors' for resettlement are more effective for protecting 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 actions for the environmental protection needs to be secured. The budget includes 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 costs 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 plan is expected to be created for the monitoring purpose. When the NPA has a hydro power plant, it will be necessary to buy additional monitoring equipment.

5) Participate and organize training

It is required to give a chance to take technical training for the environmental officers and social/ resettlement officers to equip advanced knowledge. A seminar or training on EIA or environmental monitoring is recommended for environmental officers. 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 conducted.

The current environmental disaster in the power plants 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 emissions
2. Noise emissions
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 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 will improve the operation structure of the NPA in order to take environmental and social issues into consideration.

Appendices

1. Distribution System Rehabilitation, Upgrade and Expansion Programs

Distribution Project Packages and Components

No.	Project Packages	Major Components	Financial Resources	Target Year	Cost (10^6US$)	Remarks
A:	**Phase-I (from 2010 to 2015)**					
1	Rehabilitation of 11 kV and Improvement of 33 kV System	1) Improvement of 33 kV system at Kingtom P/S 2) Construction of 33 kV line from Kingtom to Falcon Bridge S/S (about 2 km) 3) Construction of 33 kV line from Kingtom to Blackhall Road P/S (about 4 km) 4) Construction of 11/33kV Substation at Falconbridge S/S 5) Rehabilitation of 11 kV switchgears		2012	25.6	
2	Construction of 33 kV System in Goderich and Jui Area	1) Construction of 33 kV line from Wilberforce S/S to Goderich S/S (about 7 km) 2) Construction of 33 kV line from Wellington S/S to Jui S/S (about 13 km) 3) Construction of Goderich and Jui S/S 4) Improvement of 11 kV lines and extension of LV system		2014	35.4	
3	Improvement of 11 kV Distribution Facilities	1) Replacement of old 11 kV transformers (more than 40 years) 2) Replacement of old 11 kV transformers (more than 30 years) 3) Rehabilitation of existing 11 kV facilities 4) Promote new customer connections around Goderich and Jui S/S		2015	32.0	
	3 packages	**Sub-total**			**93.0**	
B:	**Phase-II (from 2016 to 2020)**					
1	Construction of 33 kV System in Lumpa and Tombo Area	1) Construction of Lumpa S/S and 33 kV line from Jui S/S to Lumpa S/S (about 15 km) 2) Construction of Tombo S/S and 33 kV line from Lumpa to Tombo S/S (about 17 km) 3) Electrification around Lumpa and Tombo S/S		2017 2017	33.7	
2	Expansion of 33 kV System and Improvement of Network	1) Installation of 161/33 kV transformer (60/80 MVA, OLTC with AVR) at Freetown S/S 2) Construction of 33 kV line from Goderich S/S to York town (29 km) 3) Rehabilitation of 11kV trunk lines and electrification		2020	31.4	
	2 packages	**Sub-total**			**65.1**	
C:	**Phase-III (from 2021 to 2025)**					
1	Expansion of Distribution Network	1) Construction of 33 kV line from Lumpa S/S to Fogbo town (about 16 km) 2) Construction of 33 kV lines from York S/S to Tombo S/S (about 20 km) 3) Extension of 11kV lines and electrification		2025	16.3	
	1 package	**Sub-total**			**16.3**	
		Grand Total			**174.4**	

Phase-I: Emergency Program (1/3)

1. Title	**Rehabilitation of 11 kV and Improvement of 33 kV System**
2. Location	Freetown Area
3. Implementing Agency	National Power Authority (NPA)
4. Objectives	Rehabilitation of 11 kV switchgears and improvement of 33 kV system from Kingtom P/S to Blackhall Road via Falcon Bridge,
5. Expected Effects	1) Establishment of reliable power supply, 2) Reducing energy losses, and 3) Reducing unexpected power cut off
6. Investment Cost	US$25.6 Million

7. Description:

The power supply to the Falcon Bridge area is coming from Kingtom and Blackhall Road P/S by 11 kV lines. There are three (3) trunk lines from Kingtom P/S and two (2) trunk lines from Blackhall Road P/S.

However, these lines are not so reliable because underground cables are too old and it is very difficult to repair them because theses cables are installed along with paved roads which are always congested by traffic and passengers.

The electric power supply to the areas will contribute to the improvement of social infrastructure, economical and industrial development as well as the improvement of living conditions for residents. The projects prepared as a part of the Master Plan shall be studied in the subsequent stage such as Feasibility Study.

Basic plans and designs should be prepared for other parts. And basic planning will follow the same procedure as taken for the area considering power supply route, etc. which may consist of the following:

1) Study power flow and system analysis including load density and protection system,
2) Conduct environmental assessment, and
3) Prepare detailed design considering existing conditions.

8. Major Components of the Project;

1) Rehabilitation of protection and metering system in 11 kV switchgear at existing major substations and junction stations,
2) Construction of 11/33 kV substation at Falcon Bridge S/S, and
3) Construction of 33 kV systems from Kingtom P/S, Falcon Bridge S/S and Blackhall Road P/S

9. References;

1) Route Map for 33 kV Distribution Line (Western Area) (DWG No. GR-2025-1)
2) Route Map for 33 kV Distribution Line (Western Urban) (DWG No. GR-2025-2)
3) Western Area Power System 2025 (DWG No. GE-2025)
4) Western Area Network (Western Part 2009) (DWG No. GE-2009-1)
5) Western Area Network (Eastern Part 2009) (DWG No. GE-2009-2)
6) 11/33 kV Switchgear Feeders: Kingtom P/S (100) (DWG No. KT-E1)
7) 11/33 kV Switchgear Feeders: Falconbridge S/S (200) (DWG No. FB-E1)
8) 11/33 kV Switchgear Feeders: Blackhall Road P/S (300) (DWG No. BR-E1)

Phase-I: Emergency Program (2/3)

1. Title	**Improvement of 33 kV System in Goderich and Jui Area**
2. Location	Western Area
3. Implementing Agency	National Power Authority (NPA)
4. Objectives	Improvement of 33 kV system and construction of Goderich and Jui S/S and expansion of LV system
5. Expected Effects	1) Establishment of stable power distribution system, 2) Reducing energy losses, and 3) Promotion of rural electrification
6. Investment Cost	US$35.4 Million

7. Description:

The power supply to Goderich and Jui areas is not stable and not enough because present power distribution system is 11 kV which cannot dispatch enough power.

There are a lot of residences around Goderich and small industry around Jui area. The electric power supply to the areas will contribute to the improvement of social infrastructure, economical and industrial development as well as the improvement of living conditions for residents.

The projects prepared as a part of the Master Plan shall be studied in the subsequent stage such as Feasibility Study.

Basic plans and designs should be prepared for other parts. And basic planning will follow the same procedure as taken for the area considering power supply route, etc. which may consist of the following:

1) Study demand and future development plans,
2) Conduct environmental assessment, and
3) Prepare detailed design considering existing conditions.

8. Major Components of the Project;

1) Expansion of 33 kV line about 30 km,
2) Construction of 11/33 kV Substation at Goderich and Jui Area, and
3) Improvement of the existing 11 kV system and expansion of LV system.

9. References;

1) Route Map for 33 kV Distribution Line (Western Area) (DWG No. GR-2025-1)
2) Route Map for 33 kV distribution Line (Western Urban) (DWG No.GR-2025-2)
3) Western Area Power System 2025 (DWG No. GE-2025)
4) 11/33 kV Switchgear Feeders: Wilberforce S/S (600) (DWG No. WF-E1)
5) 11/33 kV Switchgear Feeders: Wellington S/S (700) (DWG No. WN-E1)
6) 11/33 kV Switchgear Feeders: Regent S/S (800) (DWG No. RT-E1)
7) 11/33 kV Switchgear Feeders: Goderich S/S (1000) (DWG No. GR-E1)
8) 11/33 kV Switchgear Feeders: Jui S/S (1100) (DWG No. JU-E1)

Phase-I: Emergency Program (3/3)

1. Title	**Improvement of 11 kV Distribution Facilities**
2. Location	Western Area
3. Implementing Agency	National Power Authority (NPA)
4. Objectives	Replacement of old transformers with related facilities and improvement of 11 kV system
5. Expected Effects	1) Establishment of stable power supply system, 2) Reducing energy losses, and 3) Promotion of rural electrification
6. Investment Cost	US$32.0 Million

7. Description:

There are a lot of old distribution transformers which total capacity is about 10 MVA for more than 40 years old and about 16 MVA for more than 30 years old and also these are not only faulty but also the cause of increasing of energy losses.

Goderich and Jui area are one of developing area which requires sufficient and stable power supply.

The projects prepared as a part of the Master Plan shall be studied in the subsequent stage such as Feasibility Study.

Basic plans and designs should be prepared for other parts. And basic planning will follow the same procedure as taken for the area considering power supply route, etc. which may consist of the following:

1) Study demand and future development plans,
2) Conduct environmental assessment, and
3) Prepare detailed design considering existing conditions.

8. Major Components of the Project;

1) Replacement of more than 40 years old transformers (About 10 MVA),
2) Replacement of more than 30 years old transformers (about 16 MVA),
3) Replacement Ring Main Unit, fuse cut out switch and installation of lightning arresters,
4) Promotion of rural electrification, and
5) Improvement of power sector and review of Master Plan.

9. References;

1) General Route Map of Freetown Area (DWG No. RM-G01)
2) Route Map of Area-1 of Freetown (DWG No.RM-D01)
3) Route Map of Area-2 of Freetown (DWG No.RM-D02)
4) Route Map of Area-3 of Freetown (DWG No.RM-D03)
5) Route Map of Area-4 of Freetown (DWG No.RM-D04)
6) Western Area Power System 2025 (DWG No. GE-2025)
7) Western Area network (Western Part 2009) (DWG No. GE-2009-1)
8) Western Area network (Eastern Part 2009) (DWG No. GE-2009-2)
9) 11/33 kV Switchgear Feeders: Congo Cross J/S (DWG No. CC-E1)
10) 11/33 kV Switchgear Feeders: Brookfield J/S (DWG No. BF-E1)

Phase-II: Improvement Program (1/2)

1. Title	**Improvement of 33 kV System**
2. Location	Western Area
3. Implementing Agency	National Power Authority (NPA)
4. Objectives	Expansion of 33 kV lines with construction of Lumpa and Tombo S/S and rural electrification
5. Expected Effects	1) Improvement of 33 kV system, 2) Reducing energy losses, and 3) Promotion of rural electrification
6. Investment Cost	US$33.7 Million

7. Description:

There are a lot of non-electrified areas especially in rural areas. Lumpa and Tombo area are developing areas which require sufficient and stable power supply.

The projects prepared as a part of the Master Plan shall be studied in the subsequent stage such as Feasibility Study.

Basic plans and designs should be prepared for other parts. And basic planning will follow the same procedure as taken for the area considering power supply route, etc. which may consist of the following:

1) Study demand and future development plans,
2) Conduct environmental assessment, and
3) Prepare detailed design considering existing conditions and safety rules.

8. Major Components of the Project;

1) Expansion of 33 kV lines about 32 km,
2) Construction of Lumpa and Tombo S/S,
3) Expansion of LV system around Lumpa area, and
4) Promotion of rural electrification around Tombo area.

9. References;

1) Route Map for 33 kV Distribution Line (Western Area) (DWG No. GR-2025-1)
2) Route Map for 33 kV Distribution Line (Western Urban) (DWG No. GR-2025-2)
3) Western Area Power System 2025 (DWG No.GE-2025)
4) 11/33 kV Switchgear Feeders: Jui S/S (1100) (DWG No.JU-E1)
5) 11/33 kV Switchgear Feeders: Lumpa S/S (1200) (DWG No.LP-E1)
6) 11/33 kV Switchgear Feeders: Tombo S/S (1300) (DWG No. TB-E1)

Phase-II: Improvement Program (2/2)

1. Title	**Expansion of 33 kV System and Improvement of Network**
2. Location	Western Area
3. Implementing Agency	National Power Authority (NPA)
4. Objectives	Expansion of Freetown S/S and rural electrification
5. Expected Effects	1) Establishment of stable 33 kV system, 2) Reducing energy losses, and 3) Promotion of rural electrification
6. Investment Cost	US$31.4 Million

7. Description:

Electric power demand is increasing in proportion with economic development and new power stations will be constructed, however the 33 kV system capacity at Freetown S/S is not sufficient.

It is necessary to expand 33 kV system to comply with requirements. Accordingly, new 161/33 kV transformer shall be installed in the Freetown S/S and also it is necessary to expand trunk lines.

Also promote rural electrification around York area which is a leisure venue.

The projects prepared as a part of the Master Plan shall be studied in the subsequent stage such as Feasibility Study.

Basic plans and designs should be prepared for other parts. And basic planning will follow the same procedure as taken for the area considering power supply route, etc. which may consist of the following:

1) Study demand and future development plans,
2) Conduct environmental assessment, and
3) Prepare detailed design considering existing conditions and safety rules.

8. Major Components of the Project;

1) Installation of 1-161/33 kV, 60/80 MVA transformer at Freetown S/S,
2) Extension of 33 kV line from Goderich S/S to York area about 29 km with required distribution transformers along with lines, and
3) Promotion of rural electrification.
4) Improvement of 11 kV system

9. References;

1) Route Map for 33 kV Distribution Line (Western Area) (DWG No. GR-2025-1)
2) Route Map for 33 kV Distribution Line (Western Urban) (DWG No. GR-2025-2)
3) Western Area Power System 2025 (DWG No.GE-2025)
4) 11/33 kV Switchgear Feeders: Freetown S/S (900) (DWG No.FT-E1)
5) 11/33 kV Switchgear Feeders: Goderich S/S (1000) (DWG No.GR-E1)
6) Western Area Network (Western Part 2009) (DWG No. GE-2009-1)
7) Western Area Network (Eastern Part 2009) (DWG No. GE-2009-2)

Phase-III: Secure and Reliable Program (1/1)

1. Title	**Improvement of Distribution Network**
2. Location	Western Area
3. Implementing Agency	National Power Authority (NPA)
4. Objectives	Expansion of 33 kV system and rural electrification
5. Expected Effects	1) Establishment of secure and reliable network, 2) Reducing energy losses, and 3) Promotion of rural electrification
6. Investment Cost	US$16.3 Million

7. Description:

Electric power demand is increasing in proportion with economic development, and a more secure, reliable and qualified power supply system is required.

In order to have enough power supply to demand, it is necessary to consider international transmission lines. However before connection to neighboring country systems, it is required to complete Power Purchase Agreement (PPA) and confirm protection coordination and also it is necessary to establish Load Dispatching Center (LDC) to have stable and economic power supply system.

The projects prepared as a part of the Master Plan shall be studied in the subsequent stage such as Feasibility Study.

Basic plans and designs should be prepared for other parts. And basic planning will follow the same procedure as taken for the area considering power supply route, etc. which may consist of the following:

1) Study demand and future development plans,
2) Conduct environmental assessment, and
3) Prepare detailed design considering existing conditions and safety rules.

8. Major Components of the Project;

1) Expansion of 33 kV line from Lumpa S/S to Fogbo town about 16 km,
2) Extension of 33 kV line from York to Tombo S/S about 22 km with required distribution transformers along with lines,
3) construction of 11 kV system from Tombo S/S to Kent town about 13 km,
4) Improvement of 11 kV system,
5) Promotion of rural electrification, and
6) Protection coordination with neighboring countries.

9. References;

1) Route Map for 33 kV Distribution Line (Western Area) (DWG No. GR-2025-1)
2) Western Area Power System 2025 (DWG No.GE-2025)
3) 11/33 kV Switchgear Feeders: Lumpa S/S (1200) (DWG No.LP-E1)
4) 11/33 kV Switchgear Feeders: Tombo S/S (1300) (DWG No.TB-E1)

2. Operation and Maintenance Guidelines for Power Supply Facilities

Part-1: Operation and Maintenance of Diesel Engine Generator

1. Operation and Maintenance of Diesel Engine Generator

(1) Operation Standards for Diesel Engine Generator

Diesel engine generators are composed of many kinds of exactly designed machine elements. Without appropriate operation and maintenance, early breakdown of engine will be unavoidable instead of fulfilling its lifetime, as engines are operated under high pressure, high temperature and high speed, which are most severe conditions for mechanical materials. Operation Standards for Diesel Engine Generators are shown in Table 1-8. It is necessary to train the shift staffs to be able to operate the diesel engines properly.

(2) Maintenance Standards for Diesel Engine Generator

As diesel engines are operated in such severe conditions necessarily, appropriate maintenance is necessary with deep understanding of the principles and structures such as periodical replacement of spare parts, inspection of internal damage at rubbing surface and location exposed to high temperature, and sticking of combustion residue. Maintenance Guidelines for Diesel Engine Generators are shown in Table 1-11. In the maintenance work, high management capacity of the work is necessary, because the work includes such processes as disassembling of engine and reassembling with careful measurement of dimensions, confirmation of fitting and tightening torque. In addition, inspections after assembling need knowledge and skills to evaluate internal damage degrees in accordance with understanding of internal-combustion engine.

(3) Management Standards of Fuel Oil

Fuel oil shall be managed in accordance with the criteria shown in Table 1-1.

(4) Management Standards of Cooling Water

Cooling water shall be managed in accordance with the criteria shown in Table 1-2.

(5) Management Standards of Lubrication Oil

Lubrication oil shall be managed in accordance with the criteria shown in Table 1-3 and Table 1-4. And products which meet the criteria are shown in Table 1-5.

Table 1-1 Management Criteria of Fuel Oil

Item	Management Criteria: Heavy Oil A	Management Criteria: Heavy Oil C	Obstacle
Density at 60 °F (15.6℃)	Max. 0.853 g/cm^3	Max. 0.96 g/cm^3	Separability of water content
Kinematic viscosity at 122 °F (50℃)	Max. 2.9 mm^2/s (cSt)	Max. 175 cSt	Atomization, Combustibility
Flash point	Min. 80 ℃	Min. 150 °F (65.6℃)	Hazard
Pour point	Max. -10 ℃	Max. 75 °F (23.9℃)	Fluidity
Carbon residue	Max. 1.3 wt.% *	Max. 12.0 wt.%	Wear, Degradation of Lubrication Oil
Water content	Max. 0.02 vol.%	Max. 1.0 vol.%	Occurrence of rust, Fastening of valve
Ash content	Max. 0.01 wt.%	Max. 0.12 wt.%	Wear, Degradation of Lubrication Oil
Sulphur content	Max. 0.17 wt.%	Max. 3.0 wt.%	Low temperature corrosion
Vanadium	Nil *	Max. 150 mg/kg	High temperature corrosion
Aluminum + silicon	Nil *	Max. 30 mg/kg	Abnormal wear
Sodium	Nil *	Max. 80 mg/kg	High temperature corrosion
Asphalten	-	Max. 3 wt.%	Raise of exhaust gas temperature
Cetane index	Min. 45*	-	Flammability, Starting characteristic
CCAI (Calculated Carbon Aromaticity Index)	Max. 825# *	800〜860# *	Flammability

[Note] # CCAI = D - 140 x log [log (V + 0.85)] - 81 (wher, D: Density in kg/m^3 at 15℃, V: Kinematic viscosity in cSt at 50℃)

[Source] Documents for Management Criteria of Cooling Water prepared by Niigata Power Systems Co., Ltd.

Table 1-2 Management Criteria of Cooling Water

Item	Management Criteria		Obstacle
	Supply Water	Circulating Water	
Turbidity	10 Degree	15 Degree	Deposit, Corrosion
pH at 25℃	6 - 8.5	6 - 8.5	Corrosion
Conductivity at 25℃	< 400μS/cm	< 600μS/cm	Corrosion
M-alkalinity as $CaCO_3$	< 140 ppm	< 250 ppm	Corrosion
Total hardness as $CaCO_3$	< 80 ppm	< 120 ppm	Scale
Chloride ion ($C1^-$)	< 100 ppm	< 200 ppm	Scale
Sulphate ion ($SO4^-$)	< 100 ppm	< 100 ppm	Corrosion
Ammonium ion ($NH4^-$)	< 10 ppm	< 10 ppm	Soft scale, Deposit, Corrosion
Hydrogen sulfide (H2S)	< 10 ppm	< 10 ppm	Corrosion
Iron (Fe)	< 0.3 ppm	< 1 ppm	Corrosion
Silica ($SiO2^-$)	< 30 ppm	< 60 ppm	Coloration, Scale
Total residue on evaporation (Total Solid)	< 400 ppm	< 800 ppm	Scale
Total residue on ignition	*	*	Scale, Corrosion
Dissolve oxygen	*	*	Corrosion

[Note] 1) ppm = mg/L

2) The analysis values marked with asterisk (*) must be considered in connection with the whole items of water analysis results.

[Source] Documents for Management Criteria of Cooling Water prepared by Niigata Power Systems Co., Ltd.

Table 1-3 Management Criteria of Lubrication Oil

Item	Management Criteria	Test Method		Obstacle
Kinematic Viscosity cSt (mm^2/S) at 40℃	-20 ～+30 % of Kinematic Viscosity at the fed	JIS K 2283	applied for Heavy Oil A	Film strength, Fluidity
	-15 ～+30 % of Kinematic Viscosity at the fed		applied for Heavy Oil C	
Flash Temperature ℃	more than 160	JIS K 2265	PM Method	Safety
Total Base Number (TBN) mgKOH/g	see Table 1-4	JIS K 2501	Per chlorine Acid Method	Acid neutrality
	not specified	JIS K 2501	Hydrochloric Acid Method	
Total Acid Number (TAN) mgKOH/g	not specified	JIS K 2501		Deterioration by Acid, Detergent dispersion
Strong Acid Number (SAN) mgKOH/g	shall be not detected	JIS K 2501		Deterioration by Acid, Detergent dispersion
Moisture Content vol %	less than 0.1	JIS K 2275	Alert Value	Occurrence of rust, Emulsion
	less than 0.3		Critical Value	Occurrence of rust, Emulsion
Insoluble Content wt % (Ⅰ) n-Pentane	Alert Value：1.0 Critical Value：1.5	ASTM D893	A Method	Oxidation of oil
(Ⅱ) Toluene	Alert Value：0.8 Critical Value：1.0			Pollution
(Ⅰ)－(Ⅱ)	not specified			Oxidation of oil, Pollution

[Source] Documents for Management Criteria of Lubrication Oil prepared by Niigata Power Systems Co., Ltd.

Table 1-4 Management Criteria of Total Base Number

Type of Oil	Content of Sulfur in Oil wt %	Use of Engine		Remarks (Classification according to NES 34002)
		Land Engine, Marine Engine	High-Power Engine for Continuous Generator	
Heavy Oil A		More than 50 % of TBN at the fed and more than TBN 8		Kerosene Oil Heavy Oil A
Heavy Oil A		More than 50 % of TBN at the fed and more than TBN 10		AA
Heavy Oil C	less than 2.0	More than 50 % of TBN at the fed and more than TBN 15		(Low Sulfur Heavy Oil) BA, C10A, C25A
Heavy Oil C	from 2.0 to 3.5	More than 50 % of TBN at the fed and more than TBN 20		C25B, C35B, C35C, C45C, C55C
Heavy Oil C	from 3.5 to 5.0	more than TBN 25		C45H, C55H

[Source] Documents for Management Criteria of Total Base Number prepared by Niigata Power Systems Co., Ltd.

Table 1-5 Recommended Lube Oil

Fuel Oil	Gas Oil & Diesel Oil	Heavy Fuel Oil			
Sulphur Content	S ≦ 1.0	S ≦ 1.0	1.0 ＜S ≦ 2.0	2.0 ＜S ≦ 3.5	3.5 ＜S ≦ 5
Standard TBN	15 ～20	20 ～25	25 ～30	30 ～40	40
Min. TBN retention	8	10	15	20	25
IDEMITU	DAPHNE MARINE SW-40 (20) SX-40 (12)	DAPHNE MARINE SW-40 (20) MW-40 (25)	DAPHNE MARINE SA-40 (30) MW-40 (25)	DAPHNE MARINE SA-40 (30)	DAPHNE MARINE SA-40 (30)
MOBIL	MOBIL GARD 412 (15) POWER GARD 42 (12)	MOBIL GARD 412 (15) POWER GARD 2040 (20)	MOBIL GARD 424 (30) POWER GARD 3040 (30)	MOBIL GARD 424 (30) POWER GARD 3040 (30)	MOBIL GARD 442 (40) POWER GARD 3040 (30)
ESSO	EXXMAR 12TP40 (12) STAMARINE EXTRA 40 (15)	EXXMAR 24TP40 (24) STAMARINE EXTRA 40 (15)	EXXMAR 24TP40 (24) EXXMAR 30TP40 (30) STAMARINE EXTRA SR-40 (15)	EXXMAR 30TP40 (30) STAMARINE EXTRA SR-40 (30)	EXXMAR 40TP40 (30) STAMARINE EXTRA SR-40 (30)
CALTEX	RPM DELO 2000 40 (20) RPM DELO 1000 40 (12)	RPM DELO 2000 40 (20)	RPM DELO 3000 40 (30) RPM DELO 2000 40 (20)	RPM DELO 3000 40 (30) RPM DELO 3400 40 (40)	RPM DELO 3400 40 (40)
CHEVRON	DELO 2000 40 (20) DELO 1000 40 (12)	DELO 2000 40 (20)	DELO 3000 40 (30) DELO 2000 40 (20)	DELO 3000 40 (30) DELO 3400 40 (40)	DELO 3400 40 (40)
TEXACO	TARO XD40 (16)	TARO XD40 (16) TARO DP40 (32)	TARO DP40 (32)	TARO DP40 (32)	TARO XL40 (42)
CASTROL	220 MXD (22) MARINE MLC40 (12)	220 MXD (22) MARINE MLC40 (12)	MXD 304 (30) 220 MXD (22)	MXD 304 (30) MXD 404 (40)	MXD 404 (40)
SHELL	ARGINA S 40 (20)	ARGINA S 40 (20)	ARGINA T 40 (30) ARGINA S 40 (20)	ARGINA T 40 (30)	ARGINA X 40 (40)
ELF	DISOLA M4015 (15)	DISOLA M4015 (15) AURELIA 4030 (30)	AURELIA 4030 (30)	AURELIA 4030 (30) AURELIA XT 4040 (40)	AURELIA XT 4040 (40)
TOTAL	RUBIA ST 420 (20) RUBIA S40 (12)	RUBIA ST 420 (20)	HMA 430 (30) RUBIA ST 420 (20)	HMA 430 (30)	HMA 440 (40)
INDIAN OIL	SERVO MARINE C 204 (20) SERVO MARINE C 104 (10)	SERVO MARINE C 204 (20)	SERVO MARINE C 304 (30) SERVO MARINE C 204 (20)	SERVO MARINE C 304 (30)	---------
PETRON CORP.	PETROMAR 1540 (15)	PETROMAR 2040 (20)	PETROMAR 3040 (30) PETROMAR TPO 40 (30) PETROMAR 2040 (20)	PETROMAR 3040 (30) PETROMAR 4040 (40) PETROMAR TPO 40 (30)	PETROMAR 4040 (40)

[Note] 1) The fuel oil shall be classified into five (5) classes according to the sulphur content in fuel oil.
2) The figure in ( ) means Total Basic Number (TBN) of lube oil.
3) When lube oil other than the recommended will be used, contact NIIGATA to determine usability of that oil.

(6) Maintenance Budget Planning

The estimated costs for spare parts are shown in Table 1-6 under the condition of ex-godown (at a store in Japan) as of July, 2009. As shown in the table, the costs for the overhauls of diesel engine generators are not small. Therefore, the budget for maintenance shall be planned carefully upon setting down a standard procedure for the budget planning based on the replacement records and stock management records of spare parts. In consideration of the current financial state of the NPA, though they are high-costs, periodical overhauls are essential for stable and reliable operation of diesel engine generator. The NPA shall keep revising the table according to the latest quotations and secure the budget.

At the time of commissioning of the diesel engine generators, spare parts for two year operation are procured and the NPA shall prepare from the first 16,000 hour overhaul. Care is taken to ensure that the costs in the table are affected by price increase and do not include the costs of transport.

Maintenance terms for each overhaul are shown in Table 1-7, not including the terms for arrangement/rearrangement works. As these overhauls require expertise and skills of internal combustion engine, it is strongly recommended that experts of overhaul works shall assist the practice of the NPA at least for the term shown below and term for arrangement/rearrangement works until capacity for maintenance in the NPA has been developed.

Table 1-6 Cost of Spare Parts for Periodical Overhaul

(Unit：thousand yen)

Maintenance Classification	Maintenance Cost	Operation Hours (Unit: hours)							
		4,000	8,000	12,000	16,000	20,000	24,000	28,000	32,000
B	4,100	○	○	○	○	○	○	○	○
D1	4,800		○		○		○		○
D2	47,000				○				○
D3	13,000						○		
E2	39,000								○
Others	2,500		○		○		○		○
Total Cost		4,100	11,400	4,100	59,100	4,100	24,400	4,100	99,000

[Source] Niigata Power Systems Co., Ltd.
[Remark] *1 "Others" mean the auxiliary equipment maintenance cost.
As this equipment is not manufactured by Niigata Power Systems Co., Ltd., it is shown for reference.

Table 1-7 Maintenance Terms for Periodical Overhaul

Maintenance Classification	Operation Hours (Unit: hours)							
	4,000	8,000	12,000	16,000	20,000	24,000	28,000	32,000
B	○	○	○	○	○	○	○	○
D1		○		○		○		○
D2				○				○
D3						○		
E2								○
Maintenance Term	10 days	30 days	10 days	30 days	10 days	30 days	10 days	45 days

[Source] Niigata Power Systems Co., Ltd.

Table 1-8　Operation Guidelines for Diesel Engine

	Stages	Parts or Time	Contents	Confirmation Points or Measures
1.	Preparation for starting	Engine	Checking bolts for tightness	・inside the crankcase Main bearing stud nuts Crank pin bolts Bolts and nuts for internal oil pipe joints ・inside the cylinder heads Fuel injector stud nuts Rock arm bolts and stud nuts Starting air valve volts Cylinder head stud nuts Tappet adjusting bolts and lock nuts ・Mounting bolts and anchor bolts
			Checking the linkage for operation	Move the fuel control lever, and check that the link pins for fuel control lay shaft and governor control link, the knock pins and cotter pins for the levers are securely in place Check the linkage moves smoothly without lost motion
			Checking the fuel injection pump	Check the fuel injection
			Checking existence of rust inside the crankcase	Check, in particular, the cylinder liners, the connecting rods, and crankshaft
			Checking the clearance at main bearings and crank pin bearings	Checking the clearance at main bearings and crank pin bearings
			Checking by turning of engine	・After flushing the lubrication oil, check the followings before turning of engine Keep places the fuel control lever to the stop position Open the crankcase doors, and check there is no foreign matter left inside Start the lubrication oil pump and prime well Fully open the indicator cocks for all cylinders ・Make sure that the engine is turned smoothly without abnormal resistance ・Check to see if water or oil runs out of indicator cocks
			Checking the rocker gears and intake and exhaust valves	・Check the intake and exhaust valve rocker gears operate properly while the engine is turning ・Adjust the intake and exhaust valve tappet clearance to 0.5 mm
		Protective Devices	Pressure Switch	・Close the cock on the pipe to the pressure switch and check if the alarm sounds and the engine stops ・Check the pressure switch setting with a standard pressure tester
			Temperature Switch	・Check the alarm by making contact ・If necessary, check the temperature switch alone by using boiling pot or the like
			Water Off Relay	Slowly close the relay inlet valve and check relay operation
			Level Alarms and Control Switches for the Various Tanks	Check that the level alarms and control switches for the various tanks operate properly
			Lamps and Buzzers	Check that the lumps and buzzers operate properly
		Fuel Oil System	Heavy Fuel Oil A	・If the fuel pipes have scale, rust or the like, clean them by pickling ・Discharge drains from fuel service tank ・Check the oil level of the fuel service tank, and add

	Stages	Parts or Time	Contents	Confirmation Points or Measures
				fuel oil if necessary ・Open the fuel feed valve to the engine ・Start fuel feed pump, and make sure that both the pumps and motor operate properly ・Clean the fuel oil filter (No.1, No.2). and vent air ・Check the oil leakage ・Vent air from the fuel injection pumps, fuel injection pipes and fuel injectors ・Prime the fuel injection pumps
			Heavy Fuel Oil C	・If the fuel pipes have scale, rust or the like, clean them by pickling ・Discharge drains from fuel service tank ・Operate the fuel oil heater and purifier, and circulate the heavy fuel oil through heating circuit outside the engine (In this case, open the three-way changing over valve to the heavy oil position, and take the same steps as Heavy Oil A) ・When the fuel temperature has reached the required level, make sure it remains at the level
		Lubrication Oil System	System lubrication Oil System	・Check that the system is correctly piped, according to the specifications ・In case of a newly installed engine or an overhauled engine, be sure to flush the lubrication oil system, and clean the piping by pickling ・Clean and check the lubrication oil cooler ・Clean the filter, and set the changeover lever to the operation position (if the lubrication oil filter is a changeover open cleaning type) ・Discharge drainage from the sump tank, and check to see if cooling water is mixed with it. ・Check the sump tank oil level with the oil level gage, and add oil if necessary ・If a lubrication oil heater is provided, operate it and heat the lubrication oil from 10 to 30 degrees Start the lubrication oil priming pump, and check the followings while turning the engine ・Check that oil is fed ・Adjust the pressure regulating valve to required lubrication oil pressure. (Oil Temperature shall be from 45 to 55 degrees) ・Check that enough lubrication oil is fed to the following parts: Main bearing Crank pin bearing Piston pin bearing Pistons Roller guides Gear train ・Check the pipe joints and plugs for oil leakage ・If the filter is an automatic cleaning type, check its operation ・Open the cock of the coolers and filters, and discharge air ・After priming for some time, check the oil level of

	Stages	Parts or Time	Contents	Confirmation Points or Measures
				the sump tank, and add as much as necessary ・During operation, check the motors and pumps are free of any trouble ・Continuously operate the lubrication oil purifier to remove foreign matter and water from the lubrication oil
			Checking the lubrication oil system of accessories	・Check the oil level gage, and add the required amount of oil ・Check that all rocker gears are well and evenly lubricated ・Oil the followings not oiled by forced lubrication Governor control link Fuel control lay shaft ・Grease the parts that require greasing Starting air distributor Rod end bearing Turning handle Fuel handle
		Cooling Water System		・Charge the cooling water to the engine and piping ・Turn the valves or cocks on the piping to the operation position Start the cooling water pump and check the following ・Fill the piping with water, and make sure that no water leaks from the cylinder heads and cylinder blocks ・Check the pipe joint and plugs for water leakage ・Open the air vent cocks or plugs on the piping, and discharge air ・Check the pump seals for water leaks (small leakages are not abnormal) ・During operation, check that the motors and pumps are free of any trouble ・Check the cooling water pressure meets the requirements
		Starting Air and Mist Piping System		・Fill starting air receiver to the required pressure from 2.5 to 2.9 MPa ・After that, discharge drainage of starting air receiver by opening the drain valve ・Disconnect the joint which connects the starting distributor inlet pipe, and open the main valve or starting air stop valve to feed the starting air into the main pipe to blow clean the inside of the piping ・Disassemble and clean the starting air distributor and the starting valve ・Perform air running
		Load Limiter (Governor)		Check that the load limiter is at the 100 to 110% position
		Turning Devices with Motor		Check that, when the turning device is discharged, the flywheel and pinion are well apart from each other
2.	Starting the Engine	Check Before Starting Engine	Reminders about Engine Stopping	Check that, when the fuel control lever is moved to the stop position, the fuel injection pumps are in the fuel cut of position
		Starting Conditions		・Check the all pumps are running ・Check that all pressure and temperature readings are correct

	Stages	Parts or Time	Contents	Confirmation Points or Measures
				・Discharge the turning reduction gear ・Check the all indicator cocks are closed ・Discharge the engine load ・Set engine speed to about 1/2 the rated rpm with the governor handwheel of synchronizer ・Close the protective device circuits
		Starting Procedure		・Open the main valve from the starting air receiver ・Move the fuel control lever to an operating position ・Quickly open the starting air stop valve or main air starting valve, and then close it immediately when the sound at fuel burning heard from the engine ・Close the main valve from the starting air receiver
		Check immediately after Starting Engine		Set engine speed to about 1/2 the rated rpm, and check the following ・Immediately after starting the engine, check that the pressure gages and temperatures read normal ・If engine-driven pumps are installed, stop the standby pumps, and check that the pressure stabilizes at normal level ・Check that the engine is running at a steady speed. ・Open the indicator cocks, and check all the cylinders are working by burst gas ・Touch the following parts on the outside to see whether they are overheated: Fuel injection pump Starting air main and branch pipes Governor driving gear case Roller guide case Crankcase door Liner ring Lubrication oil pump Cooling water pump Starting air distributor Cam case door Other ・Check the following parts for abnormal vibration Exhaust manifold Intake manifold Intake and exhaust valve gears Turbocharger Air cooler Governor Pipes Other ・Check the following parts for abnormal noise Inside crankcase Inside gear case Exhaust manifold Turbocharger Other ・Check various parts the engine for oil, water and exhaust gas leaks ・Check the color and quantity of mist from the mist pipe of the crankcase ・Check the exhaust gas color

	Stages	Parts or Time	Contents	Confirmation Points or Measures
				・Check various bolts of the engine for tightness
3.	Engine Operation	Running-in Procedure	When main parts are replaced * Main parts: Pistons, Cylinder Liners, Piston Ring, Main Bearing, Crank Pin Bearing, etc	・Heavy Oil A is recommended as fuel oil ・At no-load operation, engine speed shall be increased as shown in Fig. 1-1 ・At on-load operation, engine load shall be increased as shown in Fig. 1-2 After starting the engine, check the inside at the following time and parts ・No-load operation: after operation at 30% and 100% engine speeds ・On-load operation: after operation at 75% and 100% loads ・Inside crankcase door: Inner surface condition of cylinder liners Temperatures of main bearings, crank pin bearings and cylinder liners: Check by touch ・Inside the cam case door Sliding surfaces of the cams and rollers Check the following during Running-in ・Abnormal noise, vibration and overheat ・Check that the bolts for various parts are tightened enough and are locked ・Check exhaust gas temperature and maximum cylinder pressure: Combustion ・Colors of exhaust gas and mist ・Check revolution speed of turbochargers and intake air pressure to cylinders ・Operation speed and charged air pressure of turbocharger ・Check temperatures of fuel oil, lubrication oil, and cooling water ・Operation of accessories ・Clean the lubrication oil filter at a suitable time and completely remove foreign matter
			When main parts are disassembled * Main parts: Pistons, Cylinder Liners, Piston Ring, Main Bearing, Crank Pin Bearing, etc	・Heavy Oil A is recommended as fuel oil ・At no-load operation, engine speed shall be increased as shown in Fig. 1-3 ・At on-load operation, engine load shall be increased as shown in Fig. 1-4 ・Check the followings during Running-in ・After starting the engine, check the inside at the same time and same parts as main parts replaced ・Check the the same points as main parts replaced during Running-in
		Adjustment Operation	Starting Test	Fill the starting air receiver with air, set it to the required pressure, and see how many times the engine can be started.
			Adjustment of Engine Parts	・Adjust the lubrication oil pressure with the lubrication oil pressure regulation valve ・Adjust the maximum cylinder pressure by adjustment of the fuel injection pump timing
			Measurement of Temperature of Each Bearing	Measure the temperature of each bearing ・Main bearing: Value added to engine inlet lubrication oil temperature to 20 degrees ・Crank pin bearing: Value added to engine inlet lubrication oil temperature to 25 degrees

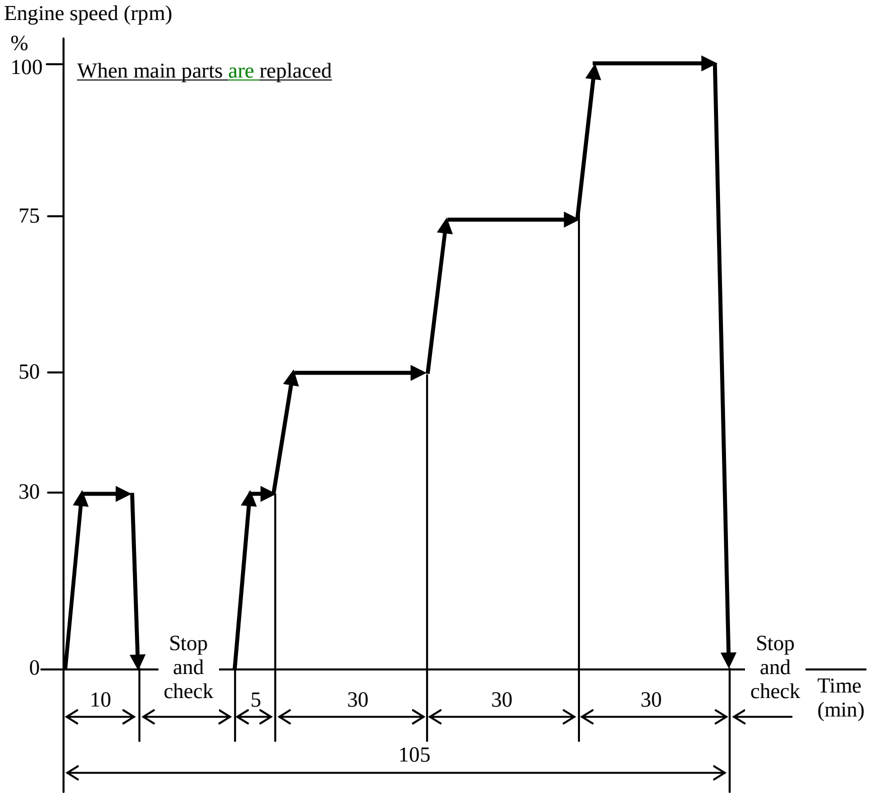
	Stages	Parts or Time	Contents	Confirmation Points or Measures
				・Piston Pin Bearing: Value added to engine inlet lubrication oil temperature to 30 degrees
			Governor Test	・Measure the momentary fluctuation rate and fluctuation rate at stabilized engine speed when the load is disengaged and engaged, and measure the time from a load change until the engine steadies ・Check time until revolution speed of engine settles after changing load
			Protective Devices Operation Test	Check the pressure switches, thermal switches, and other protective devices for operation
		Routine Operation	Load Engaging Procedures	・Load increase intervals depend on mainly the following temperatures ・Starting condition 1: In case that cooling water and lubrication oil temperatures is between 10 and 30 degrees, load shall be increased as shown in Table 1-11 ・Starting condition 2: In case that cooling water temperature is more than 40 degrees and lubrication oil temperatures is more than 30 degrees, load shall be increased as shown in Table 1-12
			Precautions to follow while increasing load	Pay attention to the following while increasing load: ・Vibration in cooling water and lubrication oil pressure ・Vibration in cylinder outlet exhaust gas temperature ・Vibration in turbocharger speed ・Mist color and quantity
		Checks during Operation	Fuel Oil System	・Check the fuel service tank oil level, and add oil if necessary ・Discharge drainage from the fuel service tank ・Clean the filter if necessary ・The pressure of fuel feed to the engine is controlled by the pressure regulating valve located between the fuel return main pipe and the service tank ・Check the feed pressure and temperature of the fuel oil to the engine ・Check the piping for oil leak and air inhalation ・Check tightness of pipe clips Shift from Heavy Oil A to Heavy Oil C shall be made after the confirmation of the following conditions ・Cylinder cooling water inlet temperature: Over 50 degrees ・Preheat the Heavy Oil C to raise the Heavy Oil A temperature at the engine inlet from 50 to 60 degrees by the line heater at a heating rate of 3 degrees per minute ・Keep the engine load at 40% to 50%, and change Heavy Oil A over to Heavy Oil C ・Gradually increase the load Shift from Heavy Oil C to Heavy Oil A shall be made after the confirmation of the following conditions ・Keep the engine load at 40% to 50%, and change Heavy Oil A over to Heavy Oil C
			Lubrication Oil System	・Check oil level of the lubrication oil sump tank,

	Stages	Parts or Time	Contents	Confirmation Points or Measures
				record it, check oil consumption and add oil if necessary ・Discharge drains from the lubrication oil sump tank ・Check that the pump delivery pressure is correct ・Check that the engine inlet pressure and temperature are correct ・Check the pipe clips for tightness ・Check the piping for oil leak and air inhalation ・Periodically analyze the properties of the lubrication oil
			Cooling Water System	・Check that the engine inlet pressure and outlet temperature are correct ・Check the piping for water leaks and air inhalation ・Check the fresh water expansion tank for water quantity, and add water if necessary ・Periodically check the quality of the fresh water
			Turbocharger	・To confirm turbocharger performance, take data periodically, and compare it with the shop trial data and local witness test data under the same operation conditions ・Watch for turbocharger speed variation, abnormal noise and abnormal vibration
			Air Cooler	Watch for the cooling efficiency of the air cooler, and clean the cooler according to the following ・If cooling efficiency is less than 0.60, clean the cooling water side of the cooler ・If cooling efficiency fails to return to more than 0.70, clean the air side of the cooler
			Main Parts of Engine	Check the following around the cylinder heads: ・Check the intake and exhaust value rocker arm devices for operation ・Check each valve water leak ・Check oil and water leaks ・Check bolts and nuts for tightness ・Check that the proper amount of oil is fed Check the following for other parts of the engine ・Check the pipe joint for water and oil leaks ・Vent air from the piping and cooler ・Check various parts for overheat, abnormal vibration and abnormal noise ・Check bolts and nuts for tightness ・Check exhaust gas color, mist quantity, and mist color Prepare engine performance journal, and periodically take the following data mainly ・Cylinder outlet exhaust gas temperature difference among the cylinders must be less than ± 30 degrees of average exhaust gas temperature ・Maximum cylinder pressure difference among the cylinders must be less than 0.7 MPa of the rated maximum pressure
4.	Stopping the Engine	Ordinary Engine Stop		・Gradually decrease the load to 50% load in 15 minutes ・Operate the engine at 50% load for 30 minutes. ・Gradually decrease the load to zero.

	Stages	Parts or Time	Contents	Confirmation Points or Measures
				・Move the fuel control lever to the stop position. ・Keep operation of cooling water and lubricating oil pumps for more than 30 minutes for after cooling while turning the engine. ・Open the indicator cocks during and after cooling to discharge burnt gases out of the cylinders. ・Close those valves, which shall be closed when the engine is still. Take the following steps to ready the engine for the next start: ・Fill the starting air receiver with air. ・Add cooling water, lubricating oil and fuel oil if necessary. ・Clean all filters ・Service and repair as necessary
		Steps taken after Stopping the Engine	Measures in case of halt for more than one week	・Completely discharge the cooling water from the engine and coolers so no remains in the piping ・Spray or apply anti-corrosive oil to the following shiny and sliding parts of the engines: Starting air valve Fuel control lay shaft Cylinder head top surface Fulcrum supporter Other machined surfaces of exposed parts ・Remove the exhaust valves or fuel injectors, spray anti-corrosive oil into the combustion chambers while turning the engine, and mount the removed valves ・Check tightness of bolts and pipe joints of main parts ・Put covers on the stack and mist outlet outside the engine ・Ventilate the engine room
		Emergency Engine Stop	Emergency Engine Stop Procedure	・Close the main valve at the fuel main pipe inlet ・Give the lowest-speed governor revolution command
			Conditions where engine stop is urgent	Stop the engine at the following conditions: ・Engine speed has increased on its own, and cannot be controlled ・Fuel scale has risen abnormally, and engine speed has dropped ・Bearings or other moving parts have been overheated ・Engine vibrates abnormally ・Engine makes abnormal noise ・Crankcase mist quantity or color is abnormal ・Lubrication oil pressure has dropped suddenly ・Cooling water temperature has risen suddenly ・Turbocharger makes abnormal noise or vibration and is over heated ・Exhaust gas temperature has changed suddenly
			Steps taken after emergency stop	・After an emergency stop, keep the cooling water pump and lubrication oil pump operating for after-cooling ・If much mist is discharged from the mist pipe, it is because the mist pressure inside the crankcase is

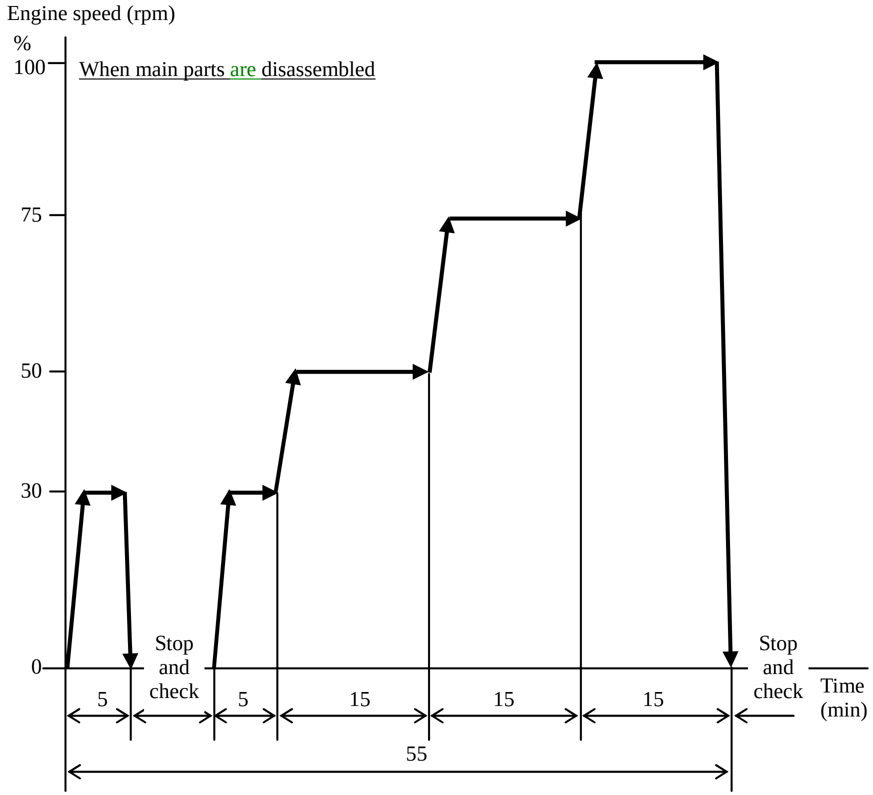
	Stages	Parts or Time	Contents	Confirmation Points or Measures
				abnormally high. In this case, do not open the crankcase door until mist discharge rage decreases. (about more than 20 minutes) ・In the case where the engine is burning in heavy oil, keep the line heater and fuel feed pump on to circulate the fuel oil as long as possible after stopping the engine
		Non-use of Engine		・Turn the engine at least once a week to change the piston and bearing positions ・Prime the lubrication oil ・Oil the sliding parts with an oiler ・Lubricate the intake and exhaust valve rocker gears ・Check the outside of the engine once a month for any signs of trouble ・Spray or apply anti-corrosive oil to the shiny and sliding parts of the engine once a month ・Remove the exhaust valves or fuel injection valves every three months, spray anti-corrosive oil into the combustion chambers while turning the engine, and remount valves ・Analyze the lubrication oil properties every month

[Source] Operation Manual for Diesel Engine 28HLX prepared by Niigata Power Systems Co., Ltd.



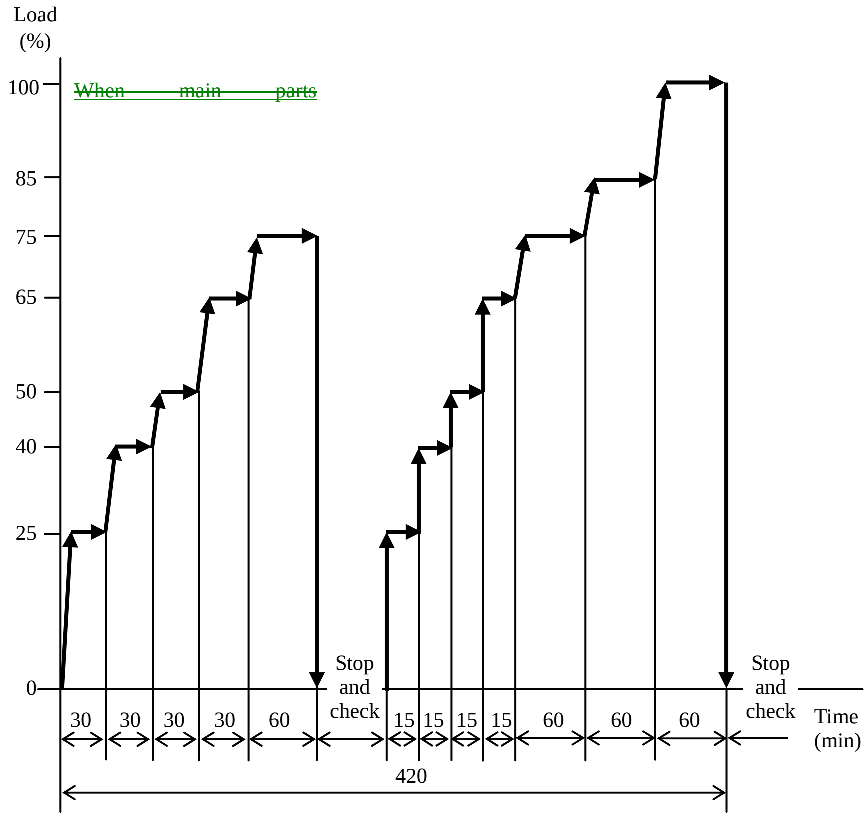
[Source] Operation Manual for Diesel Engine 28HLX
prepared by Niigata Power Systems Co., Ltd.

Fig. 1-1 Running-in Procedure No-load Operation
(When main parts are replaced)



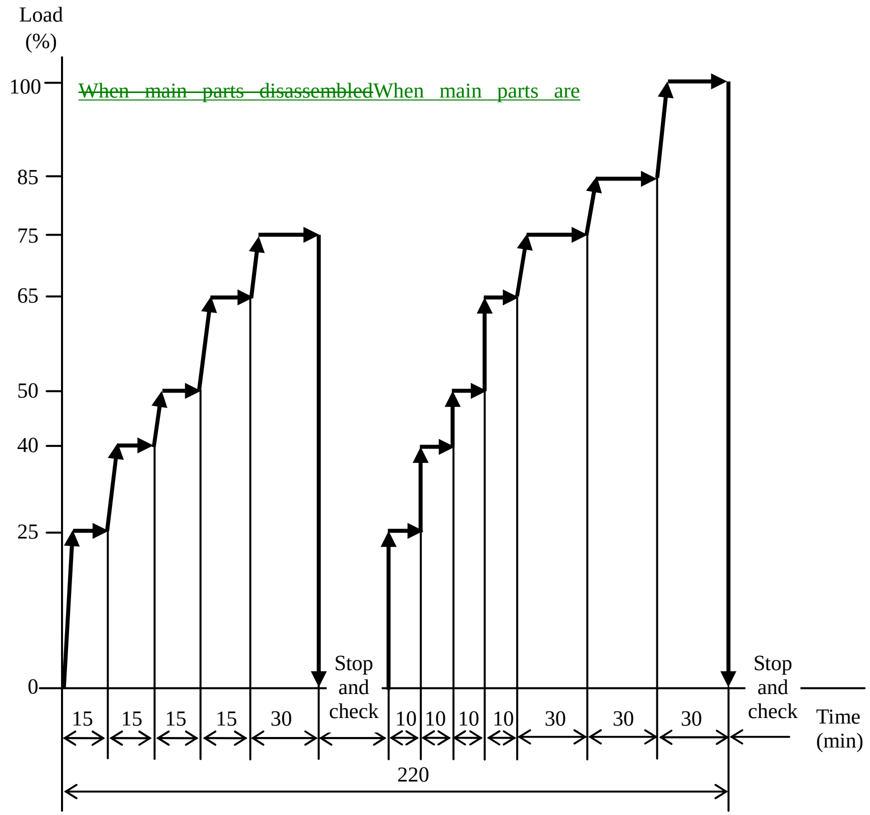
[Source] Operation Manual for Diesel Engine 28HLX
prepared by Niigata Power Systems Co., Ltd.

Fig. 1-2 Running-in Procedure No-load Operation
(When main parts are disassembled)



[Source] Operation Manual for Diesel Engine 28HLX
prepared by Niigata Power Systems Co., Ltd.

Fig. 1-3 Running-in Procedure Load Increase Operation
(When main parts are replaced)



[Source] Operation Manual for Diesel Engine 28HLX
prepared by Niigata Power Systems Co., Ltd.

Fig. 1-4 Running-in Procedure Load Increase Operation
(When main parts are disassembled)

Table 1-9 Load Engaging Procedure
(Cooling water and lubricating oil temperatures between 10°C and 30°C)

Load	Normal	Sudden Load-On	Emergency Load-On
0 ～ 65 %	8 min	4 min	2 min
65 ～ 90 %	15 min	8 min	4 min
90 ～ 100 %	7 min	4 min	2 min
Total	30 min	16 min	8 min

[Source] Operation Manual for Diesel Engine 28HLX prepared by Niigata Power Systems Co., Ltd.

Table 1-10 Load Engaging Procedure
(Cooling water 40°C or over, lubricating oil temperature 30°C or over)

Load	Normal	Sudden Load-On	Emergency Load-On
0 ～ 65 %	4 min	2 min	1 min
65 ～ 90 %	8 min	4 min	0.5 min
90 ～ 100 %	4 min	2 min	0.5 min
Total	16 min	8 min	2 min

[Source] Operation Manual for Diesel Engine 28HLX prepared by Niigata Power Systems Co., Ltd.

Table 1-11　Maintenance Guidelines for Diesel Engine

○: Check & Cleaning

●: Replace

Inspection item	Contents of maintenance	B	D1	D2	D3	E2	Remarks
Cylinder head	・ Combustion chamber, intake and exhaust passage clean and check		○	○	○	○	
	・ Combustion surface dye check		○	○	○	○	
	・ Cylinder head stud tightening force check	○	○	○	○	○	
	・ O-ring Pipe (FV body) check					●	
Intake valve	・ Valve check, measure, dye check	○	○	●	○	●	
	・ Valve guide inner diameter measuring	○	○	●	○	●	
	・ Valve seat*IV lapping	○	○	●	○	●	
	・ Spring*IEV check	○	○	○	○	●	
	・ Retainer overhaul	○	○	○	○	●	
Exhaust valve	・ Valve check, measure, dye check	○	○	●	○	●	
	・ Valve guide inner diameter measuring	○	○	●	○	●	
	・ Valve seat*EV lapping	○	○	●	○	●	
	・ Spring*IEV check	○	○	○	○	●	
	・ Retainer overhaul	○	○	○	○	●	
	・ Valve seat*EV O-ring replace			●		●	
Fuel injection nozzle	・ Fuel injection nozzle check	●	●	●	●	●	Knock pin replace if necessary
	・ Injection pressure test, spray check	○	○	○	○	○	
	・ Fuel injection valve body dye check	○	○	○	○	○	
	・ Spring and spindle check	○	○	●	○	●	
Starting air valve	・ Visually check and lapping		○	○	○	○	
	・ Spring check		○	○	○	●	
Indicator cock	・ Body*NCV and cock*indicator lapping		△	○	△	●	△ daily start stop
	・ Spring check		△	○	△	●	
Piston	・ Piston cleaning and check		○	○	○	○	
	・ Piston diameter measuring		○	○	○	○	
	・ Piston pin boss inner diameter measuring		○	○	○	○	
	・ Piston pin diameter measuring		○	○	○	○	
	・ Ring groove clearance measuring		○	○	○	○	
	・ Ring check, and ring dimension measuring		●	●	●	●	Change the Piston ring, if lube. oil consumption increased
	・ Snap ring *piston check		○	○	○	●	
	・ Bolt*piston tightening force check		○	●	○	●	
Cylinder liner	・ Visual check through doors* crankcase	○	○	○	○	○	
	・ Outer surface corrosion check			○		○	
	・ Combustion surface, and inner surface check		○	○	○	○	
	・ Deglazing			○		○	
	・ Fire ring diameter measuring and dye check		○	●	○	●	
	・ Cylinder liner dismount			○		○	
Connecting rod	・ Big-end bearing check		○	●	○	●	**
	・ Serration check		○	○	○	○	
	・ Crank pin bolt check and tightening force check		○	○	●	○	
	・ Oil holes check and cleaning		○	○	○	○	
	・ Plug check		○	○	○	○	Air blow off after washing
	・ Big end inner diameter measuring		○	○	○	○	Uneven wear measuring
	・ Small end bearing check			○		●	
Crank shaft	・ Deflection measuring	○	○	○	○	○	

Inspection item	Contents of maintenance	B	D1	D2	D3	E2	Remarks
	・ Crank pin and journal measuring check		○	○	○	○	See 5.2
	・ Crank pin and journal dye check					○	
	・ Balance weight fitting bolt tightening force check					○	
Damper (torsion)	・ Disassembly and check					○	
	・ Springs *leaf check					●	
	・ Bearing check					●	
	・ Check that the contact surface of spring guide pieces, inner and outer ring.					○	
	・ Bolts check					●	
Damper* cam gear	・ Disassembly and check			○		○	
	・ Springs*leaf check			○		●	
	・ Spacer check			○		●	
	・ Check that the contact surface of spring guide pieces, inner and outer ring.			○		○	
	・ Set screw and washer check			○		●	
Main bearing and location bearing	・ Main bearing check		△	○	●	○	**△ : Check the bearing at middle throws only.
	・ Main bearing (Location bearing) check			○		●	
	・ Thrust bearing check and clearance measuring					●	
Rocker arm	・ Shaft check and oil hole cleaning		○	○	○	○	
	・ Bushing*rocker arm check		○	○	○	●	
	・ Clearance between shaft and bushing measuring		○	○	○	○	
	・ Adjust bolt, collar, spring check		○	○	○	●	
	・ Tappet clearance adjustment	○	○	○	○	○	
	・ Rocker arm dye check		○	○	○	○	
Cam, cam roller, cam bearing	・ Cam visual check	○	○	○	○	○	
	・ Roller contact visually check	○	○	○	○	○	
	・ Cam bearing clearance measuring			○		○	
	・ Cam bearing check					●	
Valve gear	・ Push rod check		○	○	○	○	Top and bottom pieces check and push rod bend check
	・ Tappet*IE disassembly and check, and oil holes cleaning			○		○	
	・ Bush*roller check			○		●	
	・ Shaft, pin*roller*IE and tappet*IE inner diameter measuring			○		○	
	・ Roller, pin, snap ring and tappet dye check			○		●	
Fuel injection pump	・ Eye bolt and delivery valve, and plunger assembly check		○	●	○	●	
	・ Control rack scale position check		○	○	○	○	
	・ Injection timing check		○	○	○	○	
	・ Disassembly and cleaning		○	○	○	○	
	・ Spring*plunger and spring seat check		○	○	○	●	
Governor driving device	・ Gear contact and pitting check			○		○	
	・ Backlash check			○		○	
	・ Ball bearing check			●		●	
	・ Gears check					●	
Governor	・ Governor oil change	○	○	○	○	○	Send to Maker
	・ Governor overhaul		○	○	○	○	
Fuel injection union	・ Injection union seat surface check		○	○	○	○	
	・ Collar surface check		○	○	○	○	
All sorts of gear wheel	・ Crank gear contact and pitting check		○	○	○	○	
	・ Cam gear contact and pitting check		○	○	○	○	
	・ Idle gear contact and pitting check		○	○	○	○	

Inspection item	Contents of maintenance	B	D1	D2	D3	E2	Remarks
	・ Each pump driving gear contact and pitting check		○	○	○	○	
	・ Each gear backlash check		○	○	○	○	
	・ Idle gear bushing check					●	
Starting air distributor	・ Disassembly, cleaning and check		○	○	○	●	
	・ Rotor check		○	○	○	●	
Main starting valve	・ Disassembly, cleaning and check		○	○	○	○	
	・ Valve seat lapping		○	○	○	○	
	・ Spring check		○	○	○	●	
Lubricating oil pump	・ Gear pitting check			○		○	The engine driving
	・ Bushing *LOP check			○		●	
Fuel control lay shaft and Governor linkage	・ Linkage looseness check	○	○	○	○	○	
	・ Spring *GV link check		○	○	○	●	
	・ Ball bearing and bushing wear check		○	●	○	●	
	・ Pin*lack, Reamer bolt, Link wear check		○	○	○	●	
	・ Rod end bearing and link pin check		○	●	○	●	
Turbo charger	・ Disassembly, cleaning and check		○	○	○	○	Refer to the instruction Manual for Turbo charger
	・ Bearing and labyrinth ring check		○	●	○	●	
Air cooler	・ Cooling water passage cleaning		○	○	○	○	
	・ Air passage cleaning		○	○	○	○	
	・ Pressure test		○	○	○	○	
	・ Anti-corrosion zinc replace (only sea water, if provided)		●	●	●	●	
Spring	・ Turing safety valve spring check			○		●	
	・ Lube. Oil pressure regulating valve spring (turbo charger)			○		●	
Exhaust manifold	・ Expansion joint check		○	○	●	○	
	・ Manifold inner surface check and cleaning				○		
	・ Expansion joint fitting surface deformation check				○		
	・ Lagging repair		○	○	○	○	
	・ Gasket (branch) replace	●	●	●	●	●	
Intake manifold and intake duct	・ Drain separator check		○	○	○	○	
	・ Duct crack check		○	○	○	○	
	・ Manifold inner surface check and cleaning				○		
Cooling water pump	・ Oil seal replace		●	●	●	●	Depend on specification
	・ Mechanical seal replace		●	●	●	●	
	・ Ball bearing and roller bearing change		○	●	○	●	
Lubricating oil cooler	・ Cleaning and check		○	○	○	○	
Low temperature water cooler	・ Cleaning and check		○	○	○	○	
High temperature water cooler	・ Cleaning and check		○	○	○	○	

** [Note] After checking the condition of bearing, if necessary replace crank pin gearing and main bearing.

Table 1-12 Contents of daily check (A check)

Inspection Item	Contents of maintenance	Interval	Remarks
General item	• Each tank level check • Each gauge indication check • Each thermometer indication check • Oil leak, water leak check • Exhaust gas color check • Each part vibration check • Each valve opening and closing check • Each drain discharge • Abnormal noise check	Every day Every day Every day Every day Every day Every day Every day Every day Every day	Watch and record Record Record Watch Watch Watch and touch
Fuel oil system	• Viscosity control • Fuel oil drain quantity check • fuel oil temperature check	Every day Every day Every day	
Cooling water system	• Water quality analysis	500h	
Lubricating oil system	• Lubricating oil quality analysis • Spot testing • Sludge checker check	500h 500h Every day	
Turbo charger	• Sponge filter cleaning • Blower washing • Turbine washing	100h 500h 100h	
Engine mist	• Color and quantity check	Every day	
Exhaust gas	• Color and quantity check	Every day	

Part-2: Operation and Maintenance of Transmission and Distribution Network

2. Operation and Maintenance of Transmission and Distribution Network

(1) Operation Guidelines for Power System

Standard operation services are shown in Table 2-1. To supply qualitative power with appropriate management of voltage and frequency, it is prerequisite to compose the system of reliable equipment. In addition, it is necessary for achievement of qualitative supply to plan Supply and Demand Balance based on operation data, operate the system based on it and modify it while forecasting the demand change momentarily. In case of the NPA, it is difficult to operate and maintain the system in accordance with Operation and Maintenance Guidelines, as the system of the NPA deviates from the sound status in that the system is decrepit and needs a huge number of repair works and the reliability is significantly low. The following guidelines are simply one example. From the situation of the NPA, they will be effective gradually after engineers who can plan replacement and empowerment of the system are secured in the NPA and the system is improved.

Table 2-1 Standard Operation Services of Power System

Items	Contents
Observation	Observe operation situations of power supply equipment, demand and so on for reliable and qualitative power supply
Operation	Decide, order and operate load dispatching commands for reliable and qualitative power supply
Demand and Supply Planning	Plan Demand and Supply Balance
Voltage, Frequency Management	Decide and maintain the management range of voltage and frequency
Recovery Works for Failures	Minimize blackout area and recover failures in power system safely and rapidly
Load Shedding	Decide, order and operate load shedding commands
Management of Operation Records	Prepare and keep operation records, manuals and reports

[Source] JICA Study Team

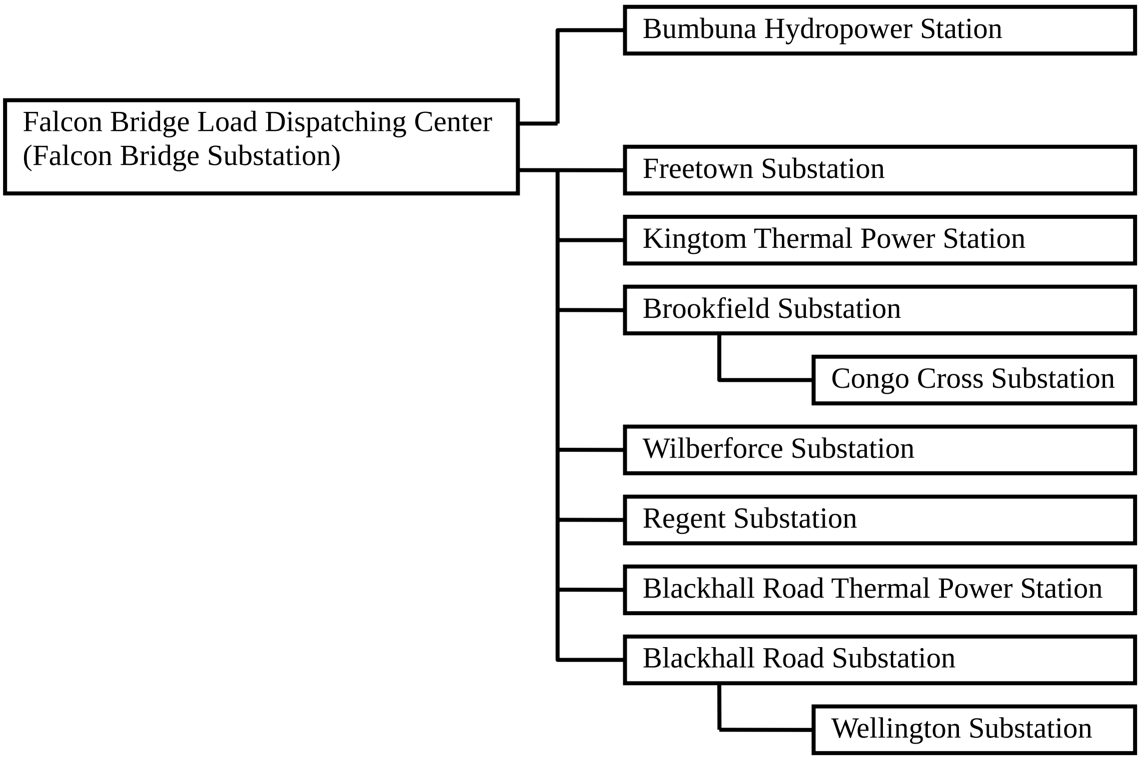
1) Observation and Operation of Power System

To keep power in qualitative status, proper observation of operation data of the system is necessary such as frequency, voltage and power flow. It is also necessary to build up the framework for chain of load dispatching commands, communicate information of operation or failure in accordance with the framework and operate equipment surely based on the commands made under appropriate judgment. The types of load dispatching commands and an example of the framework for the NPA are shown in Table 2-2 and Fig. 2-1. In near future, Bumbuna Hydraulic Power Plant will be commissioned and operated and maintained by other corporate entities under the power supply contract. It is necessary to regulate properly such items as types of generator control, power conditioning and protection coordination between the NPA and the entities. While clarifying the work demarcation between them, the internal framework of the NPA for load dispatching shall be made clear at early stage.

Table 2-2 Load Dispatching Commands

Items	Contents
Generator	ON / OFF, Power Conditioning, Control Function
Transformer	ON / OFF
Phase modifying equipment	ON / OFF
Transmission and Distribution Lines	ON / OFF
Grounding Equipment	ON / OFF
Protection Relay	Setting, Control Function

[Source] JICA Study Team



[Source] JICA Study Team

Fig 2-1 Example of the Framework for Load Dispatching Commands

2) Demand and Supply Planning

Supply shall meet demand changing momentarily while considering the load characteristics and generator characteristics, and keeping hot reserve and instant reserve of power, as electrical power is not storable. It can be secured by planning demand and supply balance, operating the system based on the balance and reflecting actual load situation to generator outputs. To plan demand and supply balance, firstly, such data as operation records, timetable of equipment maintenance, reservoir utilization plan shall be prepared. As the first step, the NPA shall prepare these data.

Table 2-3 Classification of Demand and Supply Balance

Classification	Contents
Short-Term Planning	Plan Demand and Supply Balance in consideration of past operation data, weather, social affairs and so on Daily Plan Next Day Plan Next Week Plan Next Month Plan
Long-Term Planning	Plan demand and supply balance in consideration of operation records, timetable of equipment maintenance, reservoir utilization plan and so on from longer viewpoint than short-term planning Dry Season / Rainy Season Plan Annual Plan

[Source] JICA Study Team

3) Voltage Management

It is the duty of power companies to maintain voltage in management range even at the tail of distribution lines at times of heavy load, as all electrical appliances are manufactured as they exercise normal functions under the rated voltage. Measures for management of voltage and an example of management range of voltage are shown in Table 2-4 and Table 2-5.

Table 2-4 Adjustment Measures of Voltage

Adjustment Measures
Adjustment by excitation of generators
Adjustment by modification of tap locations
Adjustment by reactive power from phase modifying equipment
Adjustment by reactive power from Start / Stop of generators
Adjustment by switching of power system

[Source] Load Dispatching Service Manual
prepared by Okinawa Power Company

Table 2-5 Example of Management Range

Voltage	Range
Low Voltage 415 V	415 V ± 42V
240 V	240 V ±24V

[Source] JICA Study Team

In case of the NPA, concerning 11 kV and low-voltage, such basic data as single-line diagram, route map are not prepared. In addition, as operation records have not been kept, there is no way to know the distribution situation of voltage. Firstly, the NPA shall prepare such basic data for proper voltage management. Then, it is necessary to plan appropriate replacement and empowerment of the distribution system and arrange it so that it does not suffer from voltage drop even in time of heavy load by relocation of the secondary substations (11 kV / low-voltage). As a result of the improvement work, voltage management is possible by the measures in Table 2-4.

4) Frequency Management

Fluctuation of power frequency causes various obstacles as fluctuation of revolution speed of rotary machines in manufacturing processes of large demand as manufacturing plant. For proper management of frequency, it is necessary to operate the system based on demand and supply planning and keep the balance between demand and supply. In case of the NPA, holding capacity of power supply is too limited in the present situation to keep balance with demand. The NPA shall keep frequency in the management range after commissioning of Bumbuna Hydraulic Power Plant and other power plants have been developed. An example of management criteria of frequency is shown as follows:

Frequency management range： 50 Hz ± 0.25 Hz

In addition, hereafter, there is concern that load sharing cannot be controlled only by governor-free control and it is necessary to apply the control systems of load frequency control and economic load dispatching, in the case where a number of power plants are developed.

5) Recovery Operations after Failures

In case failures occur in the power system, first aid actions of operation staffs are immediately required based on load dispatching commands. From viewpoints of personnel protection and prevention of expansion of blackout area, operation staffs shall conduct emergency measures and recovery works based on load dispatching commands. As the NPA frequently suffers from many faults arising from decrepit equipment, the issues which the NPA shall work on at the present time are to prepare a format for fault record, record the faults and classify the recurrent faults. For these faults, the emergency measures, diagnosis procedures and recovery works shall be standardized and such a framework shall be secured as site staffs can solve the problems by themselves in communication with engineers.

6) Load Shedding

At present, the NPA has no choice but to operate the system under a lack supply capacity to demand

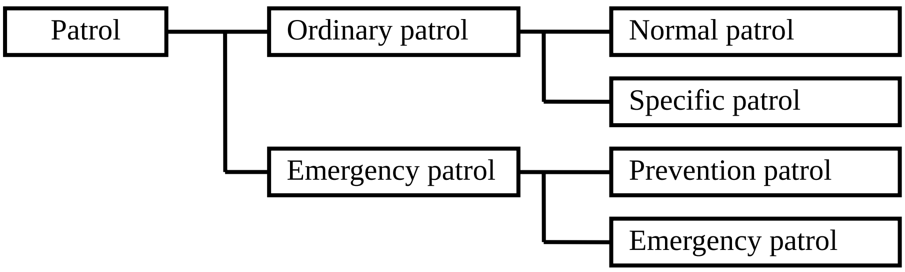
and load shedding is carried out as daily work. Though the Load Shedding Manual is set down in the NPA, management of load shedding cannot be conducted according to the manual because of frequent faults. After achievement of proper management of power flow, voltage and frequency, the policy for load shedding and Load Shedding Manual shall be reconstructed.

(2) Maintenance Guidelines for Transmission and Distribution Network

Maintenance work of transmission and distribution network is composed of patrol, inspection and repair. In these three kinds of work, Patrol and Inspection shall be standardized and carried out periodically. Contents of patrol and inspection are shown below. As overhead lined are located in the public, it is necessary to grasp the conditions of the equipment and keep them in sound status by periodical and efficient observation. Patrol is carried out mainly by visual observation and it is the purpose to find out effectively parts which need to be repaired. On the other hand, inspection examines more details by using measurement instruments.

1) Patrol of Overhead Transmission and Distribution Lines

Patrols are classified as shown in Fig. 2-2. The definition and frequency of each patrol is shown in Table 2-6. Especially, as Normal Patrol is most effective for confirmation of status of equipment, the contents of Normal Patrol are shown in Table 2-7.



[Source] JICA Study Team

Fig. 2-2 Classification of Patrols

Table 2-6 The Definition and Frequency of Patrols for Overhead Line

Type of Patrol		Definition	Frequency
Ordinary patrol	Normal patrol	This is a patrol regularly performed along whole lines to investigate the condition of the concerned equipment and the surrounding condition of transmission and distribution lines. Such as over closing of house and trees to said lines, topographical situation, sinking of road and over construction crossing over closed.	Once per 3 months
	Specific patrol	This is a patrol performed deciding specific zones / individual lines to find out abnormality earlier and prevent the damage, which is apt to happen where construction such as building, reclamation, laying something underground, and road will be done within the area of security	Over once per 1 month
Emergency patrol	Prevention patrol	This is a patrol temporally performed to prevent damage during times of storm, abnormal weather or growing period of vegetation	As required
	Emergency patrol	This is a patrol performed to find out the spot and to grasp the condition when an accident or damage of line happens	As required

[Source] Service Works of Power Systems, Corona Sya

Table 2-7 Contents of Normal Patrol

Items	Detail Items	Contents
Right-of-way	Interfering and dangerous trees	Interfering and dangerous trees, bush, stumps and other inflammable material
	Crossing	Situation of crossing of houses, distribution line and/or etc to right-of-way
	Lay of the land	Confirmation of subsidence, crumbling slope, falling rock and/or etc
	Access road	Damage of access road
Supports	Pole	Damage of pole, pole hole depth, direction, unfastened bolt
	Cross arm	Warping, crack, damage and unfastened bolt
	Neighbourhood of pole	Crack, collapse
	Guy wire	Snapping, rust, damage of ball type insulator, exposed anchor, damage of grounding wire
Conductors	Conductor	Rust, kink, abnormal sag, abnormal sound
	Sleeve	Rust, deformation, abnormal sound
Insulators	Prefabricated conductor tie for top tie insulator	Slipping conductor, rust, discoloration
	Insulator	Crack, damage, chipping, vestige of arcs, unfastened bolt

[Source] JICA Study Team

2) Inspection of Overhead Transmission and Distribution Lines

The contents of Inspection of Overhead Transmission and Distribution Lines are shown in Table 2-8.

Table 2-8 Inspection items and Frequency of Patrol for Overhead Line

Items		Contents	Frequency
Supports	Steel tower Steel pole	Foundation concrete and lay of the land Deformation and bend of materials Rust in material and bolt/nut Unfastened bolt Measurement of earthing resistance	Once every 5 years
	Wooden	Deterioration Tilt Damage of guy wire Measurement of earthing resistance	Once every 4 years
Conductors		Damage, Rust Abnormal Clamp, Sleeve and Spacer	Once every 4-5 years
Insulators		Defect Insulator Crack, Chipping Rust and damage in cotter bolt and pin Unfastened binding wire Abnormal fitment	Once every 3-10 years
Others		Caution sign	As required

[Source] JICA Study Team

3) Patrol and Inspection of Underground Transmission and Distribution Lines

In case of the underground transmission and distribution lines of the NPA, as they are directly located in the ground, the parts observed by patrol are only cable head and rising part from the ground. Such items as insulation resistance test and conduction of pipes for cables shall be carried out in the period of about 5 years. In case of the NPA’s cables, as earth faults are recurrent because of deterioration of equipment, diagnosis measures for fault location such as Murray-loop Method shall be achieved firmly and efficient repair works shall be carried out.

(3) Maintenance Guidelines for Transformation Equipment

Maintenance work of transformation equipment is also composed of patrol, inspection and repair. In these three kinds of work, patrol and inspection shall be standardized and carried out periodically.

1) Patrol of Transformation Equipment

The classification of patrol of transformation equipment is shown in Table 2-9. The observation points in patrol are shown in Table 2-10.

Table 2-9 Categories of Patrol for Transformation Installation

Item	Interval	Condition	Description
Daily Patrol	Daily	energized	Visual inspection
Weekly Patrol	Every week	energized	Visual inspection and recording of indication of instruments
Monthly Patrol	Every month	energized	Visual inspection, recording of indication of instruments and repair work which can be carried out under energized condition
Emergency Patrol	-	energized	Performed upon requirements

[Source] Final Report on the Master Plan Study for the Upgrading of Electric Power Supply in the Republic of Palau

Table 2-10 Items of Patrol for Transformation Installation

Equipment	Item of check	Action		
		Daily	Weekly	Monthly
Transformer	Appearance	×	×	×
	Oil level	×	○	○
	Temperature	×	○	○
	Silica Gel	-	-	×
	Counter of hot line oil purifier	×	○	○
	On load tap changer			
	Counter	×	○	○
	Tap position	×	○	○
Circuit Breaker	Appearance	×	×	○
	Operation counter	×	×	○
Protection & Control Board	Appearance	×	×	×
	Target	×	×	×
	Meters	×	○	○
Disconnecting Switch	Appearance	×	×	×
Arrester	Appearance	×	×	×
	Counter	×	○	○
Station Service Transformer	Appearance	×	×	×
Cable & Bushing	Appearance	×	×	×
Lamps	Replacement of damaged bulbs	×	×	×
Battery	Electrolyte level	-	×	×
Potential Transformer	Appearance	×	×	×

×: Confirmation

○: Confirmation and Recording

[Source] Final Report on the Master Plan Study for the Upgrading of Electric Power Supply in the Republic of Palau

2) Inspection of Transformation Equipment

The classification of inspection of transformation equipment is shown in Table 2-11. The confirmation points in patrol are shown in Table 2-12.

Table 2-11 Categories of Inspection

Item	Interval	Condition	Description
Periodical Inspection	Once per 2 or 3 years	Blackout	Confirmation of functions of equipment and cleaning not including disassembling
Periodical Inspection	Once per 2 or 3 years	Blackout	Disassembling based on manufacturer's recommendation
Special Inspection	As required	Blackout	Performed in the following conditions – When abnormal phenomenon is found at Patrol or Inspection – When number of short-circuit interruptions or over loads occur more than specified – When the equipment is contaminated by salt due to surrounding conditions – When the equipment has been given a severer condition exceeding the rating assigned – When fault occurs in the equipment

[Source] Final Report on the Master Plan Study for the Upgrading of Electric Power Supply in the Republic of Palau

Table 2-12 Items of Inspection

Equipment	Items of Inspection	Period
Transformer	Appearance	Once a year
	Alarm contact	Once every 3 years
	Insulation Check	Once every 3 years
	Main circuit	
	Insulation oil	
	Bushing	Once every 3 years
	On load tap chnger	Once every 3 years
	Changing silica gel	Once a year
Circuit Breaker	Appearance	Once a year
	Operation test	Once every 3 years
	Insulation check	Once every 3 years
	Bushing	Once every 3 years
	Operation mechanism	Once every 3 years
	Interrupting parts	Once every 3 years
	Accessories	Once every 6 years
	Others	Once every 6 years
Protection & Control Board	Appearance	Once a year
	Characteristic test	Once every 3 years
	Calibration of meters	Once every 3 years
	Sequence test	Once every 3 years
Disconnecting Switch	Appearance	Once a year
	Operation test	Once every 3 years
Potential Transformer	Appearance	Once a year
	Insulation check	Once every 3 years
	Bushing	Once every 3 years
	Insulation oil	Once every 3 years
Insulator	Appearance	Once a year
	Cleaning	Once every 3 years
Battery	Appearance	Once a year
	Equalizing charge	Once every 6 months

[Source] Final Report on the Master Plan Study for the Upgrading of Electric Power Supply in the Republic of Palau