Chapter 7 Study on optimization of the transmission system development plan

7.1 Current power system in Angola

Figure 7-1 shows the transmission system map of Angola as of July 2017. The transmission network has a maximum voltage of 400 kV and is composed of transmission voltages of 220 kV, 150 kV, 132 kV, 110 kV, and 60 kV. The maximum demand is slightly less than 2,000 MW. In RNT, where the voltage classes are being organized, there are expected to be three levels of building in the future: 400 kV, 220 kV, and 60 kV.

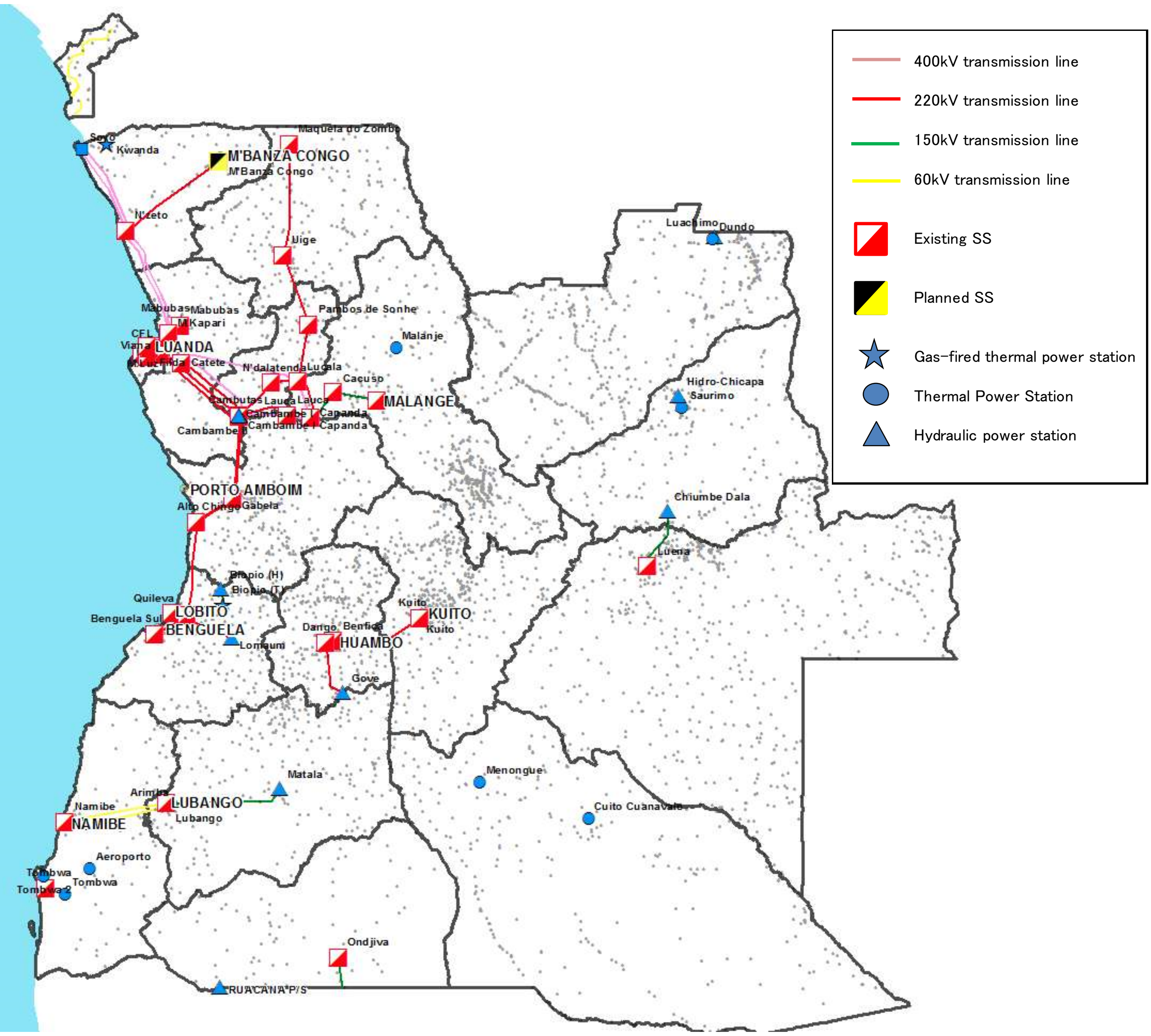
The transmission network of Angola country is currently divided into three parts: the northern part, central part, and southern part. In the northern power system, large hydroelectric power plants such as Capanda and Cambambe supply power to provinces such as Bengo, Malanje, Cuanza Norte, Cuanza Sul, Uige, and Zaire, as well as the capital city of Luanda (which has the highest demand). The northern part covers 80% of the power supply of all of Angola and accounts for nearly 80% of the total demand.

In 2018, Alto Chingo SS in the northern part, the Novo Biopio SS - Quileva SS - Lomaum hydro power station network, and Benguela sul SS in central Benguela province are expected to be interconnected to 220 kV transmission lines. The west coast side of the northern part and central part are linked as one network. The network, however, is unavailable due to aging of the Cambambe HPS - Gabela SS transmission line transmitting hydroelectric power from the north to the Alto Chingo SS. For the reasons above, the power systems are not interconnected. A new 220 kV transmission line under construction at Cambambe HPS - Gabela SS began operating in 2017. When the line was completed, the northern-central system was connected and united.

Huanbo and Bie provinces in the central part have the Gove hydroelectric power plant - Dango SS - Kuito SS transmission line, a network connected with a single circuit 220 kV transmission line. The demand rate of the central region is forecasted to compose about 10% of the total demand rate for all of Angola, provided that the demand in Benguela province is included in the calculation.

Double circuit 400 kV transmission lines have already been completed from N'Zeto SS to Soyo Thermal Power Station currently under construction in the northern end of the country. Kapary SS has been completed, and a single circuit 400 kV transmission line from Kapary SS to Catete SS has been completed. Preparations for electric power transmission from the Soyo TPS to the capital city Luanda, the largest demand site, are progressing. In addition, the 400 kV transmission line constitutes a single circuit transmission line loop system that returns from Catete SS to Catete SS via Viana SS - Lucala SS - Canpanda Elevadora HPS - Lauca HPS - Cambutas HPS. As a result, a 400 kV transmission system interconnecting large hydraulic and thermal power plants and high-demand areas has already been established.

The Namibe SS, Lubango SS, and Matala SS in Namibe and Huila provinces of the southern lineage are interconnected with Namibe SS - Lubango SS 150 kV transmission line and Lubango SS - Matala SS 60 kV transmission line. Overall, the demand in the south accounts for less than 10% of total demand in Angola. As described above, the power system of Angola is currently divided into three main electric power systems, all of which will be interconnected in the future.



(Source: RNT)

Figure 7-1 Transmission system map of Angola (July 2017)

7.2 Transmission system of the capital city Luanda

FIGURE 7-2 shows the current transmission system in the center of the capital city Luanda. Six 220 kV substations (Camama, Cacuaco, Sambizang, Cazenga, Filda and Futungo) operate under two 400 kV substations (Kapary,Viana) interconnected with the 400 kV Catete substation. The substations provide electric power to the center of the city from sites located around it.

The 400 kV Kapary substation has been supplied mainly from Soyo thermal power plant since it began full-scale operation as a power source. The 400 kV Viana substation is mainly supplied from the Cambambe hydro power station and partly supplied from the Lucala hydro power station.

(Sourse: RNT, JICA Survey Team)

Figure 7-2 Transmission system map of the center of the capital city Luanda

7.3 Power system enhancement plan by RNT

Figure 7-3 and Figure 7-4 the power network system in 2025 and 2027, respectively.

According to RNT, a plan slightly different from that shown in FIGURE 7-1 is in place. Specifically, 400 kV transmission lines will be extended from Lauca to WakoKungo SS -Dango SS - Lubango SS -Biopio SS as well as Cabaca SS - Biopio SS in 2022, while the 400 kV transmission lines will be extended from Canpanda Elevadora HPS to east side and be connected to XaMuteba SS - Saurimo SS.

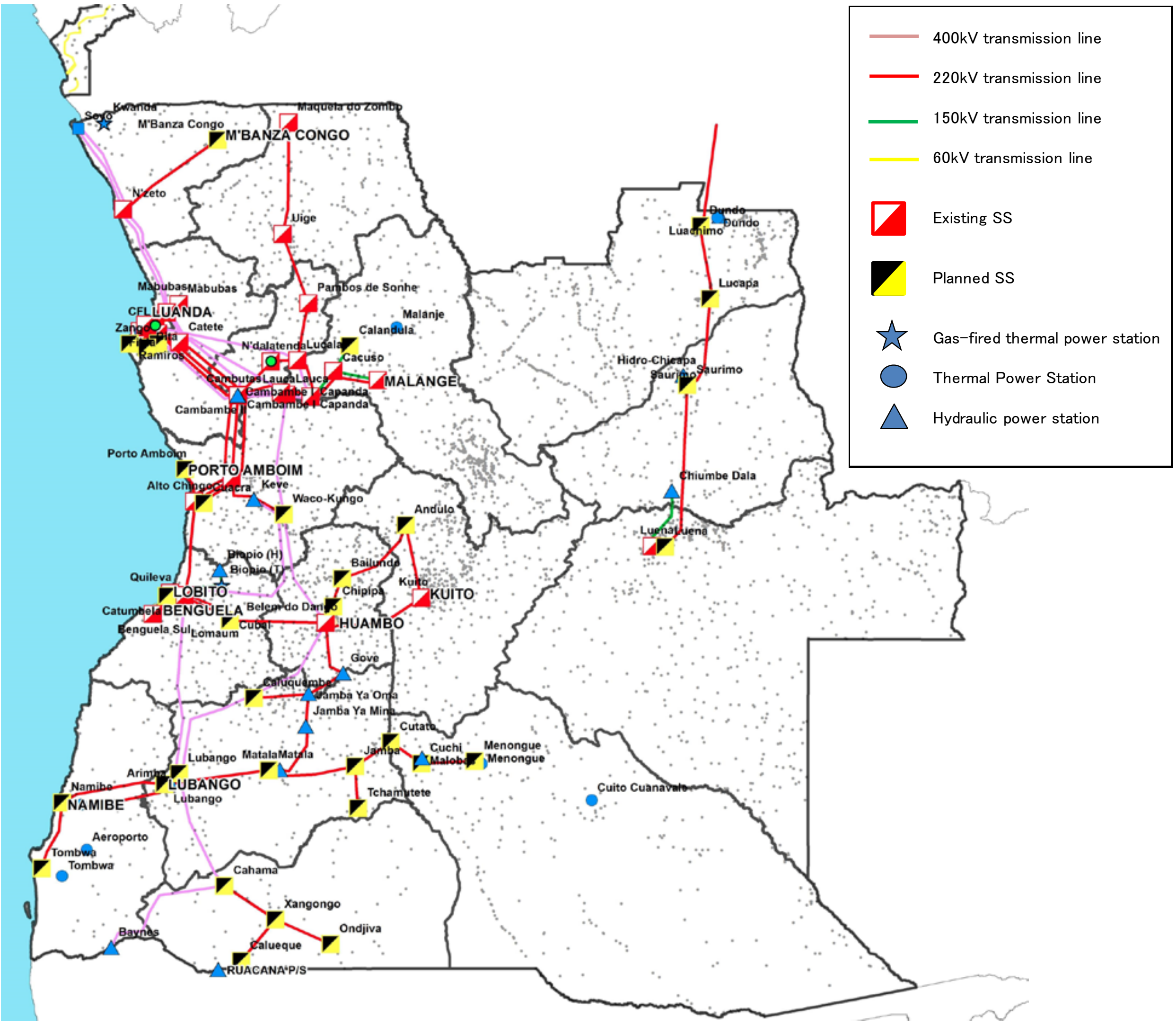
As a result, the four power systems of Angola (north system, central system, south system, and east system) will be interconnected by 400 kV transmission lines. In addition, 200 kV transmission lines will connect Saurimo in LuandaSul province to Luena in Moxio province. RNT assumes that maximum demand will be about 4200 MW.

Four hundred kV transmission lines will interconnect Biopio SS - Dango SS, and Biopio SS - Lubango SS to constitute a 400 kV loop system in 2025. Moreover, an enhancement of the 220 kV transmission line system is being developed to connect Menogue SS in CuandoCubango province, and a 400 kV- 200 kV loop system will be completed by interconnecting WakoKungo SS - Dango - SS Lubango SS - NovaBiopio SS.

The plan mentioned above will enhance the central system and the south system. At this point in the plan, 17 of the 18 provinces of Angola (the exception being Cabinda province, the enclave) will be interconnected by power systems. In addition, the 400 kV transmission lines will be extended from Lubango SS to Baynes HPS and connected with neighboring Namibia by international tie lines. RNT assumes that maximum demand will be about 4200 MW.

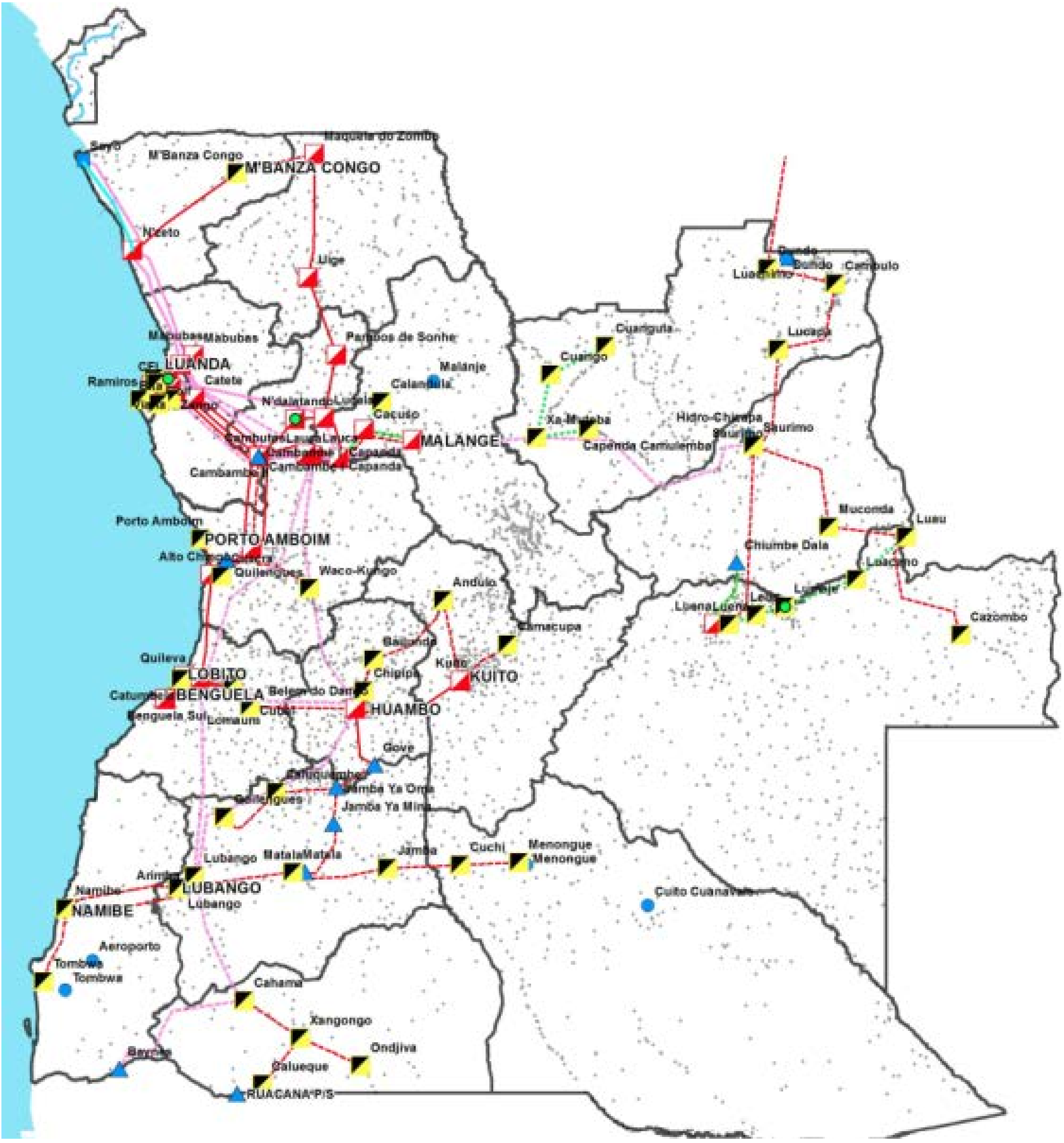
Under plans for 2027, Ondjive SS in Cunene province and Menongue SS in CubangoCubango province are to be connected by 220 kV transmission lines and the southern system is to be a 400 kV- 200 kV loop system. RNT assumes that maximum demand will be about 7100 MW.

Additionally, Luena SS in Moxico province and Camacupa SS in Bie province are to be connected by 220 kV transmission lines in the future, and the north, central system, and east systems will form a loop system to improve the reliability of the east system.



(Source: RNT)

Figure 7-3 Transmission system map of Angola (2025)



(Source: RNT)

Figure 7-4 Transmission system map of Angola (2027)

7.4 Characteristics of the main power system in Angola

The RNT plan for 2027 describes a bulk power system mainly constituting a single circuit transmission line, with 400 kV double circuit transmission lines linking Soyo SS - N'zeto SS - Kapary SS - Catete SS. Hence, the bulk power system will constitute a 400 kV - 200 kV loop system.

As a result, the power flow will become very complicated and troublesome to evaluate if the N-1 criteria are met.

7.4.1 Voltage reference

Voltage reference is defined as follows in the planning criteria of RNT power system:

Table 7-1 Voltage criteria

Voltage class (kV)	Normal operating condition "n"				Single contingency condition "n-1"			
	Minimum		Maximum		Minimum		Maximum	
	kV	p.u.	kV	p.u.	kV	p.u.	kV	p.u.
400	380	0.95	420	1.05	360	0.9	420	1.05
220	209	0.95	231	1.05	198	0.9	242	1.1
150	142	0.95	157	1.05	135	0.9	165	1.1
110	104.5	0.95	115.5	1.05	99	0.9	121	1.1

(Source: RNT)

7.5 Information gathering and analysis of the existing transmission facilities in Angola

7.5.1 Outline

The JICA Survey Team confirmed the existing transmission lines when moving within Luanda city or surveying the local area (such as Benguela, Huambo, and Soyo). The team also conducted hearings with transmission engineers from RNT and then gathered information about the transmission lines in Angola. In parallel, the team confirmed the status of the substation equipment in Angola by meeting with RNT and visiting substations in field surveys.

7.5.2 The existing transmission lines

The supporting structures for the 66 kV transmission lines consisted of concrete poles (see Figure 7-5), steel angle towers (see Figure 7-6 and Figure 7-7), and steel pipe towers (see Figure 7-8). The 220 kV transmission lines were mainly supported by steel angle towers, though many steel pipe towers were also built along the roads. There were both single and double circuits, and in one case we observed a single circuit tower and double circuit tower (one circuit is empty) mixed in one circuit transmission line.

According to RNT, trees in contact with electric wires cause many accidents. At the same time, extensive tree trimming under the wires is prohibitively expensive. It seems that ground clearance from the electric wires and the height of the transmission line tower were designed to be lower. For the transmission lines along the roads, however, the ground clearance was sufficient.

The insulators used were mainly glass. In some cases, polymer insulators were used for transmission lines below 220 kV.

The conductors used were mainly copper for 60 kV transmission lines, and ACSR and AAAC for 220 kV or 400 kV transmission lines (the latter mainly for the large-capacity transmission lines).

As for the ground wires, OPGW (optical fiber composite overhead ground wire) and AW (aluminum-clad steel overhead ground wire) were used.

Figure 7-5 66 kV concrete pole

Figure 7-6 66 kV one circuit angle tower

Figure 7-7 60 kV underground cable branch tower

Figure 7-8 60 kV steel pipe tower

Figure 7-9 220 kV steel pipe tower (tension)

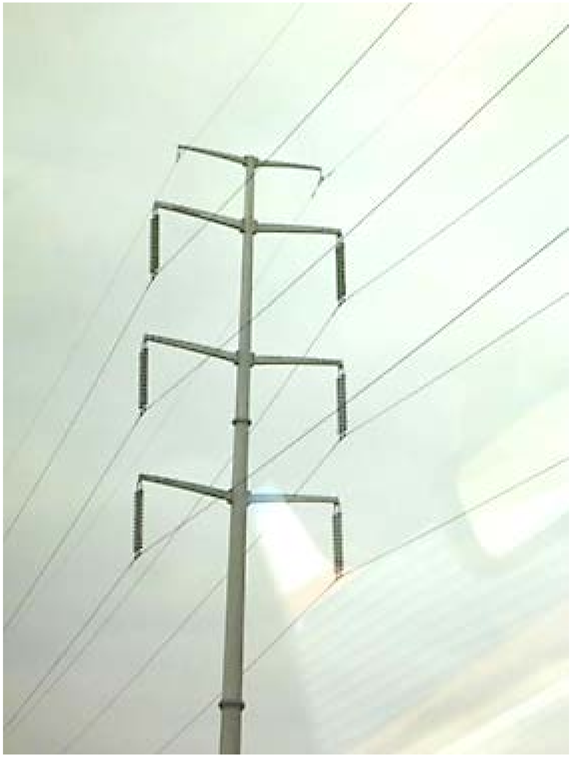


Figure 7-10 220 kV steel pipe tower (suspension)

Figure 7-11 220 kV Transmission line along the road

Figure 7-12 220 kV steel angle tower

Figure 7-13 400 kV one circuit transmission lines (distant view)

Table 7-2 and Table 7-3 list the 400 kV and 220 kV transmission lines of Angola, respectively. As shown in the outline of the Angola power system of August 2016, the country's 400 kV transmission lines ran a total distance of 281 km on 2 lines and the country's 24 kV transmission lines ran a distance of 1964.1 km on 24 lines. As of October 2017, less than a year later, the 400 kV transmission lines spanned 1183 km on 11 lines and the 220 kV transmission lines spanned 2597.4 km on 36 lines. The quantity of transmission line facilities is rapidly increasing.

Table 7-2 List of 400 kV transmission lines (as of October 2017)

Area	Name of Transmission line	Start point	End point	Voltage[kV]	Circuit	Length [Km]	Type of Conductor
North	Capanda_elv - Lucala	Capanda_elve	Lucala	400	1	61	3 x ACSR Crow 409 mm^2
	Lucala - Viana	Lucala	Viana	400	1	220	3 x ACSR Crow 409 mm^2
	Cambutas - Catete	Cambutas	Catete	400	1	123	2 x AAAC Sorbus 659,4 mm^2
	Soyo TPS - Soyo	Soyo TPS	Soyo	400	2	40	3 x AAAC Sorbus 659,4 mm^2
	Soyo - N'Zeto	Soyo	N'Zeto	400	2	142	3 x AAAC Sorbus 659,4 mm^2
	N'Zeto - Kapary	N'Zeto	Kapary	400	2	194	3 x AAAC Sorbus 659,4 mm^2
	Kapary - Catete	Kapary	Katete	400	2	57	3 x AAAC Sorbus 659,4 mm^2
	Catete - Viana	Catete	Viana	400	1	39	2 x AAAC Sorbus 659,4 mm^2
	Lauca - Capanda_elve	Lauca	Capanda_elve	400	1	41	2 x AAAC Sorbus 659,4 mm^2
	Lauca - Cambutas	Lauca	Cambutas	400	1	76	3 x AAAC Sorbus 659,4 mm^2
	Lauca - Catete	Lauca	Catete	400	1	190	2 x AAAC Sorbus 659,4 mm^2
	Total Length of 400kV Transmission lines [Km]					1183	

(Source: RNT, JICA Survey Team)

Table 7-3 List of 220 kV transmission lines (as of October 2017)

Area	Name of Transmission line	Start point	End point	Voltage [kV]	Circuit	Length [Km]	Type of Conductor
North	Cambambe - Catete	Cambambe	Catete	220	1	116	ACSR Crow 54/7 409 mm^2
	Catete - Camama	Catete	Camama	220	1	64	ACSR Crow 54/7 409 mm^2
	Cambambe - Catete	Cambambe	Catete	220	1	116	ACSR Crow 54/7 409 mm^2
	Catete - Viana	Catete	Viana	220	1	42	ACSR Crow 54/7 409 mm^2
	Cambambe - Viana	Cambambe	Viana	220	1	158	AAAC Yew 479 mm^2
	Cambambe - Cmbutas	Cambambe	Cambutas	220	2	1.3	ACSR Crow 54/7 409 mm^2
	N' Dalatando - Cambutas	N' Dalatando	Cambutas	220	1	73	ACSR Crow 54/7 409 mm^2
	Cambambe - Gabela	Cambambe	Gabela	220	1	130	ACSR Crow 54/7 409 mm^2
	Gabela - Alto chingo	Gabela	Alto Chingo	220	1	81	2xAAAC Yew 479 mm^2
	Viana - Camama	Viana	Camama	220	1	34.5	ACSR Crow 54/7 409 mm^2
	Viana - Cazenga I	Viana	Cazenga	220	1	21.5	ACSR Crow 54/7 409 mm^2
	Viana - Cazenga II	Viana	Cazenga	220	1	18	ACSR Crow 54/7 409 mm^2
	Viana - Cazenga III	Viana	Cazenga	220	1	18	AAAC Yew 470 mm^2
	Viana - Cacuaco	Viana	Cacuaco	220	1	14.5	ACSR Crow 54/7 409 mm^2
	Cacuaco - Sambizanga	Cacuaco	Sambizanga	220	2	19.3	AAAC Yew 479 mm^2
	Viana - Filda I	Viana	Filda	220	1	18	AAAC Yew 479 mm^2
	Viana - Filda II	Viana	Filda	220	1	18	AAAC Yew 479 mm^2
	Capanda - Cambutas	Capanda	Cambutas	220	1	120	ACSR Crow 54/7 409 mm^2
	Capanda - Lucala	Capanda	Lucala	220	1	70.7	ACSR Crow 54/7 409 mm^2
	Capanda - Capanda Elev A	Capanda	Capanda Elev.	220	1	3.6	ACSR Crow 54/7 409 mm^2
	Capanda - Capanda Elev B	Capanda	Capanda Elev.	220	1	3.6	ACSR Crow 54/7 409 mm^2
	Lucala - N' Dalatando	Lucala	N' Dalatando	220	1	35.7	ACSR Crow 54/7 409 mm^2
	Lucala - Pambos de Sonhe - Uíge	Lucala	Pambos de Sonhe - Uíge	220	1	211	ACSR Crow 54/7 409 mm^2
	Uíge - Maquela do Zombo	Uíge	Maquela do Zombo	220	1	200	ACSR Crow 54/7 409 mm^2
	Kapary - Cacuaco	Kapary	Cacuaco	220	1	26.7	AAAC Yew 479 mm^2
	Kapary - Ada	Kapary	Ada	220	1	14	AAAC Yew 479 mm^2
	Camama - Futungo de Belas	Camama	Futungo de Belas	220	2	14.5	AAAC Yew 479 mm^2
	Catete-Ramiros	Catete	Ramiros	220	2	91	AAAC Yew 479 mm^2
	N'Zeto - M'Banza Congo	N'Zeto	M'Banza Congo	220	1	181	AAAC Yew 479 mm^2
Central	Alto Chingo - Novo Biopio	Alto Chingo	Novo Biopio	220	1	156	2xAAAC Yew 479 mm^2
	Lomaum HPS - Novo Biopio	Lomaum HPS	Novo Biopio	220	2	95.8	ACSR Crow 54/7 409 mm^2
	Novo Biopio - Quileva	Novo Biopio	Quileva	220	1	18	2xAAAC Yew 479 mm^2
	Novo Biopio - Benguela Sul	Novo Biopio	Benguela Sul	220	1	57	AAAC Yew 479 mm^2
	Gove HPS - Belém do Dango	Gove HPS	Belém do Dango	220	1	93	ACSR Crow 54/7 409 mm^2
	Belém do Dango - Kuíto	Belém do Dango	Kuíto	220	1	150	ACSR Crow 54/7 409 mm^2
	Lomaum HPS - Quileva	Lomaum HPS	Quileva	220	1	114	ACSR Crow 54/7 409 mm^2
	Total Length of 220kV Transmission lines [Km]					2598.7	

(Source: RNT, JICA Survey Team)

7.5.3 The existing substations

Transformers made in China were mainly used for the new substations in the capacity range from 60 kV to 400 kV (see Figure 7-14), though some made in Germany were also seen. At the newly constructed 400 kV Soyo substation, four single-phase transformers were set as one unit. One was left on reserve as a spare for later use for any phase. A variable compensation reactor (manufactured by Siemens AG, see Figure 7-15) was also installed for phase modification.

The circuit breakers used were insulator types for 66 kV substations and vertical type polymer-insulated gas circuit breakers made in China (see Figure 7-16) for 220 kV substations. There was no big difference, however, from the usual outdoor substation. Specifically, a gas-insulated switchgear (GIS, manufactured by ABB; see Figure 7-17) was used at the 400 kV switchgear of the Soyo thermal power plant.

In addition, the bus configuration was standardized as a double bus configuration (see Figure 7-18), a highly reliable type.

Figure 7-14 66 kV/15 kV transformer made in China

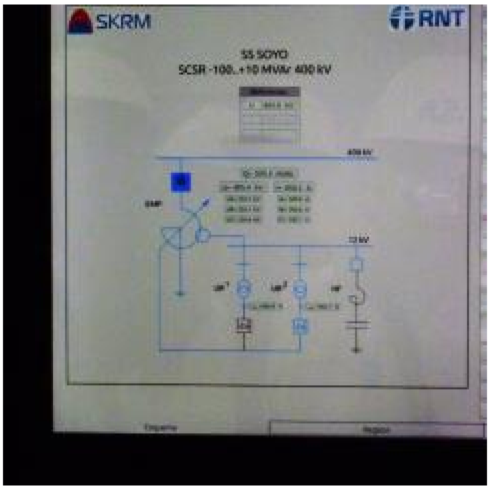
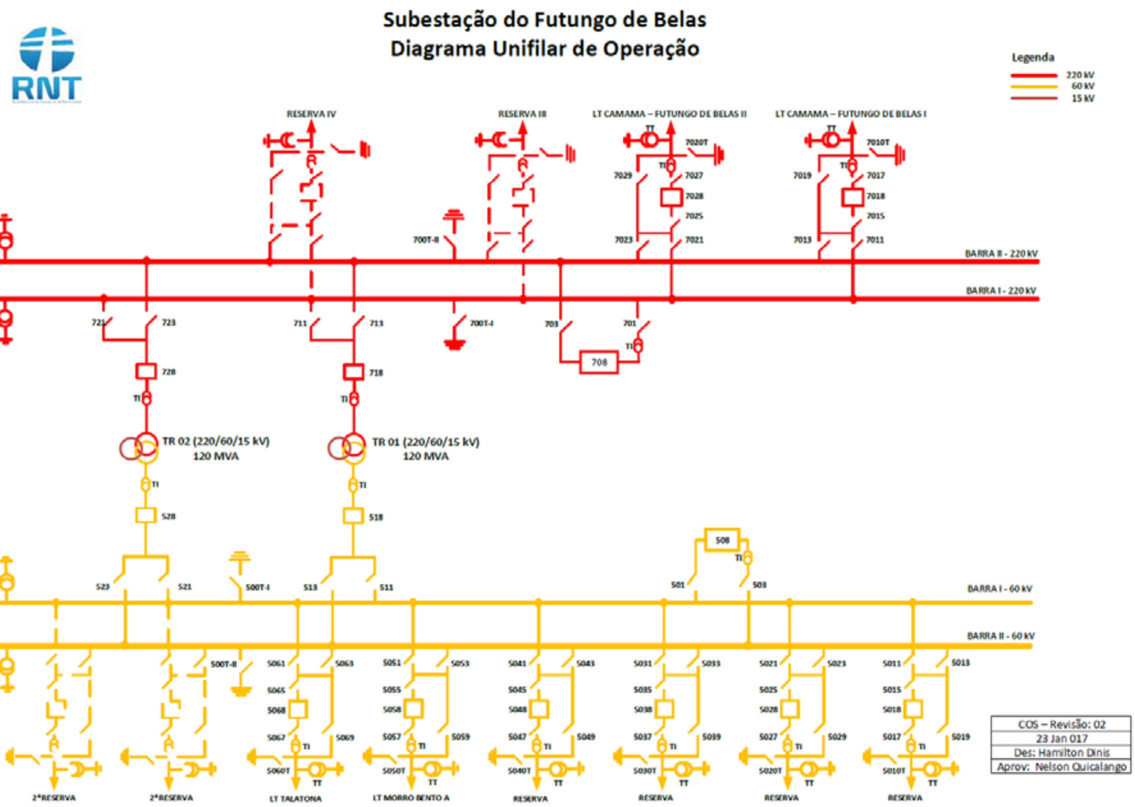


Figure 7-15 Control screen for variable compensation reactor

Figure 7-16 220 kV vertical type gas-insulated circuit breaker

Figure 7-17 Indoor type gas-insulated switchgear



(Source: RNT)

Figure 7-18 Example of a multiple bus configuration (220 kV Futungo substation)

Table 7-4 and Table 7-5 list Angola's 400 kV and 220 kV substations, respectively. As shown in the Angola Electric Power System Outline of August 2016, one 400 kV substation with a total generation capacity of 420 MVA in one facility and fifteen 220 kV substations with a total capacity of 2129 MVA were in operation. As of October 2017, nine 400 kV substations with 4950 MVA capacity and twenty-three 220 kV substations with 4086 MVA capacity were in operation. The quantity of substation facilities is also rapidly increasing.

Table 7-4 List of 400 kV substations (as of October 2017)

Area	Province	Substation Name	Voltatge[kV]	Tramsformer	Capacity[MVA]
North	Luanda	Viana substation	400/220	210 x 2	420
		Catete substation	400/220	450 x 2	900
	Bengo	Kapary substation	400/220	450 x 2	900
	Zaire	Soyo substation	400/60	120 x 2	240
		N'Zeto substation	400/220	90 x 1	90
	Kwanza Norte	Cambutas substation	220/400	930 x 2	1860
		Capanda_elev substation	220/400	270 x 2	540
	Total Capacity of 400kV substation facilities[MVA]				4950

(Source: RNT, JICA Survey Team)

Table 7-5 List of 220 kV substations (as of October 2017)

Area	Province	Substation Name	Voltage[kV]	Transformer	Capacity[MVA]
North	Luanda	Catete substation	220/60	120 x 2	240
		Cazenga substation	220/60/15	60 x 5	300
		Viana substation	220/60	60 x 5	300
		Filda substation	220/60	120 x 2	240
		Camama substation	220/60	120 x 3	360
		Cacuaco substation	220/60	60 x 2	120
		Sambizanga substation	220/60	120 x 2	240
		Futungo de Belas substation	220/60	120 x 2	240
		Ramiros substation	220/60	120 x 2	240
	Bengo	kapary substation	220/60	120 x 2	240
		Ada substation	220/15	25,40	65
	Kwanza Norte	N' Dalatando substation	220/30	40 x 1	40
		Pambos de Sonhe substation	220/30	30 x 1	30
		Cambutas substation	220/60	120 x 2	240
	Malanje	Capanda Elevadora substation	220/400	270 x 2	590
			220/30	30 x 1	
			220/110	20 x 1	
	Uíge	Uíge substation	220/60	40 x 1	40
		Maquela do Zombo substation	220/30/15	10 x 1	40
			220/60/15	30 x 1	
	Zaire	N'Zeto substation	220/60	63 x 1	63
		M'Banza Congo substation	220/60	63 x 1	63
Central	Benguela	Quileva substation	220/64/32	100 x 2	200
	Kwanza Sul	Alto Chingo substation	220/60	60 x 1	60
		Gabela substation	220/60/30	35 x 1	35
	Huambo	Belém do Dango substation	220/60/30	60 x 1	60
		Kuito substation	220/60/10	20 x 1	40
Total Capacity of 220kV substation facilities[MVA]					4086

(Source: RNT, JICA Survey Team)

7.6 Information gathering and analysis of the latest transmission development plan

7.6.1 Existing development strategies and plans

Based on Angola Energia 2025, the plan through 2027 is currently under consideration at RNT.

The skeletal system from the northernmost Soyo thermal power plant to Luanda and the transmission line from the hydraulic power plant in the Kuwanza River basin to Luanda are already being completed. A 400 kV core line to transmit this electricity to the central and southern regions is planned for the future. Under the plans by SAPP, this line will eventually be connected to the international linkage line with Namibia, the neighboring country to south of Angola. For this purpose, electricity sales to the African electricity market and interchange during the drought period are considered. Moreover, the 400 kV transmission line also plays a role as a power supply line for a newly developed large-scale power plant.

The current plans for the 400 kV main transmission lines and substations are shown in Table 7-7 and Table 7-6.

The 220 kV lines now connect the northern system and central system, but they will take on a growing role as a regional supply lines from the main 400 kV substation in each province. They also serves as a power line for small-scale thermal power plants.

Similarly, the existing plans for the 220 kV transmission lines and substations are shown in Table 7-9 and Table 7-8.

Table 7-6 Existing 400 kV main power transmission plans by RNT (~ 2027)

Project#	Area	Voltage (kV)	Starting point	End point	number of circuit	Line Length (km)	Year of operation	Project Status	Donar
1	Central	400	Lauca	Waco kungo	1	177	2020	Under Construction(Cmec)	China
2	〃	400	Waco kungo	Belem do Huambo	1	174	2020	〃	China
3	Northern	400	Catete	Bita	1	54	2022	Project in progress(Odebrecht)	Brazil
4	〃	400	Cambutas	Bita	1	167	2022	〃	Brazil
5	Central	400	Belem do Huambo	Lubango	1	337	2022	Plannning(or No information)	—
6	〃	400	Belem do Huambo	Capelongo	1	202	2022	〃	—
7	Northern	400	Cambutas	Caculo Cabaca	1	49	2023	〃	—
8	〃	400	Caculo Cabaca	Bita	1	214	2023	〃	—
9	Central	400	Caculo Cabaca	Nova Biopio	1	348	2025	〃	—
10	〃	400	Nova Biopio	Lubango	1	317	2025	〃	—
11	Southern	400	Lubango	Cahama	1	179	2025	〃	—
12	〃	400	Cahama	Baynes	1	312	2025	〃	—
13	Eastern	400	Capanda_elev	Xa-Muteba	2	266	2025	〃	—
14	〃	400	Xa-Muteba	Surimo	2	335	2025	〃	—
15	Southern	400	Capelongo	Ondjiva	1	312	2027	〃	—
16	〃	400	Cahama	Ondjiva	1	175	2027	〃	—
17	〃	400	Nova Biopio - Lubango	Caluquembe	2	5	2027	〃	—
18	〃	400	Belem do Huambo - Lubango	Quilengues	2	5	2027	〃	—
19	〃	400	Cahama	Ruacana	2	125	2027	〃	—
					Total	3753			

(Source: RNT, JICA Survey Team)

Table 7-7 Existing 400 kV main substation plans by RNT (~ 2027)

Project#	Area	Voltage (kV)	Substation Name	Capacity (MVA)	Year of operation	Project Status	Donar
1	Cuanza Sul	400	Waco kungo	450	2020	Under Construction(Cmec)	China
2	Huambo	400	Belem do Huambo	900	2020	〃	China
3	Luanda	400	Bita	900	2020	Project in progress(Odebrecht)	Brazil
4	Huila	400	Lubango	900	2022	Plannning(or No information)	—
5	〃	400	Capelongo	900	2022	〃	—
6	Benguera	400	Nova Biopio	900	2025	〃	—
7	Southern	400	Cahama	420	2025	〃	—
8	Eastern	400	Saurimo	900	2025	〃	—
9	Luanda Norte	400	Xa-Muteba	240	2025	〃	—
10	Cunene	400	Ondjiva	420	2027	〃	—
11	Huila	400	Caluquembe	180	2022	〃	—
12	〃	400	Quilengues	180	2027	〃	—
			Total	7290			

(Source: RNT, JICA Survey Team)

Table 7-8 Existing 220 kV main power transmission line plans by RNT (~ 2027)

Project#	Area	Voltage (kV)	Starting point	End point	number of circuit	Line Length (km)	Year of operation	Project Status	Donar
1	Northern	220	Kapary	Caxito	1	18	2022	Plannning(or No information)	－
2	〃	220	Filda	Golf	2	7	2022	〃	－
3	〃	220	Bita	Camama	1	17	2022	〃	－
4	〃	220	Bita	Rammiros	1	23	2022	〃	－
5	〃	220	Capanda	Marange	1	101	2022	〃	－
6	Central	220	Cambambe	Gabela	1	134	2022	〃	－
7	〃	220	Gabela	Alto Chingo	1	64	2022	〃	－
8	〃	220	Gabela	Quibala	1	64	2022	〃	－
9	〃	220	Quibala	Waco Kungo	1	68	2022	〃	－
10	〃	220	Lomaum	Cubal	1	4	2022	〃	－
11	〃	220	Belem do Huambo	Cubal	1	146	2022	〃	－
12	Southern	220	Lubango	Namibe	2	151	2022	〃	－
13	〃	220	Namibe	Tombwa	1	110	2022	〃	－
14	〃	220	Lubango	Matala	1	154	2022	〃	－
15	〃	220	Matala HPS	Matala	1	15	2022	〃	－
16	〃	220	Capelongo	Cuchi	2	71	2022	〃	－
17	〃	220	Cuchi	Menongue	2	77	2022	〃	－
18	Northern	220	Viana	PIV	1	4	2027	〃	－
19	〃	220	Cazenga	PIV	1	21	2027	〃	－
20	〃	220	Sambizanga	Chicala	1	5	2027	〃	－
21	〃	220	Futungo de Belas	Chicala	1	12	2027	〃	－
22	〃	220	Catete	Maria Teresa	2	50	2027	〃	－
23	Central	220	Alto Chingo	Cuacra	2	15	2027	〃	－
24	〃	220	Alto Chingo	Port Amboim	2	50	2027	〃	－
25	〃	220	Quileva	Catumbela	1	8	2027	〃	－
26	〃	220	Benguela Sul	Catumbela	1	33	2027	〃	－
27	〃	220	Nova Biopio	Bocoio	1	5	2027	〃	－
28	〃	220	Lomaum	Bocoio	1	5	2027	〃	－
29	〃	220	Cubal	Ukuma	1	5	2027	〃	－
30	〃	220	Belem do Huambo	Ukuma	1	5	2027	〃	－
31	〃	220	Belem do Huambo	Catchiungo	1	9	2027	〃	－
32	〃	220	Kuito	Catchiungo	1	9	2027	〃	－
33	〃	220	Belem do Huambo	Kuito	1	144	2027	〃	－
34	〃	220	Kuito	Andulo	1	110	2027	〃	－
35	Southern	220	Cahama	Xangongo	1	88	2027	〃	－
36	〃	220	Ondjiva	Xangongo	1	90	2027	〃	－
37	〃	220	Capelongo	Matala	1	158	2027	〃	－
38	〃	220	Matala	Jamba Mina	2	83	2027	〃	－
39	〃	220	Jamba mina	Jamba Oma	2	49	2027	〃	－
40	〃	220	Capelongo	Tchamutete	2	93	2027	〃	－
41	Eastern	220	Saurimo	Lucapa	1	157	2022	〃	
42	〃	220	Lucapa	Dundo	1	135	2022	〃	
43	〃	220	Saurimo	Luena	1	246	2027	〃	－
44	〃	220	Saurimo	Muconda	1	169	2027	〃	－
45	〃	220	Muconda	Luau	1	100	2027	〃	－
46	〃	220	Luau	Cazombo	1	187	2027	〃	－
					Total	3269			

(Source: RNT, JICA Survey Team)

Table 7-9 Existing 220 kV main substation plans by RNT (~ 2027)

Project#	Area	Voltage (kV)	Substation Name	Capacity (MVA)	Year of operation	Project Status	Donar
1	Bengo	220	Caxito	120	2022	Plannning(or No information)	—
2	Luanda	220	Golf	240	2022	〃	—
3	〃	220	Bita	240	2022	〃	—
4	Maranje	220	Maranje	200	2022	〃	—
5	Cuanza Sul	220	Gabela	120	2022	〃	—
6	〃	220	Quibala	60	2022	〃	—
7	〃	220	Waco Kungo	60	2022	〃	—
8	Benguela	220	Cubal	120	2022	〃	—
9	Huambo	220	Belem do Huambo	240	2022	〃	—
10	Huila	220	Lubango	240	2022	〃	—
11	Namibe	220	Namibe	120	2022	〃	—
12	〃	220	Tombwa	120	2022	〃	—
13	Huila	220	Matala	120	2022	〃	—
14	Cuando Cubango	220	Cuchi	40	2022	〃	—
15	〃	220	Menongue	240	2022	〃	—
16	Luanda	220	PIV	240	2027	〃	—
17	〃	220	Chicala	240	2027	〃	—
18	Bengo	220	Maria Teresa	120	2027	〃	—
19	Cuanza Sul	220	Cuacra	60	2027	〃	—
20	〃	220	Port Amboim	120	2027	〃	–
21	Benguela	220	Catumbela	240	2027	〃	—
22	〃	220	Bocoio	120	2027	〃	—
23	Huambo	220	Ukuma	120	2027	〃	—
24	〃	220	Catchiungo	120	2027	〃	—
25	Bie	220	Andulo	120	2027	〃	—
26	Cunene	220	Xangongo	120	2027	〃	—
27	〃	220	Tchamutete	180	2027	〃	—
28	Moxito	220	Luena	240	2027	〃	—
29	Luanda Sul	220	Muconda	40	2027	〃	—
30	Moxito	220	Luau	120	2027	〃	—
31	〃	220	Cazombo	80	2027	〃	—
			Total	4560			

(Source: RNT, JICA Survey Team)

For reference, the transmission system diagrams as of 2022 and 2027 obtained from RNT are shown in Figure 7-19 to Figure 7-22.

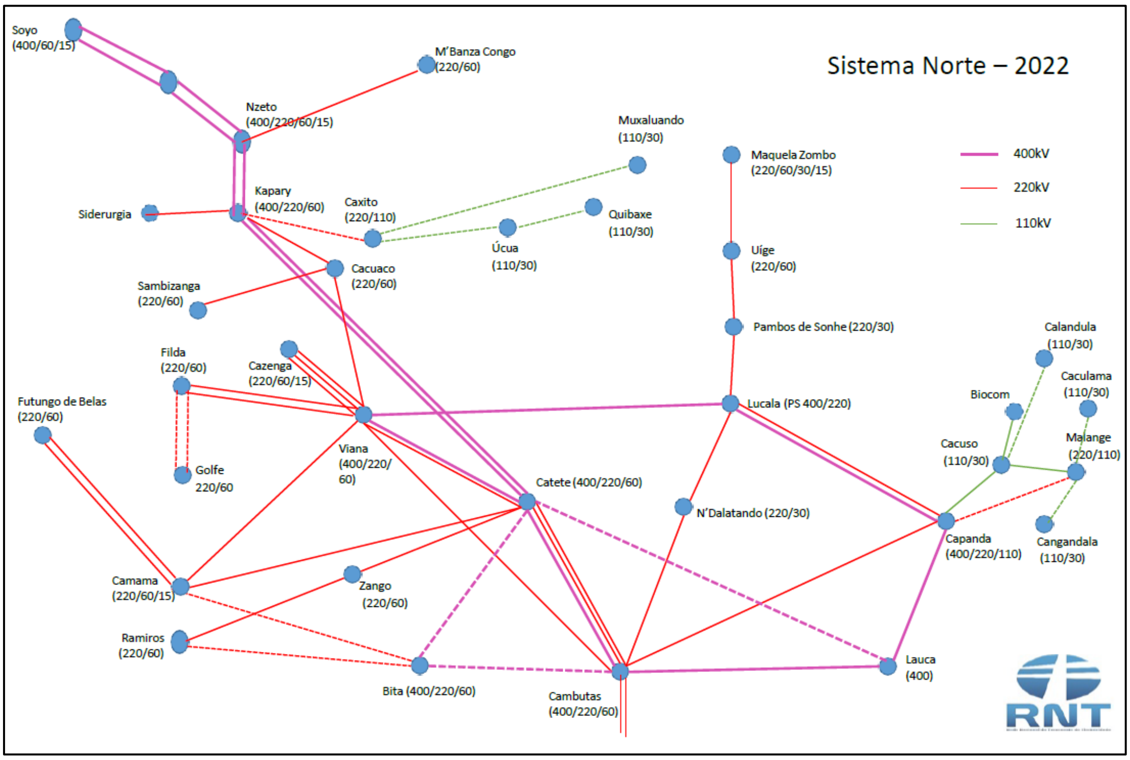


Figure 7-19 Existing plan for the northern system as of 2022 by RNT

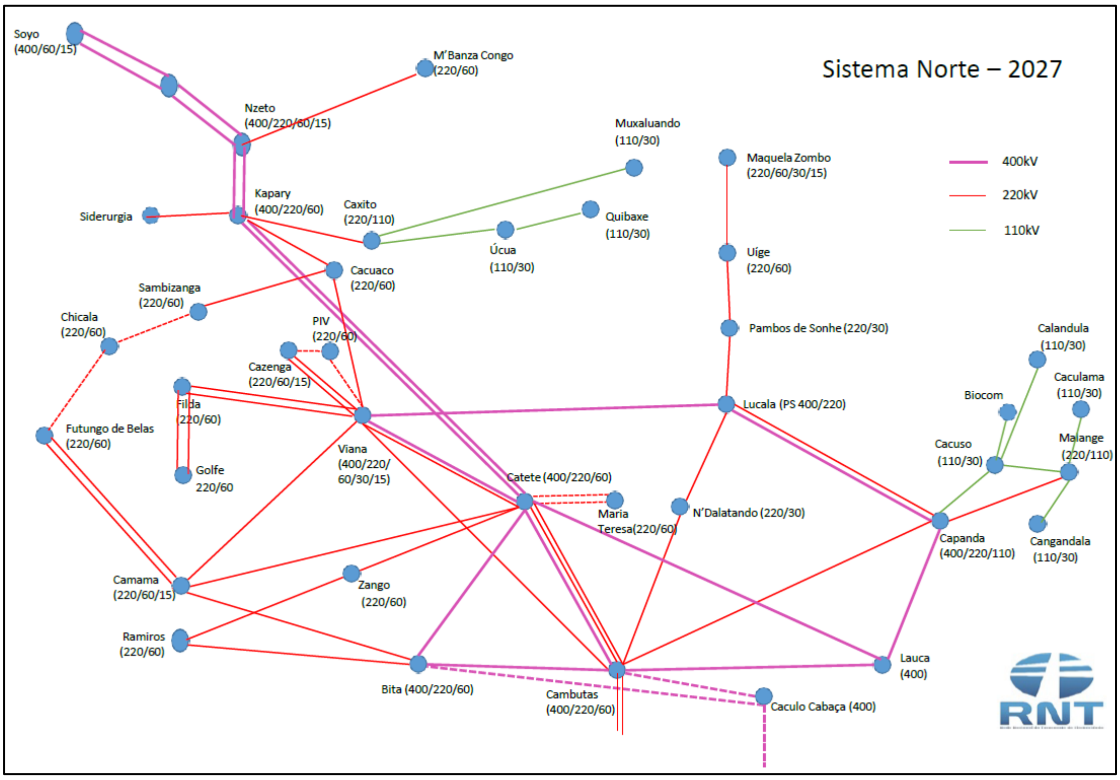


Figure 7-20 Existing plan for the northern system as of 2027 by RNT

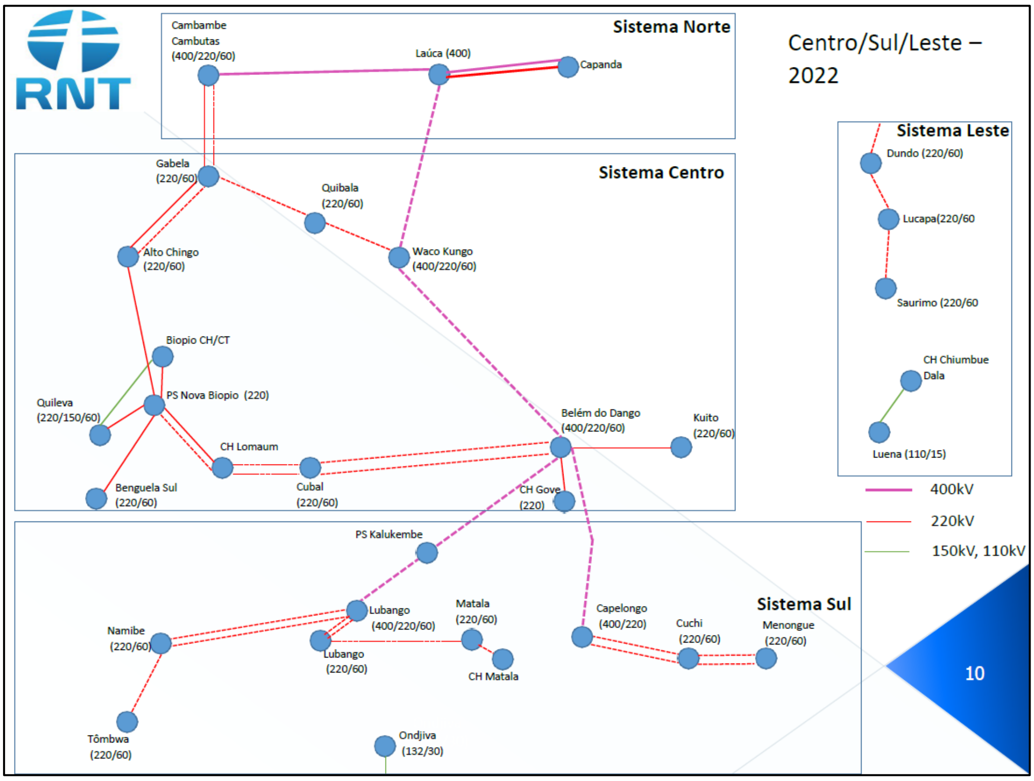


Figure 7-21 Existing plan for the central, southern and western systems as of 2022 by RNT

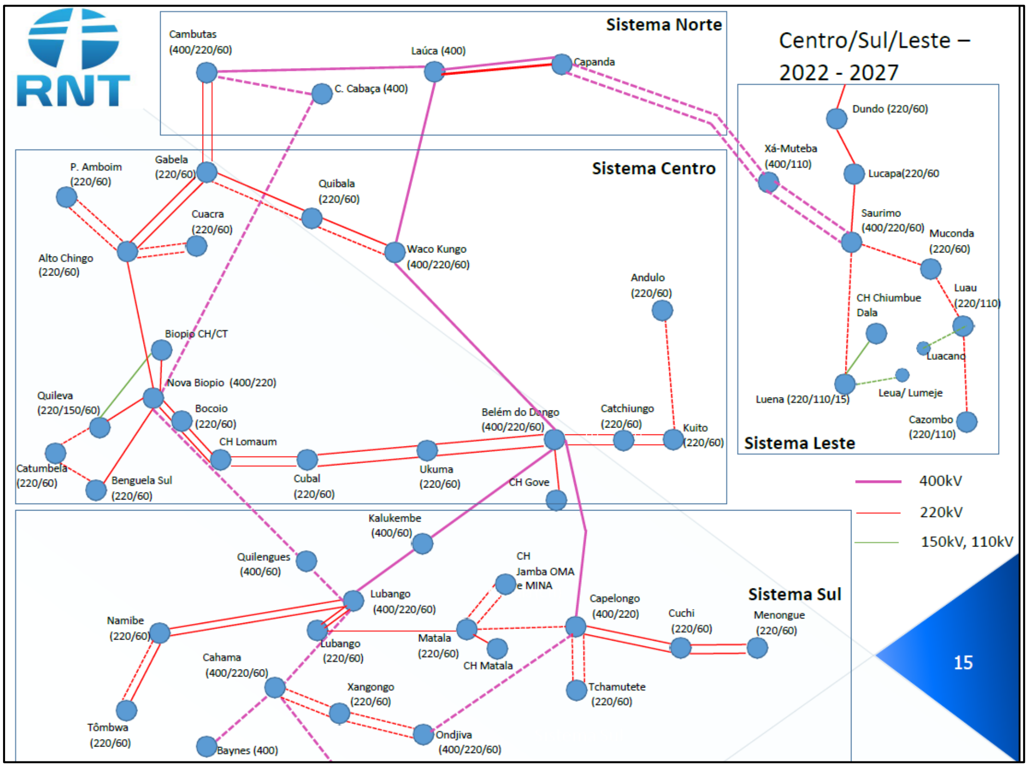


Figure 7-22 Existing plan for the central, southern and western systems as of 2027 by RNT

7.6.2 Analysis of the technical data and the latest cost in existing facilities

In order to confirm the design content of the existing facilities, we asked for technical information on the transmission lines and substations by questionnaire, during interviews, etc. We were only able, however, to obtain fragmentary technical standards and technical specifications on individual projects. The information confirmed that the transmission line and substation designs were basically based on IEC standards.

We examined details related to the transmission lines and substations from two packages of materials obtained from RNT: "ESPECIFICAÇÕES TECHNICAS GERAIS Redes de Distribution Technical specifications for AT, MT e BT (high voltage (60 kV - 35 kV), medium voltage (35 kV - 1 kV), low voltage (less than 1 kV) distribution equipment ET - E - 001 to 008, 2014.10)" and "ESPECIFICA ES TECHNICAS GERAIS Rede de Transporte MAT (General technical specifications for special high-voltage (60 kV or higher) transmission system, ET-E-101 to 121, 2014.7)."

By examining the contents of "Projectos de Linhas aéreas de MAT" (project of special high-voltage overhead transmission line: ET-E-110) and "Projects de Substitution de E de Postos de Seccionamento de MAT" (project of special high-voltage substation or switch station: ET-E-119), we confirmed the design methods and parameters used in the world standard 400 kV or 220 kV transmission lines and substations, based on IEC standards, etc.

Regarding the cost of the transmission lines and substations in Angola, only one example of 220 kV transmission line and substation construction work was available locally. For the cost estimation, we therefore considered the recent international procurement prices in developing countries that have installed transmission lines and substations based on IEC standards.

To estimate the cost per km of the 400 kV transmission line, we adopted a cost estimate used in a Bangladesh country project based on the recent international procurement price. To estimate the cost per km of the 220 kV transmission line we referred to the result in the Angola project.

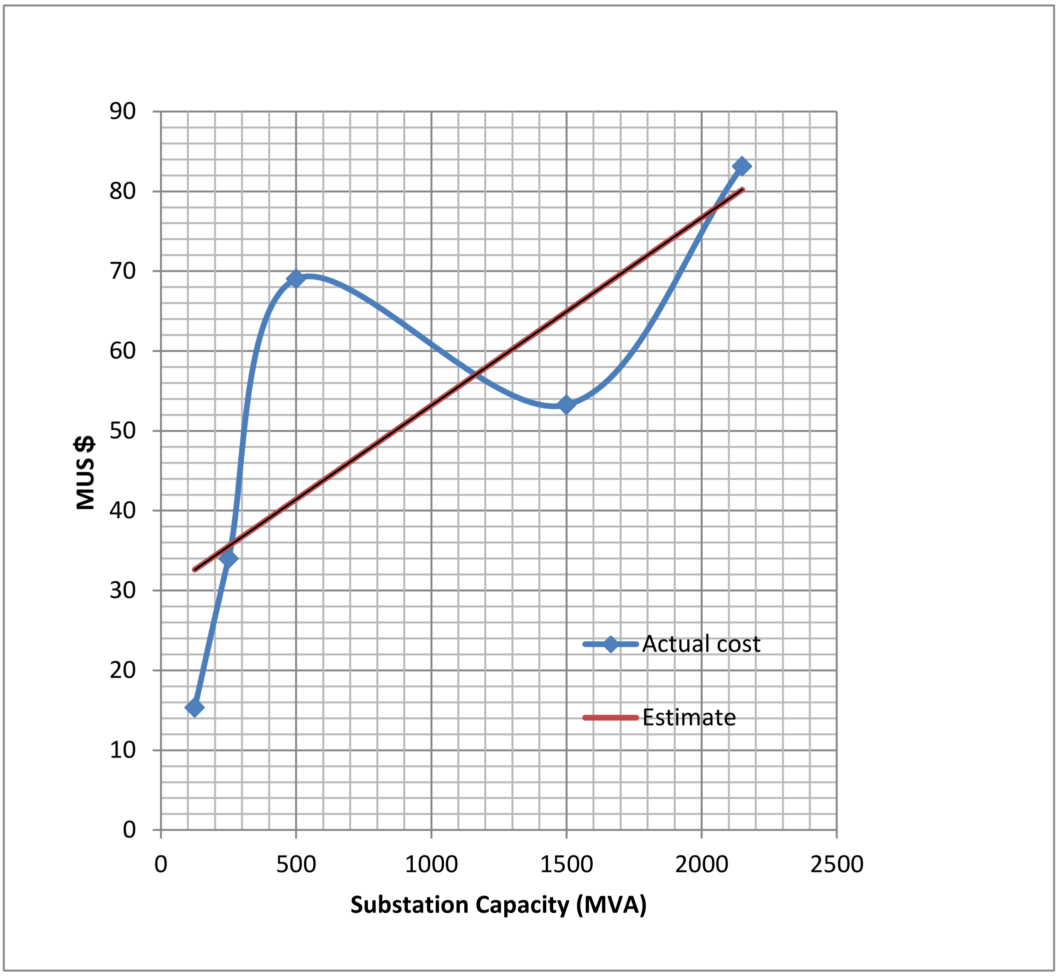
As this cost estimate was for a two circuit transmission line, the cost per km of a one-circuit transmission line was estimated to be 80% of that for a two-circuit line, from the past record. The estimated cost per km for the transmission lines is shown in Table 7-10

Table 7-10 Estimated transmission line cost per km

Voltage	Number of cct	TL cost per km (Unit: MUSD/km)
400kV	1	0.78
	2	0.98
220kV	1	0.36
	2	0.45

(Source: JICA Survey Team)

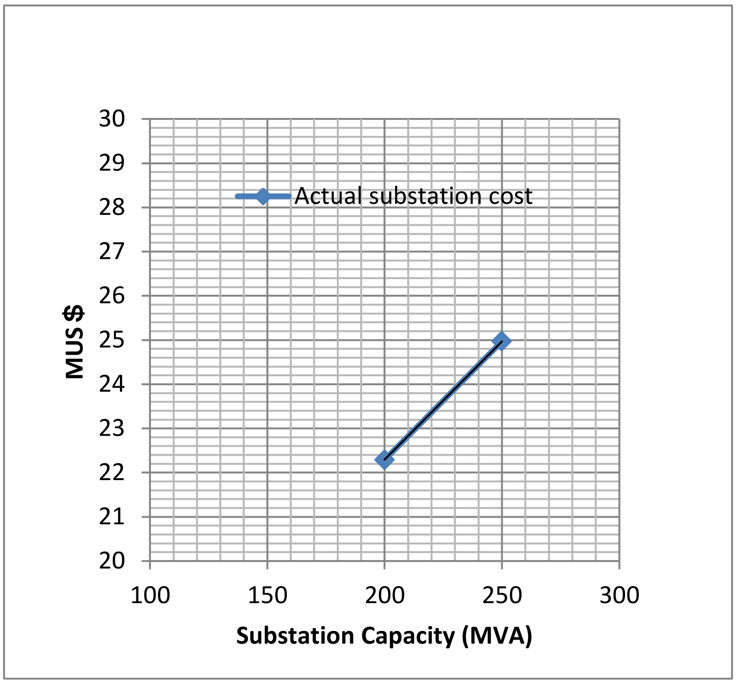
As for the cost of the substations, five cost estimates for 400 kV substation constructions were available from recent cases (3 in Mozambique and 2 in Bangladesh). The cost of substations is known to correlate with the transformer capacity. By knowing this correlation, we were able to linearize the cost of the 400 kV substations by the least squares method and make estimations from the data.



(Source: JICA Survey Team)

Figure 7-23 Estimated 400 kV substation cost

Likewise, the two recent cost estimastes for 220 kV substations elsewhere (Angola 1 case, Mozambique 1 case) allowed us to linearize the value by the least squares method and make an estimate.



(Source: JICA Survey Team)

Figure 7-24 Estimated 220 kV substation cost

According to the above results, the cost per substation based on the transformer total capacity is as shown in Table 7-11.

Table 7-11 Cost per substation based on the total transformer capacity

Voltage	Cost per substation based on total transformer capacity P (Unit: MUSD/substation)
400kV	**0.024xP(MVA) ＋29.67**
220kV	**0.054xP(MVA) ＋11.58**

(Source: JICA Survey Team)

7.6.3 Analysis based on international interconnection with neighboring countries (Democratic Republic of Congo, Namibia, Zambia)

We studied the international interconnection plan with neighboring countries (Democratic Republic of Congo, Namibia, and Zambia) described in Angola Energia 2025.

The international interconnections described in Angola Energia 2025 cover the following four areas.

I. Democratic Republic of Congo Inga Hydroelectric Power Station and Soyo Substation

II. International ties with Western strains from the Kananga substation in the Democratic Republic of Congo

III. International interconnection with western strains from the Copper Belt substation in Zambia

IV. Interconnection with an SAPP interconnection transmission line via the Ruakana substation in Namibia

Figure 7-25 outlines the interconnections.

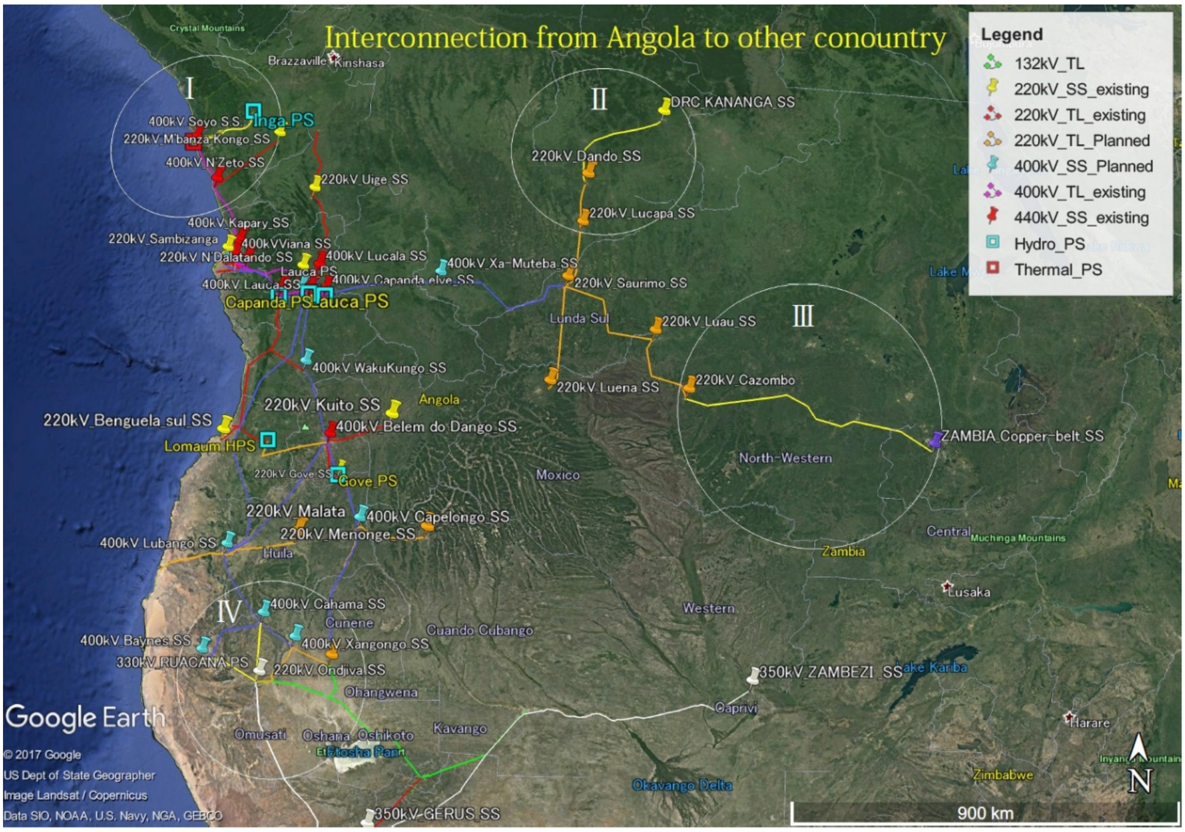


Figure 7-25 Outline of international interconnections with Angol

(Source: RNT, JICA Survey Team)

Turning to the current status of the examination, information gathered from RNT reveals the following contact points with SAPP (Southern Africa Power Pool) in the field. The concept for I is as follows: the electric power produced by the large-scale development of the Inga hydropower station in the Democratic Republic of Congo is transmitted through the power system of Angola, then onward through the SAPP international interconnection line, and finally to South Africa.

The investigation has been suspended, however, because of political problems with the Democratic Republic of Congo. When the investigation is resumed, the SAPP team currently examining the feasibility study for interconnection with Namibia will to do the same for this interconnection plan.

As for Ⅱ, there is no power transmission system that can be connected to the Congo side at present. There are reports that electric power is being received by a private line from a small hydropower station on the Congo side. A similar scheme will be conducted after the development of the Western transmission line. Thus, we confirmed that international connection with Congo would not take place.

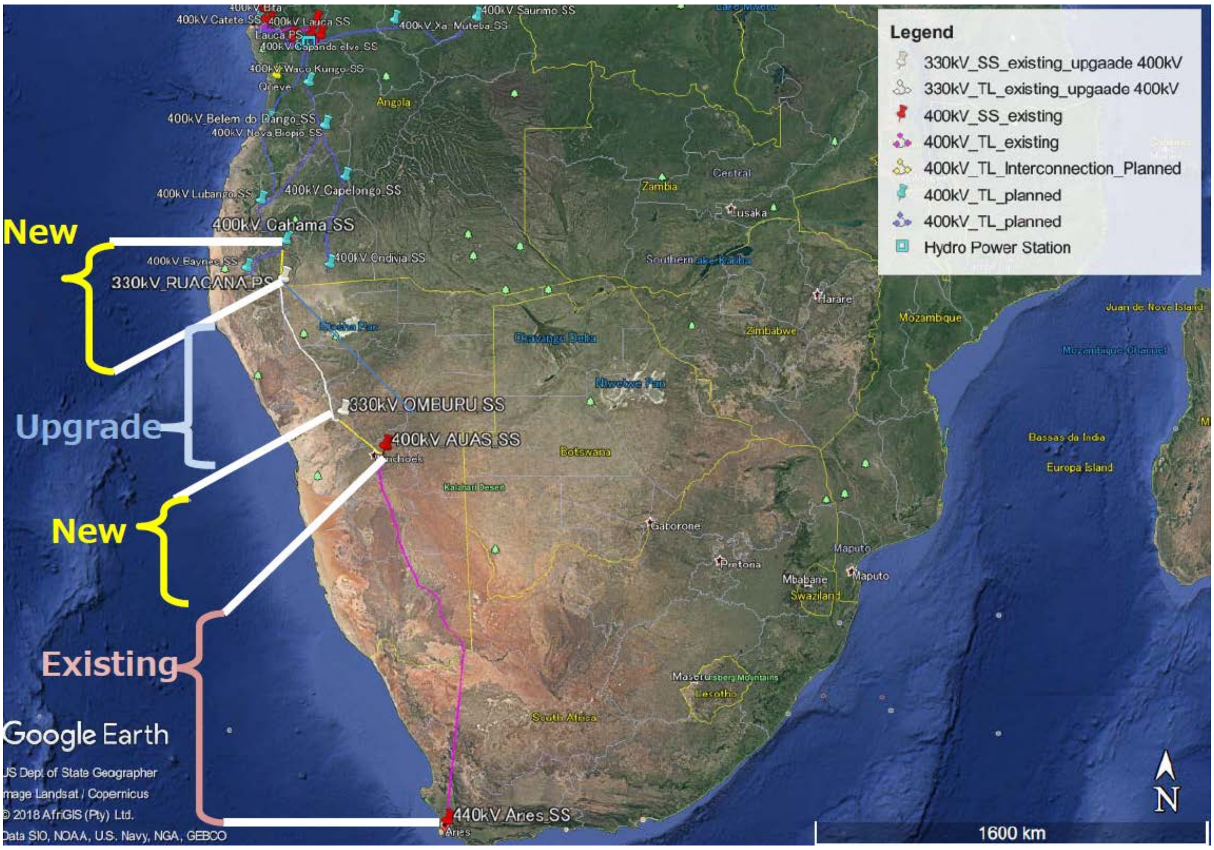
As for Ⅲ, there were once plans to sell electricity to the Copper Belt region, a mining development zone in Zambia. Those plans are now abandoned.

As for Ⅳ, the purposes are to sell electricity to South Africa through the international interconnection line passing through Namibia and to aim to ensure a stable supply of electricity by receiving power in drought periods. The SAPP team is currently considering a feasibility study. The concept study has been completed, and international linkage is judged to be possible. The final report of the feasibility study is scheduled to be submitted in FY 2018, after financing. We believe that the project will be started in 2025 after the environmental impact assessment procedure is completed.

The concept for the international interconnection line consists of establishing a new 400 kV transmission line from the Cahama substation in Angola to the Ruakana substation in Namibia, boosting the 330 kV transmission line between the Ruakana substation and Omburu substation in Namibia to 400 kV, establishing a new 400 kV transmission line from the Omburu substation to the Auasa substation in Namibia, the end point of the international interconnection line between South Africa and Namibia, and connecting to the existing 400 kV international interconnection line.

Figure 7-26 shows the concept for the international interconnected transmission lines.

Since the international interconnection line from Angola to South Africa will be a long distance transmission line of over 2,000 km, it will be necessary to carefully consider the system stability problem. While the stability problem falls outside the direct scope of this survey, we want to call attention to it. An interchange power of 400 MW is assumed. If the power development is carried out smoothly in Angola, we believe that there will be no big influence on the electricity supply and demand.



(Source: RNT, JICA Survey Team)

Figure 7-26 Outline of the international interconnection plan concept with SAPP

Under these circumstances, cases I and IV are considered to be international interconnections affecting the future interconnection of Angola.

This situation is not considered ideal from a general perspective, as the tidal current control becomes difficult when interconnecting at two or more connection points with a power system based on alternative current. It would be inappropriate, however, to form a direct current interconnection. Doing so would be costly for the conversion facilities and poorly suited to the selling of electricity. There therefore seems to be no problem with case Ⅳ, whose feasibility study is currently advancing.

Furthermore, when interconnecting I, it is advisable to connect a part of the generator of the Inga hydroelectric power plant as a power source with a dedicated line, without interconnection with the power system of the Republic of Congo.

The Angola side was apprised of this situation at the JCC meeting and workshop.

Moreover, in order to conduct international interconnection, it will be necessary to first establish a plan to monitor and control the domestic power system. The maintenance of power frequency and economic operations seems to be severely challenged in the current monitoring and control system in Angola.

At the workshop, therefore, we urged the Angola side to understand the need for system monitoring and control. In this report we also introduced the SCADA system to the central dispatching center, the entity supervising and controlling the entire system, in order to enhance the grid monitoring control we would like to propose.

7.7 Transmission network development plan

7.7.1 Policy

First, as for the 220 kV system, a 220 kV substation representing the regional load has been determined to ensure consistency with the regional demand assumption. The 220 kV substation is connected with the 400 kV substation via a 220 kV transmission line, and the existing 220 kV transmission lines, substations, and 220 kV transmission lines connecting the power plant are adjusted as needed to make a plan.

Regarding the 400 kV core system, since RNT is already planning to form a skeleton by 2027, we basically adopt that plan to the system and check the consistency of the new 400 kV transmission lines connecting a power plant and 220 kV power lines with the plan to revise it.

Ultimately, the substation capacity, transmission line capacity, and capacity of the phase modifying facility are determined by a power system analysis.

The development planning procedure is shown in the flowchart of Figure 7-27.

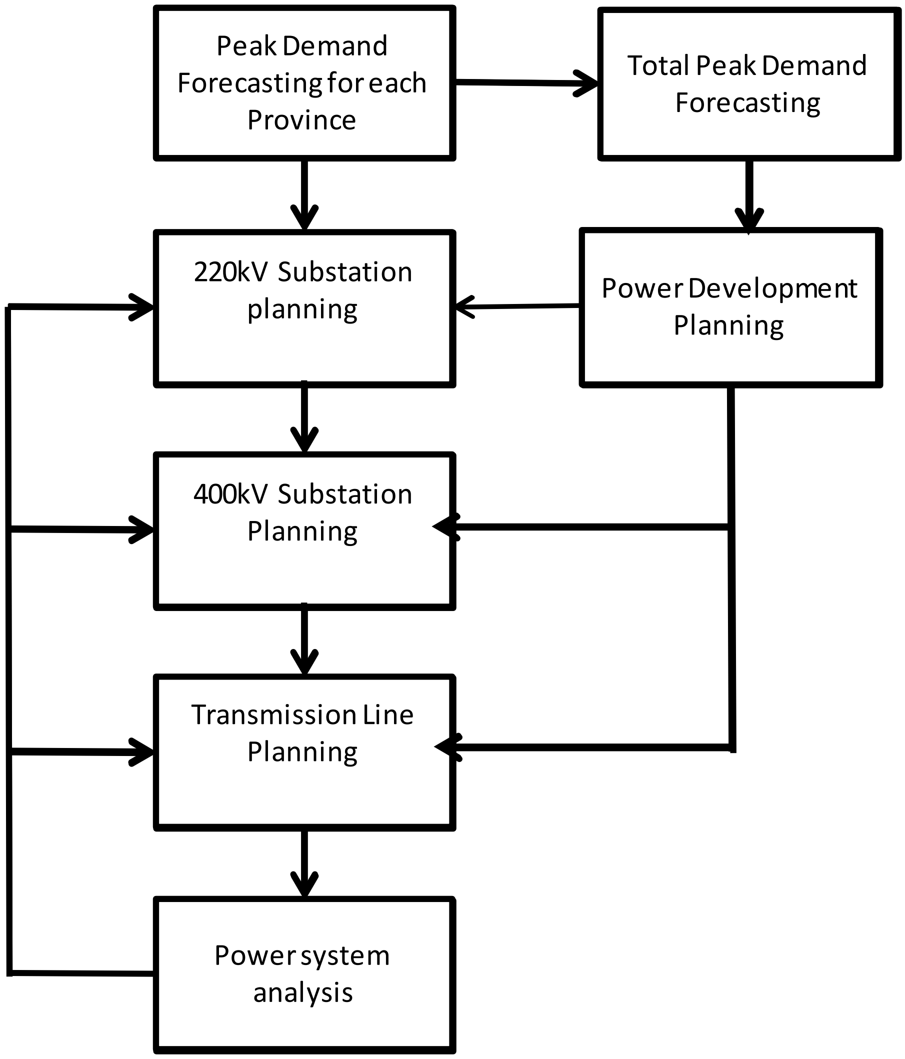


Figure 7-27 Flowchart of the Transmission Network Development Plan
(Source: JICA Survey Team)

7.7.2 Regional supply substation plan based on demand forecasts

The following table outlines the required substations and capacity for each province (Province) based on the annual maximum electric power demand forecast.

Table 7-12 220 kV Substation plan based on demand forecast of northern region

Provincia	Capital	Year	2020	2025	2030	2035	2040	
Luanda	Luanda	Forecasted Demand (MW)	2123	2752	3183	4220	4734	Remarks (Operation Year)
		> 220kV Gnenrator (MW)	614	0	0	0	0	
		Neccesary Capacity (MVA)	1,677	3,058	3,537	4,689	5,259	
		Existing Capacity(MVA)	2520	2520	4920	5160	6000	
		Insufficient capacity (MVA)	—	538	-1,383	-471	-741	
		Total Planned Capacity(MVA)	2520	4920	5160	6000	6240	
		Subastation Name	Substation Capacity(MVA)					
		Catete	240	240	240	240	240	exsitng
		Cazenga	300	300	300	420	420	exsitng upgrade2035
		Viana	300	900	900	900	900	exsitng upgrade2025
		Filda	240	240	240	240	240	exsitng
		Camama	360	360	480	480	480	exsitng upgrade2025
		Cacuaco	120	480	480	720	720	exsitng upgrade2021 2034
		Sambizanga	240	480	480	480	720	exsitng upgrade2025 2036
		Futungo de Belas	240	240	360	360	360	exsitng upgrade2030
		Ramiros	240	240	240	240	240	exsitng
		Bita	240	240	240	240	240	2020
		Zango		360	360	360	360	2022
		Golfe		360	360	360	360	2022
		Chicara		480	480	480	480	2025
		PIV				480	480	2035
Bengo	Caxito	Forecasted Demand (MW)	59	119	177	242	316	Remarks (Operation Year)
		> 220kV Gnenrator (MW)						
		Neccesary Capacity (MVA)	65	132	197	269	351	
		Existing Capacity(MVA)	305	305	425	425	425	
		Insufficient capacity (MVA)	-240	-173	-228	-156	-74	
		Total Planned Capacity(MVA)	305	425	425	425	545	
		Subastation Name	Substation Capacity(MVA)					
		Kapary	240	240	240	240	360	exsitng upgrade2035
		ADA	65	65	65	65	65	exsitng
		Caxito		60	60	60	60	2025
		Maria Teresa		60	60	60	60	2025
Kuanza Norte	N'dalatando	Forecasted Demand (MW)	67	151	221	288	358	Remarks (Operation Year)
		> 220kV Gnenrator (MW)						
		Neccesary Capacity (MVA)	75	168	246	320	398	
		Existing Capacity(MVA)	310	310	390	390	510	
		Insufficient capacity (MVA)	—	-142	-144	-70	-112	
		Total Planned Capacity(MVA)	310	390	390	510	510	
		Subastation Name	Substation Capacity(MVA)					
		Cambutas	240	240	240	240	240	exsitng
		N' Dalatando	40	120	120	120	120	existing upgrade2025
		Pambos de Sonhe	30	30	30	30	30	exsitng
		Lucala				120	120	2035
Malanje	Malanje	Forecasted Demand (MW)	103	152	216	290	359	Remarks (Operation Year)
		> 220kV Gnenrator (MW)						
		Neccesary Capacity (MVA)	115	169	240	323	399	
		Existing Capacity(MVA)	130	130	370	370	370	
		Insufficient capacity (MVA)	—	39	-130	-47	29	
		Total Planned Capacity(MVA)	130	370	370	370	490	
		Subastation Name	Substation Capacity(MVA)					
		Capanda Elevadora	130	130	130	130	130	existing upgrade2020
		Malanje2(Catepa)		240	240	240	360	2022 Upgrade2040
Uíge	Uíge	Forecasted Demand (MW)	73	156	256	370	501	Remarks (Operation Year)
		> 220kV Gnenrator (MW)						
		Neccesary Capacity (MVA)	81	173	284	412	556	
		Existing Capacity(MVA)	80	80	280	280	280	
		Insufficient capacity (MVA)	—	93	4	132	276	
		Total Planned Capacity(MVA)	80	280	460	580	620	
		Subastation Name	Substation Capacity(MVA)					
		Uíge	40	240	240	240	240	existing upgrade2022
		Maquela do Zombo	40	40	40	40	80	existing upgrade2036
		Negage			180	180	180	2030
		Sanza Pombo				120	120	2035
Zaire	Zaire	Forecasted Demand (MW)	55	105	164	230	303	Remarks (Operation Year)
		> 220kV Gnenrator (MW)						
		Neccesary Capacity (MVA)	61	117	182	256	337	
		Existing Capacity(MVA)	366	406	406	406	523	
		Insufficient capacity (MVA)	—	-289	-224	-150	-186	
		Total Planned Capacity(MVA)	406	406	406	523	523	
		Subastation Name	Substation Capacity(MVA)					
		Soyo	240	240	240	240	240	exsitng
		N'Zeto	63	63	63	63	63	exsitng
		M'Banza Congo	63	63	63	180	180	exsitng upgrade2031
		Tomboco	40	40	40	40	40	2020
Cabinda	Cabinda	Forecasted Demand (MW)	104	135	178	222	269	Remarks (Operation Year)
		> 220kV Gnenrator (MW)	104	135	0	0	0	
		Neccesary Capacity (MVA)	0	0	198	247	299	
		Existing Capacity(MVA)	0	0	0	360	360	
		Insufficient capacity (MVA)	—	0	198	-113	-61	
		Total Planned Capacity(MVA)	0	0	360	360	360	
		Subastation Name	Substation Capacity(MVA)					
		Cabinda			240	240	240	2030
		Cacongo			120	120	120	2030
Subtotal			3751	6791	7571	8768	9288	

(Source: JICA Survey Team)

Based on the anticipated demand for each province, the JICA Survey Team chose the location of the demand center and decided the substation position, working in consultation with RNT. In areas small-scale demand will continue in the future, the substation capacity (originally set to less than 60 MVA) was standardized to 120 MVA or 240 MVA according to the demand scale. For heavy load areas in Luanda area, 480 MVA or 720 MVA was adopted.

In Table 7-12, the red indicates the existing substation and its capacity, and the blue indicates the new substation and its capacity and the capacity of the substation after expansion. The year of new establishment and year of enhancement are stated in the remarks column.

The same applies to Table 7-13 to Table 7-15.

Table 7-13 220 kV Substation plan based on the demand forecast for the central region

Area	Provincia	Capital	Year	2020	2025	2030	2035	2040	
Centeral	Cuanza Sul	Sumbe	Forecasted Demand (MW)	101	174	263	369	494	Remarks (Operation Year)
			> 220kV Gnenrator (MW)						
			Neccesary Capacity (MVA)	113	193	292	410	549	
			Existing Capacity(MVA)	240	240	480	480	480	
			Insufficient capacity (MVA)	–	-47	-188	-70	69	
			Total Planned Capacity(MVA)	240	480	480	480	600	
			Substation Name	Substation Capacity(MVA)					
			Alto Chingo	120	120	120	120	120	exsitng
			Gabela	120	120	120	120	180	exsitng upgrade 2037
			Waco Kungo		60	60	60	60	2022
			Quibala		60	60	60	120	2022
			Porto Amboim		120	120	120	120	2025
			Cuacra		60	60	60	60	2025
	Benguela	Benguela	Forecasted Demand (MW)	300	415	563	734	882	Remarks (Operation Year)
			> 220kV Gnenrator (MW)						
			Neccesary Capacity (MVA)	333	462	625	815	980	
			Existing Capacity(MVA)	550	550	910	1150	1270	
			Insufficient capacity (MVA)	–	-88	-285	-335	-290	
			Total Planned Capacity(MVA)	550	910	1150	1270	1390	
			Substation Name	Substation Capacity(MVA)					
			Quileva	310	310	310	310	310	exsitng
			Benguela Sul	240	240	240	240	240	2018
			Catumbela		120	120	240	240	2025 upgrade2035
			Cubal		120	120	120	240	2022 upgrade2038
			Alto Catumbela			120	120	120	2030
			Baria Farta			120	120	120	2030
			Bocoio		120	120	120	120	2025
	Huambo	Huambo	Forecasted Demand (MW)	132	205	318	454	614	Remarks (Operation Year)
			> 220kV Gnenrator (MW)						
			Neccesary Capacity (MVA)	147	228	354	505	682	
			Existing Capacity(MVA)	240	240	420	540	540	
			Insufficient capacity (MVA)	–	-12	-66	-35	142	
			Total Planned Capacity(MVA)	240	420	540	540	780	
			Substation Name	Substation Capacity(MVA)					
			Belém do Dango	240	240	240	240	480	exsitng upgrade2036
			Ukuma		60	60	60	60	2025
			Catchiungo		120	120	120	120	2025
			Bailundo			120	120	120	2030
	Bié	Kuito	Forecasted Demand (MW)	41	82	131	208	323	Remarks (Operation Year)
			> 220kV Gnenrator (MW)						
			Neccesary Capacity (MVA)	46	91	145	231	359	
			Existing Capacity(MVA)	120	120	180	300	360	
			Insufficient capacity (MVA)	–	-29	-35	-69	-1	
			Total Planned Capacity(MVA)	120	180	300	360	480	
			Substation Name	Substation Capacity(MVA)					
			Kuito	120	120	240	240	360	exsitng upgrade2027 2037
			Andulo		60	60	60	60	2025
			Camacupa				60	60	2035
	Subtotal			1150	1990	2470	2650	3250	

(Source: JICA Survey Team)

Table 7-14 220 kV Substation plan based on the demand forecast for the southern region

Area	Provincia	Capital	Year	2020	2025	2030	2035	2040	
Southern	Huíla	Lubango	Forecasted Demand (MW)	121	201	311	443	602	**Remarks (Operation Year)**
			＞220kV Gnenrator (MW)	121					
			Neccesary Capacity (MVA)	0	224	345	493	668	
			Existing Capacity(MVA)	0	0	780	840	840	
			Insufficient capacity (MVA)	—	224	-435	-347	-172	
			Total Planned Capacity(MVA)	0	780	840	840	900	
			Substation Name	Substation Capacity(MVA)					
			Lubango		240	240	240	240	2022
			Nova Lubango		120	120	120	120	2025
			Matala		120	120	120	120	2022
			Caluquembe		60	60	60	120	2025 upgrade2040
			Quilengues		60	60	60	60	2025
			Tchamutete		120	120	120	120	2025
			Capelongo		60	60	60	60	2022
			Chipindo			60	60	60	2030
	Cunene	Ondjiva	Forecasted Demand (MW)	39	83	137	200	273	Remarks (Operation Year)
			＞220kV Gnenrator (MW)	39					
			Neccesary Capacity (MVA)	0	92	152	223	304	
			Existing Capacity(MVA)	0	0	240	240	360	
			Insufficient capacity (MVA)	—	92	-88	-17	-56	
			Total Planned Capacity(MVA)	0	240	240	360	360	
			Substation Name	Substation Capacity(MVA)					
			Ondjiva		120	120	240	240	2025 upgrade2032
			Cahama		60	60	60	60	2025
			Xangongo		60	60	60	60	2025
	Cuando-Cubango	Menongue	Forecasted Demand (MW)	42	86	141	204	275	Remarks (Operation Year)
			Planned Gnenrator (MW)	42					
			Neccesary Capacity (MVA)	0	96	157	227	306	
			Existing Capacity(MVA)	0	0	300	300	360	
			Insufficient capacity (MVA)	—	96	-143	-73	-54	
			Total Planned Capacity(MVA)	0	300	300	360	420	
			Substation Name	Substation Capacity(MVA)					
			Cuchi		60	60	60	60	2022
			Menangue		240	240	240	240	2022
			Cuito Cuanavale				60	60	2035
			Mavinga					60	2040
	Namibe	Namibe	Forecasted Demand (MW)	65	129	169	212	259	Remarks (Operation Year)
			Planned Gnenrator (MW)	65					
			Neccesary Capacity (MVA)	0	143	188	236	287	
			Existing Capacity(MVA)	0	0	360	360	360	
			Insufficient capacity (MVA)	—	143	-172	-124	-73	
			Total Planned Capacity(MVA)	0	360	360	360	360	
			Namibe		240	240	240	240	2022
			Tombwa		120	120	120	120	2022
	Subtotal			0	1680	1740	1920	2040	

(Source: JICA Survey Team)

Table 7-15 220 kV Substation plan based on the demand forecast for the western region

Area	Provincia	Capital	Year	2020	2025	2030	2035	2040	
Eastern	Moxico	Luena	Forecasted Demand (MW)	28	75	109	157	224	**Remarks (Operation Year)**
			Planned Gnenrator (MW)	28					
			Neccesary Capacity (MVA)	0	84	122	175	249	
			Existing Capacity(MVA)	0	0	240	360	360	
			Insufficient capacity (MVA)	—	84	-118	-185	-111	
			Total Planned Capacity(MVA)	0	240	360	360	360	
			Substation Name	Substation Capacity(MVA)					
			Luena		240	240	240	240	2025
			Cazombo			60	60	60	2027
			Luau			60	60	60	2027
	Lunda Norte	Lucapa	Forecasted Demand (MW)	38	97	144	198	260	Remarks (Operation Year)
			Planned Gnenrator (MW)	38					
			Neccesary Capacity (MVA)	0	107	160	221	289	
			Existing Capacity(MVA)	0	0	300	300	300	
			Insufficient capacity (MVA)	—	107	-140	-79	-11	
			Total Planned Capacity(MVA)	0	300	300	300	420	
			Substation Name	Substation Capacity(MVA)					
			Lucapa		60	60	60	60	2022
			Dundo		120	120	120	240	2022 upgrade2036
			Xa-Muteba		120	120	120	120	2025
	Lunda Sur	Saurimo	Forecasted Demand (MW)	26	77	92	135	181	Remarks (Operation Year)
			Planned Gnenrator (MW)	26					
			Neccesary Capacity (MVA)	0	86	103	149	201	
			Existing Capacity(MVA)	0	0	120	180	300	
			Insufficient capacity (MVA)	—	86	-17	-31	-99	
			Total Planned Capacity(MVA)	0	120	180	300	300	
			Substation Name	Substation Capacity(MVA)					
			Saurimo		120	120	240	240	2022 upgrade2032
			Muconda			60	60	60	2027
	Subtotal			0	660	840	960	1080	
TOTAL				4901	10941	12081	14058	15418	

(Source: JICA Survey Team)

7.7.3 220 kV power transmission line plan based on the regional supply substation plan

Based on the result of 7.7.2, the connections between the regional supply substations and main system in the existing plan are decided based on the geographical positions and the starting year of operation. Table 7-17 shows the power transmission line plan compiled based on the result of the power flow analysis.

With regard to the connecting transmission line, a two-line connection was basically adopted in consideration of the N-1 reliability criteria.

Also, a loop circuit formed with a 220 kV system could cause unexpected overloads at the time of an accident. Power transmission lines with one circuit connection were removed to reduce the complexity of the system and make the system as easy to operate as possible.

Regarding the substations located nearby the existing transmission line, we decided to divide the power transmission line into 4 lines π.

Finally, we formed an appropriate power transmission equipment plan by considering these factors and working through a process of repeated trials and errors.

Projects stricken out by red line lines in Table 7-16 are deleted to avoiding the aforementioned loop circuit.

Projects stated in blue are new substation facility plans derived from the demand forecast up to the 2040 fiscal year. All have been added to the existing plans.

The revised number of lines and operation starting years in the existing plan are written in blue.

According to the review of the plan based on the substation supply plan, the length of the transmission line work increased by about 500 km, from 3,269 km to 3,766 km.

Table 7-16 Review of the Transmission Line plan accompanying the regional supply substation plan

Project#	Area	Voltage (kV)	Starting point	End point	number of circuit	Line Length (km)	Year of operation	Remarks
1	Northern	220	**Filda**	**Golfe**	2	7	2022	
2	Northern	220	**Bita**	**Camama**	2	21	2022	
	~~Northern~~	~~220~~	~~**Bita**~~	~~**Rammiros**~~	~~1~~		~~2022~~	Avoiding Loop circuit
3	Northern	220	**Catete**	**Zango**	2	40	2022	
4	Northern	220	**Capanda elev.**	**Maranje**	2	110	2022	
5	Northern	220	**Kapary**	**Caxito**	2	26	2025	
6	Northern	220	**N'Zeto**	**Tomboco**	2	5	2025	Substation inserted
7	Northern	220	**M'banza Congo**	**Tomboco**	2	5	2025	Substation inserted
8	Northern	220	**Sambizanga**	**Chicala**	2	7	2025	
	~~Northern~~	~~220~~	~~**Futungo de Belas**~~	~~**Chicala**~~	~~1~~		~~2025~~	Avoiding Loop circuit
9	Northern	220	**Catete**	**Maria Teresa**	2	51	2025	
10	Northern	220	**Viana**	**PIV**	2	7	2035	
	~~Northern~~	~~220~~	~~**Cazenga**~~	~~**PIV**~~	~~1~~		~~2035~~	Avoiding Loop circuit
11	Northern	220	**Uige**	**Negage**	2	5	2030	Substation inserted
12	Northern	220	**Pambos de Sonhe**	**Negage**	2	5	2030	Substation inserted
13	Northern	220	**Negage**	**Sanza Pombo**	2	109	2035	
	~~Central~~	~~220~~	~~**Cambambe**~~	~~**Gabela**~~	~~1~~		~~2022~~	Avoiding Loop circuit
14	Central	220	**Gabela**	**Alto Chingo**	1	81	2022	Dualization
	~~Central~~	~~220~~	~~**Gabela**~~	~~**Quibala**~~	~~1~~		~~2022~~	Avoiding Loop circuit
15	Central	220	**Quibala**	**Waco Kungo**	2	92	2022	
16	Central	220	**Lomaum**	**Cubal**	2	2	2022	
	~~Central~~	~~220~~	~~**Belem do Dango**~~	~~**Cubal**~~	~~1~~		~~2022~~	Avoiding Loop circuit
17	Central	220	**Alto Chingo**	**Cuacra**	2	25	2025	
18	Central	220	**Alto Chingo**	**Port Amboim**	2	60	2025	
19	Central	220	**Quileva**	**Nova Biopio**	1	18	2025	Dualization
20	Central	220	**Quileva**	**Catumbela**	2	8	2025	
21	Central	220	**Nova Biopio**	**Bocoio**	2	5	2025	Substation inserted
22	Central	220	**Lomaum**	**Bocoio**	2	5	2025	Substation inserted
	~~Central~~	~~220~~	~~**Cubal**~~	~~**Ukuma**~~	~~1~~		~~2025~~	Avoiding Loop circuit
23	Central	220	**Belem do Huambo**	**Ukuma**	2	66	2025	
24	Central	220	**Belem do Huambo**	**Catchiungo**	2	9	2025	Substation inserted
25	Central	220	**Kuito**	**Catchiungo**	2	9	2025	Substation inserted
	~~Central~~	~~220~~	~~**Belem do Dango**~~	~~**Kuito**~~	~~1~~		~~2027~~	Avoiding Loop circuit
26	Central	220	**Kuito**	**Andulo**	2	124	2025	
27	Central	220	**Cubal**	**Alto Catumbela**	2	47	2030	
28	Central	220	**Benguela Sul**	**Catumbela**	2	26	2025	
29	Central	220	**Catchiungo**	**Bailundo**	2	66	2030	
30	Central	220	**Benguela Sul**	**Baia Farta**	2	30	2030	
31	Central	220	**Kuito**	**Chitembo**	2	145	2035	
32	Southern	220	**Lubango2**	**Lubango**	2	30	2020	
33	Southern	220	**Lubango2**	**Namibe**	2	162	2020	
34	Southern	220	**Namibe**	**Tombwa**	2	97	2020	
35	Southern	220	**Lubango2**	**Matala**	2	168	2022	
36	Southern	220	**Matala HPS**	**Matala**	1	5	2022	
37	Southern	220	**Capelongo**	**Cuchi**	2	91	2022	
38	Southern	220	**Cuchi**	**Menongue**	2	94	2022	
39	Southern	220	**Cahama**	**Xangongo**	2	97	2025	
40	Southern	220	**Ondjiva**	**Xangongo**	1	97	2025	
	~~Southern~~	~~220~~	~~**Capelongo**~~	~~**Matala**~~	~~1~~		~~2027~~	Avoiding Loop circuit
41	Southern	220	**Matala**	**Jamba Mina**	1	86	2035	
42	Southern	220	**Jamba mina**	**Jamba Oma**	1	37	2035	
43	Southern	220	**Capelongo**	**Tchamutete**	2	98	2025	
44	Southern	220	**Menongue**	**Cuito Cuanavale**	2	189	2035	
45	Southern	220	**Cuito Cuanavale**	**mavinga**	2	176	2035	
46	Eastern	220	**Saurimo**	**Lucapa**	2	157	2020	
47	Eastern	220	**Lucapa**	**Dundo**	2	135	2020	
48	Eastern	220	**Saurimo**	**Luena**	2	265	2025	
49	Eastern	220	**Saurimo**	**Muconda**	2	187	2027	
50	Eastern	220	**Muconda**	**Luau**	2	115	2027	
51	Eastern	220	**Luau**	**Cazombo**	2	264	2027	
					Total	3,766		

(Source: JICA Survey Team)

7.7.4 Transmission Development plan based on the Generation Development Plan

Based on the Generation Development Plan, we considered connection to the substation or the transmission line in the voltage class transmission system at the closest point from the power generation site, vis-à-vis the generation capacity. The results are shown in Table 7-17.

The connecting transmission lines are omitted for the hydroelectric power plants not scheduled to start operation by 2040.

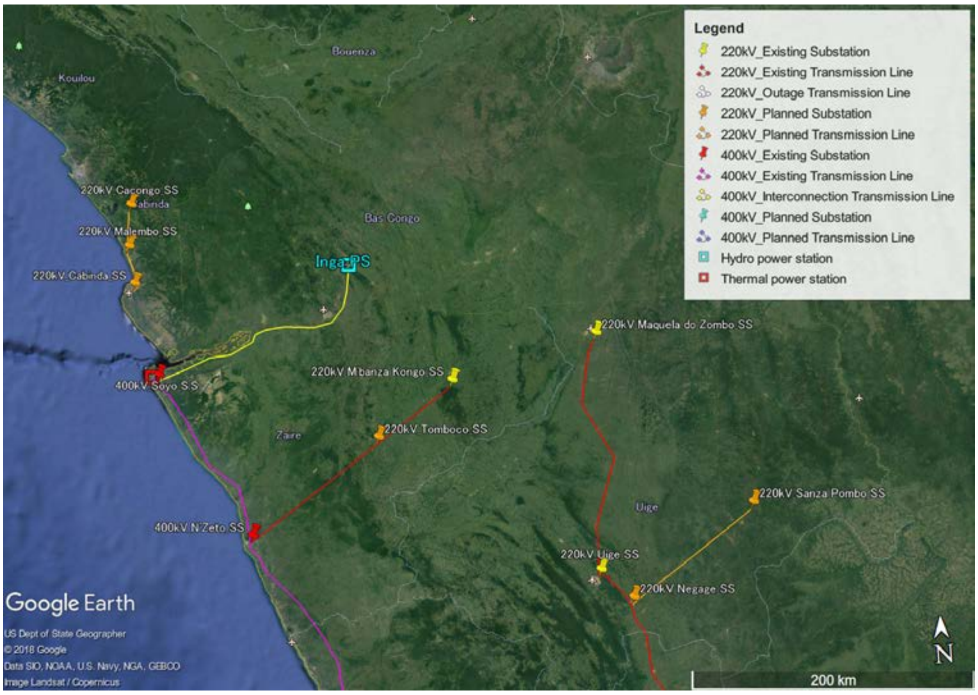
Table 7-17 Result of Transmission Line connection based on the power generation plan

Hydropower Plant	(River)	Area	Installed	2017	2018	2020	2025	2030	2035	2040	Transmission Line		
<Existing PP (Available Capacity)>	-	-	1,699	1699	1649	1649	1594	1594	1594	1594	Voltage	Connected Substation	Distance (km)
<Development Plan>				931.5	1928	2169	4341	4851	6701	7154			
HPP Lauca	Kwanza	North	2,070	931.5	1863	2070	2070	2070	2070	2070	400kV	Cambutas	224
HPP Caculo Cabaça	Kwanza	North	2,172				2172	2172	2172	2172	400kV	Cambutas	54
HPP Zenzo	Kwanza	North	950						950	950	400kV	Cambutas	41
HPP Túmulo Caçador	Kwanza	North	453							453	220kV	Cambutas	16
HPP Quissonde	Kwanza	North	121								220kV	—	—
HPP Genga ②	Quive	North	900						900	900	400kV	Benga Switch-yard	30
HPP Benga	Quive	North	1,000								400kV	—	—
HPP Quilengue ⑤	Quive	North	210					210	210	210	220kV	Gabera	37
HPP Lomaum Extension	Catumbela	Central	215		65	65	65	65	65	65	220kV	Nova_Biopio	81
HPP Lomaum2	Catumbela	Central	150								220kV	—	—
HPP Baynes (50% Angola)	Cunene	South	300					300	300	300	400kV	Cahama	195
HPP Jamba Ya Oma	Cunene	South	79								220kV	HPP Jamba Ya Mina	37
HPP Jamba Ya Mina	Cunene	South	205								220kV	Matala	86
HPP Luachimo (extention)		East	34			34	34	34	34	34	60kV	Dundo	5
	Candidate Total =		7,154	2631	3577	3818	5935	6445	8295	8748			

Thermal Power Plant <Development Plan>	Type	Area	(MW)	2017	2018	2020	2025	2030	2035	2040	Transmission Line Voltage	Connected Substation	Distance (km)
TPP Soyo 1	CCGT	Zaire	750	250	750	750	750	750	750	750	400kV	Soyo_SS	5
TPP Soyo 2	CCGT	Zaire	750				750	750	750	750	400kV	Soyo_SS	5
TPP Lobito CCGT No.1	CCGT	Benguela	750				375	750	750	750	400kV	Nova_Biopio_SS	23
TPP Lobito CCGT No.2	CCGT	Benguela	750						750	750	400kV	Nova_Biopio_SS	23
TPP Namibe CCGT No.3	CCGT	Namibe	750							750	220kV	Namibe_SS	17
TPP Lobito CCGT No.4	CCGT	Benguela	375							375	400kV	Nova_Biopio_SS	23
TPP Cacuaco GT No.1	GT	Luanda	375				125	250	375	375	220kV	Cacuaco	5
TPP Cacuaco GT No.2	GT	Luanda	375				125	125	250	375	220kV	Cacuaco	5
TPP Boavista GT No.3	GT	Luanda	375				125	125	250	375	220kV	Sambizanga	5
TPP Quileva GT No.4	GT	Benguela	250					125	250	250	220kV	Quileva	1
TPP Quileva GT No.5	GT	Benguela	250					125	250	250	220kV	Quileva	1
TPP Quileva GT No.6	GT	Benguela	250					125	250	250	220kV	Quileva	1
TPP Soyo GT No.7	GT	Zaire	375					125	250	375	400kV	Soyo_SS	5
	Candidate Total =		6,375	250	750	750	2,250	3,250	4,875	6,375			

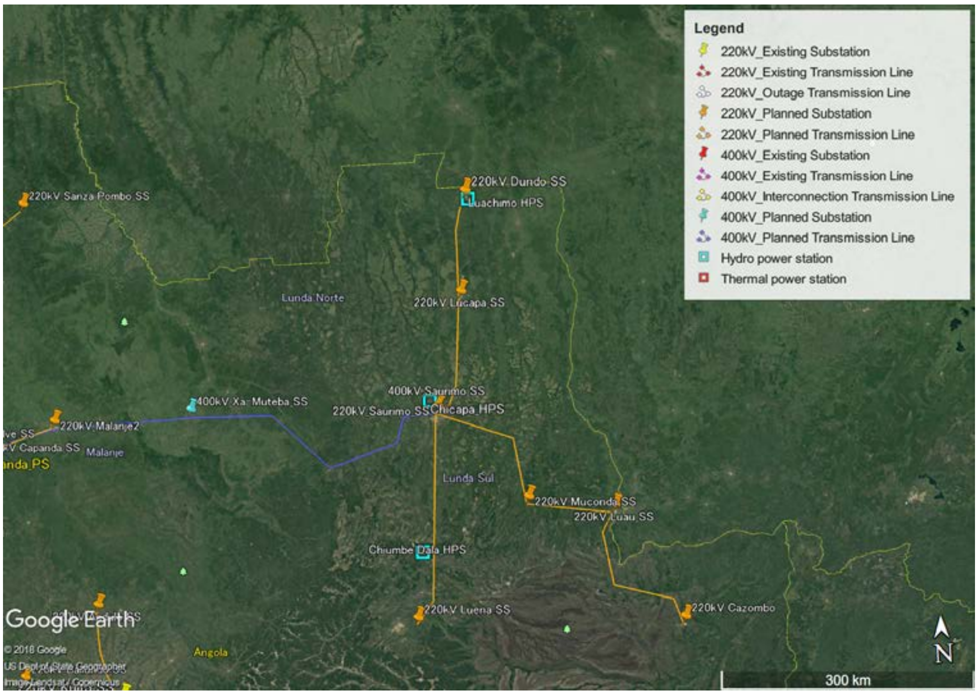
(Source: JICA Survey Team)

The following pages show schematic figures of each transmission line connecting to the power station.



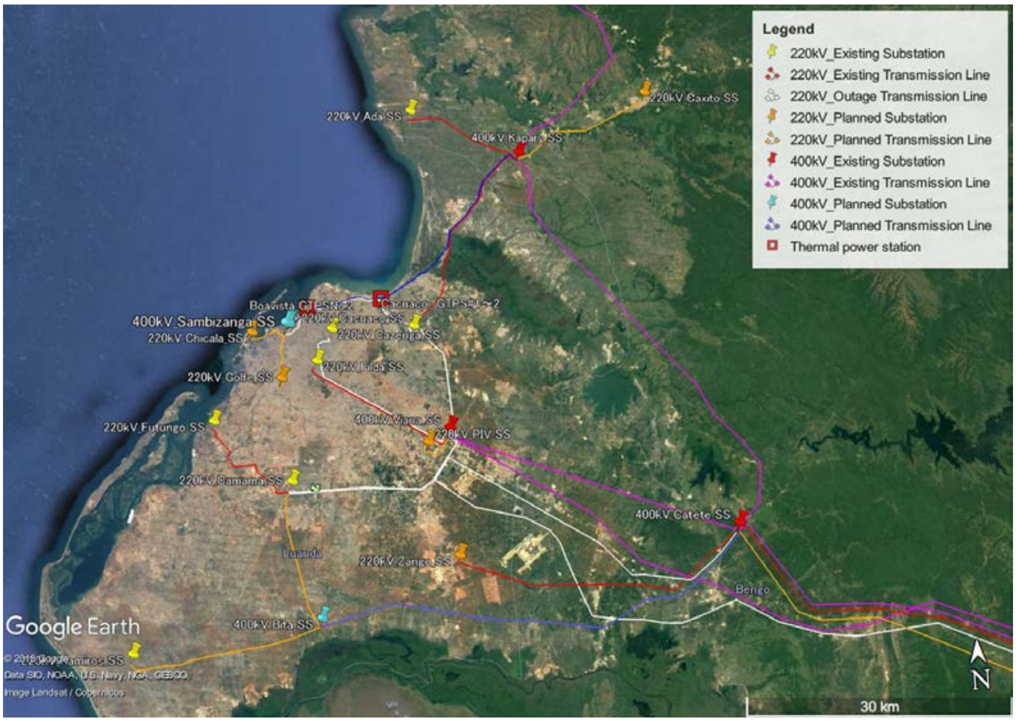
(Source: JICA Survey Team)

Figure 7-28 System connection status of Soyo thermal power station



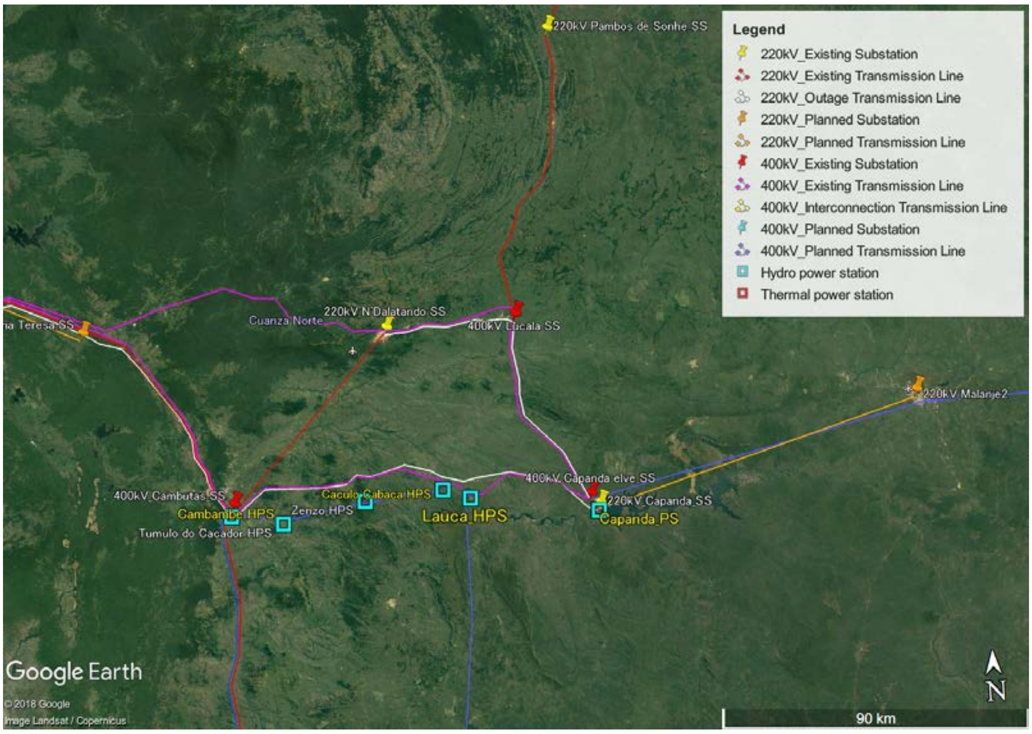
(Source: JICA Survey Team)

Figure 7-29 Status of connection of Luachimo hydroelectric power station



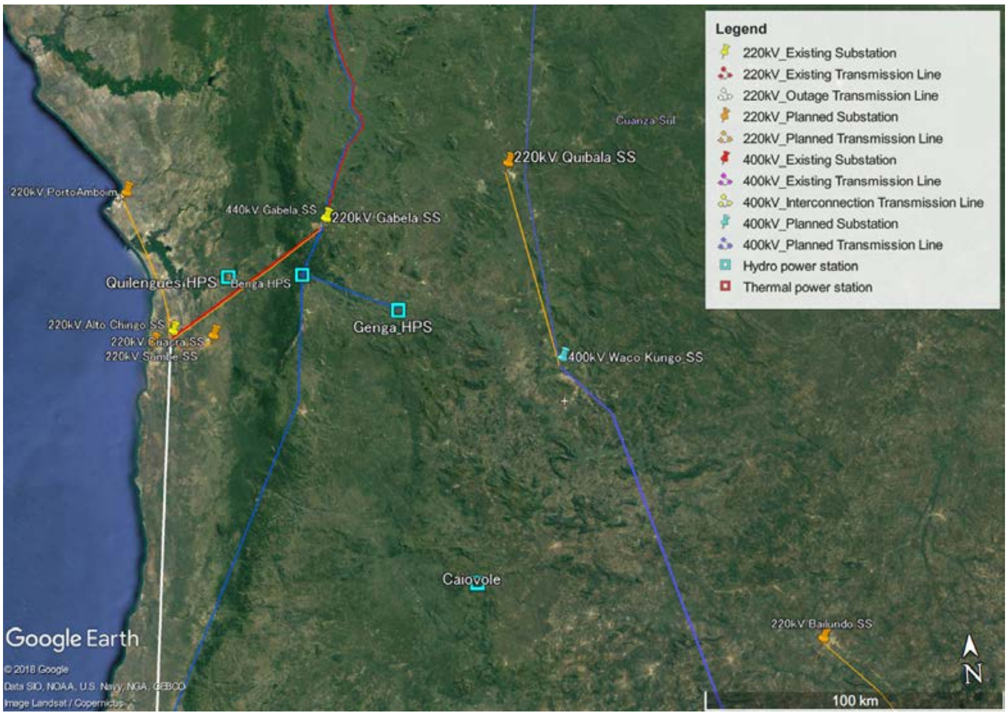
(Source: JICA Survey Team)

Figure 7-30 Connection status of thermal power stations in the Luanda area



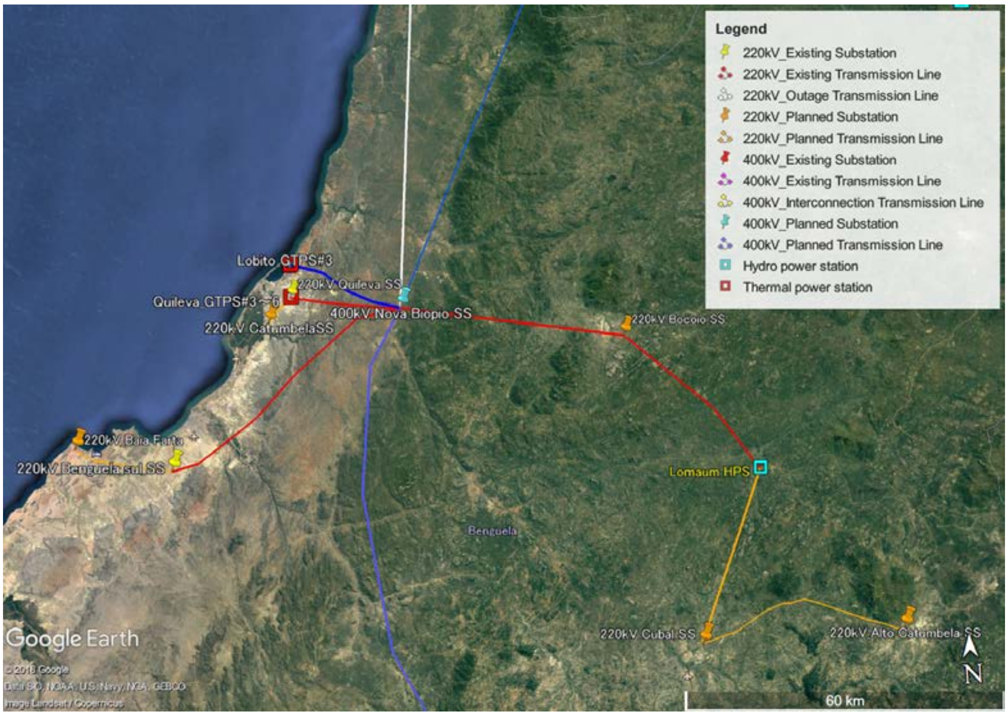
(Source: JICA Survey Team)

Figure 7-31 Connection status of hydropower stations in the Cuanza River area



(Source: JICA Survey Team)

Figure 7-32 Connection status of hydropower stations in the Quive River area



(Source: JICA Survey Team)

Figure 7-33 System connection status around the Lobito thermal power plant

(Source: JICA Survey Team)

Figure 7-34 System connection status of the Namibe thermal powerplant and Baynes hydropower plant

7.7.5 400 kV main Transmission Line and Substation Plan based on electric power system analysis

Based on the existing power grid development plan for RNT and subsequent studies, we determined the load from the demand assumption for each region, determined the capacity of the regional supply substation, and analyzed the data using the power system analysis program (PSSE), the de facto world standard.

A review of the 400 kV transmission and transformation plan described in 7.6.1 based on the results is shown in Table 7-18 and Table 7-19.

With respect to the 400 kV substation plan, based on the demand assumption of 2040, we plan to establish four (4) new substations and review the capacities and operation years of the planned substations. The required incremental capacities of existing substations were also added.

The total capacity of the new substation is 12,720 MVA, that is, about 5,500 MVA more than the 7,290 MVA capacity of the existing plan up to 2027. In 2040, the rapid increase in the scale of the system will bring the capacity up to 21,840 MVA. The main factor will be the approximately 2,000 MVA increase in the existing substation to meet increased demand from the capital Luanda, about 5,000 MVA (mainly Viana substation). It will be necessary to strengthen the local system by about 2,000 MVA.

Table 7-18 400 kV main Substation plan based on electric power system analysis

Project#	Area	Voltage (kV)	Substation Name	Capacity (MVA)	Year of operation	Upgrade				Final Capacity (MVA)
						2025	2030	2035	2040	
1	**Cuanza Sul**	400	**Waco kungo**	450	2020	450				900
2	**Huambo**	400	**Belem do Huambo**	1,350	2020					1,350
3	**Luanda**	400	**Bita**	900	2022	450		450		1,800
4	**Huila**	400	**Lubango**	900	2025					900
5	**Huila**	400	**Capelongo**	900	2025					900
6	**Huila**	400	**Caluquembe**	120	2025					120
7	**Benguera**	400	**Nova Biopio**	900	2025					900
8	**Southern**	400	**Cahama**	900	2025					900
9	**Eastern**	400	**Saurimo**	900	2025					900
10	**Lunda Norte**	400	**Xa-Muteba**	360	2025					360
11	**Cunene**	400	**Ondjiva**	900	2035					900
12	**Huila**	400	**Quilengues**	120	2025					120
13	**Cuanza Sul**	400	**Gabela**	900	2025					900
14	**Luanda**	400	**Sambizanga**	1,860	2025					1,860
15	**Malanje**	400	**Lucala**	900	2025			450		1,350
16	**Chipindo**	400	**Chipindo**	360	2025					360
17	**Zaire**	400	**N'Zeto**	450	existing	450				900
18	**Luanda**	400	**Viana**	210	existing	2,790	930			3,720
19	**Bengo**	400	**Kapary**	450	existing	450	450			1,350
20	**Luanda**	400	**Catete**	900	existing		450			1,350
New Substation capacity Total				12,720	Sub Total	4,590	1,830	900	0	21,840

(Source: JICA Survey Team)

As for the 400 kV transmission lines, we will satisfy the N-1 reliability criteria by dualizing the transmission lines connecting to important large-scale hydropower stations and adding a new construction of 6 transmission lines. We reexamined several single circuit transmission lines connecting to the large-scale hydropower station to be changed to double circuit. Also, in response to the addition of four (4) substations to the plan, we re-examined the plan with a total of (10) related transmission lines. We also decided to construct two (2) lines for connection of the Caculo Cabaca hydropower station and to transmit to the Catete substation via the Lauca substation.

Table 7-19 400 kV main Transmission Line plan based on electric power system analysis

Project#	Area	Voltage (kV)	Starting point	End point	number of circuit	Line Length (km)	Year of operation	Remarks
1	Northern	400	**Catete**	**Bita**	2	54	2022	
	~~Northern~~	~~400~~	~~Cambutas~~	~~Bita~~	~~1~~		~~2022~~	
2	Northern	400	**Cambutas**	**Caculo Cabaca**	2	54	2023	Dualization
3	Northern	400	~~Caculo Cabaca~~	~~Bita~~	~~1~~		~~2023~~	
4	Northern	400	**Cambutas**	**Catete**	1	123	2025	Dualization
5	Northern	400	**Catete**	**Viana**	1	36	2025	Dualization
6	Northern	400	**Lauca**	**Capanda elev.**	1	41	2025	Dualization
7	Northern	400	**Kapary**	**Sambizanga**	2	45	2025	For New Substation
8	Northern	400	**Lauca**	**Catete**	2	190	2025	Changing Connection Plan
9	Northern	400	**Lauca**	**Caculo Cabaca**	2	25	2025	Changing Connection Plan
10	Central	400	**Lauca**	**Waco kungo**	1	177	2020	
11	Central	400	**Waco kungo**	**Belem do Huambo**	1	174	2020	
	~~Central~~	~~400~~	~~Belem do Dango~~	~~Lubango~~	~~1~~		~~2022~~	
	~~Central~~	~~400~~	~~Belem do Dango~~	~~Capelongo~~	~~1~~	~~202~~	~~2022~~	
12	Central	400	**Lauca**	**Waco kungo**	1	177	2025	Dualization
13	Central	400	**Waco kungo**	**Belem do Huambo**	1	174	2025	Dualization
	~~Central~~	~~400~~	~~Caculo Cabaca~~	~~Nova Biopio~~	~~1~~		~~2025~~	
14	Central	400	**Cambutas**	**Gabela**	2	131	2025	For New Substation
15	Central	400	**Gabela**	**Benga**	2	25	2025	For New Substation
16	Central	400	**Benga**	**Nova Biopio**	2	200	2025	For New Substation
	~~Central~~	~~400~~	~~**Nova Biopio**~~	~~**Lubango**~~	~~1~~		~~2025~~	
17	Central	400	**Benga**	**Genga**	2	30	2035	
18	Southern	400	**Belem do Huambo**	**Caluquembe**	2	175	2025	For New Substation
19	Southern	400	**Caluquembe**	**Lubango2**	2	168	2025	For New Substation
20	Southern	400	**Belem do Huambo**	**Chipindo**	2	114	2025	For New Substation
21	Southern	400	**Chipindo**	**Capelongo**	2	109	2025	For New Substation
22	Southern	400	**Nova Biopio**	**Quilengues**	2	117	2025	For New Substation
23	Southern	400	**Quilengues**	**Lubango2**	2	143	2025	For New Substation
24	Southern	400	**Lubango2**	**Cahama**	2	190	2025	
25	Southern	400	**Capelongo**	**Ondjiva**	1	312	2035	
26	Southern	400	**Cahama**	**Ondjiva**	1	175	2035	
	~~Southern~~	~~400~~	~~**Biopio - Lubango**~~	~~**kaluquembe**~~	~~2~~	~~5~~	~~2027~~	
	~~Southern~~	~~400~~	~~**Dango - Lubango**~~	~~**Quilengues**~~	~~2~~	~~5~~	~~2027~~	
27	Southern	400	**Cahama**	**Ruacana**	2	125	2027	International Interconnection
28	Southern	400	**Cahama**	**Baynes**	2	195	2030	
29	Eastern	400	**Capanda_elev**	**Xa-Muteba**	2	266	2025	
30	Eastern	400	**Xa-Muteba**	**Surimo**	2	335	2025	
					Total	4,292		

(Source: JICA Survey Team)

7.7.6 The future vision of the main power system

Power plants are generally located far from the demand center. To resolve regional power demand unbalance, the transmission lines in the power supply system must have the appropriate specifications to cope with this issue. Thus, the main power system development plan should be basically considered in consideration of the demand from the respective regions and ensure the supply of surplus power efficiently for the regions at times of electricity shortage.

Extending the vision of the main power system over a time frame of at least 20 years is very important for avoiding double investment, given the span of 20 or more years once the transmission lines are built. For the reason above, 2040 is the final year considered under the power master plan.

7.7.7 Demand assumptions for the substations

Based on the load of the substation modeled in the 2037 PSSE data received from RNT, we estimate loads such as those for the 110 kV, 60 kV systems for 2025, 2030, 2035, and 2040 by adjusting to the total demand and the demand of each province in each year, respectively. The estimated load (active power load, Pload; reactive power load, Qload) of each substation is shown in Table 7-20.

Table 7-20 Substation load data

Bus Number	Bus Name	Zone Name	2025		2030		2035		2040	
			Pload (MW)	Qload (Mvar)	Pload (MW)	Qload (Mvar)	Pload (MW)	Qload (Mvar)	Pload (MW)	Qload (Mvar)
10011	M_CONGO_60 60.000	ZAIRE	29.06	9.07	52.16	16.29	79.28	24.75	115.63	36.10
10013	NZETO_15 15.000	ZAIRE	5.77	1.80	10.28	3.21	11.87	3.71	16.79	5.24
10018	SOYO_60_1 60.000	ZAIRE	68.05	21.25	98.29	30.69	129.47	40.43	151.82	47.41
10031	TOMBOCO_30 30.000	ZAIRE	2.03	0.63	3.70	1.15	9.72	3.04	18.95	5.92
11001	UIGE_60 60.000	UIGE	139.82	43.66	187.84	58.65	175.63	54.84	203.45	64.24
11008	M_ZOMBO_60 60.000	UIGE	16.18	5.05	21.81	6.81	20.43	6.38	44.82	14.15
11013	NEGAGE_60 60.000	UIGE	0.00	0.00	46.42	14.49	125.35	39.14	144.47	45.62
11018	S_POMBO_60 60.000	UIGE	0.00	0.00	0.00	0.00	31.19	9.74	81.74	25.81
11021	DAMBA_30 30.000	UIGE	0.00	0.00	0.00	0.00	17.82	5.56	26.04	6.46
12001	CACUACO_60 60.000	LUANDA	304.86	95.19	386.60	120.72	517.88	161.71	557.44	174.06
12003	CAMAMA_60 60.000	LUANDA	271.93	84.91	333.47	104.13	415.85	129.85	418.94	130.81
12006	CAZENGA_60 60.000	LUANDA	163.32	51.00	208.49	65.10	281.24	87.82	300.37	93.79
12008	FILDA_60 60.000	LUANDA	108.88	34.00	138.99	43.40	187.49	58.54	200.25	62.53
12010	VIANA_60 60.000	LUANDA	623.39	194.65	798.05	249.19	672.06	209.85	666.65	208.16
12127	SAMBZANG_60 60.000	LUANDA	270.79	84.56	368.45	115.05	42.35	13.22	489.18	152.75
12133	M_BENTO_60 60.000	LUANDA	203.95	63.68	250.10	78.09	311.89	97.39	314.20	98.11
12138	CATETE_60 60.000	LUANDA	30.98	9.67	43.63	13.62	55.60	17.36	56.89	17.76
12140	RAMIROS_60 60.000	LUANDA	75.79	23.67	95.10	29.70	118.74	37.08	119.72	37.38
12143	BITA_60 60.000	LUANDA	135.97	42.46	166.74	52.06	207.93	64.93	209.47	65.41
12146	PIV_60 60.000	LUANDA	0.00	0.00	0.00	0.00	403.23	125.91	399.99	124.90
12268	ZANGO_60 60.000	LUANDA	155.85	48.66	199.51	62.30	268.82	83.94	266.66	83.26
12301	CHICALA 60.000	LUANDA	236.94	73.99	322.40	100.67	430.14	134.31	428.04	133.65
12306	GOLF_60 60.000	LUANDA	169.25	52.85	230.28	71.91	307.24	95.94	305.74	95.47
13006	KAPARY_60 60.000	BENGO	88.91	27.76	135.29	42.25	203.53	63.55	267.05	83.39
13007	DANDE_220 220.00	BENGO	20.68	6.46	27.17	8.48	24.18	7.55	28.48	8.89
13031	CAXITO_110 110.00	BENGO	9.51	2.97	14.19	4.43	14.47	4.52	20.18	6.30
14010	NDALAT_60 60.000	KWANZA NORTE	52.51	16.39	77.90	24.32	46.56	14.54	60.40	18.86
14012	P.SONHE_30 30.000	KWANZA NORTE	8.47	2.64	14.98	4.68	15.30	4.78	25.47	7.95
14024	CAMBUTAS_60 60.000	KWANZA NORTE	66.04	20.62	94.69	29.57	111.38	34.78	141.40	44.15
14044	M_TERESA_60 60.000	KWANZA NORTE	23.98	7.49	32.96	10.29	41.44	12.94	47.67	14.89
14070	LUCALA_60 60.000	KWANZA NORTE	0.00	0.00	0.00	0.00	73.39	22.92	83.02	25.92
15017	MALANJE_110_110.00	MALANGE	95.43	29.80	140.14	43.76	189.35	59.12	237.14	74.05
15020	CAP_ELEV_110110.00	MALANGE	51.38	16.04	67.90	21.20	89.60	27.98	104.00	32.47
15021	K_NZOJI_110 110.00	MALANGE	0.00	0.00	0.00	0.00	0.97	0.30	2.20	0.69
15022	CANGNDAL_110110.00	MALANGE	4.99	1.56	8.15	2.54	10.55	3.30	15.68	4.89

Bus Number	Bus Name	Zone Name	2025		2030		2035		2040	
			Pload (MW)	Qload (Mvar)	Pload (MW)	Qload (Mvar)	Pload (MW)	Qload (Mvar)	Pload (MW)	Qload (Mvar)
20027	KILEVA_60 60.000	BENGUELA	106.25	33.18	144.68	45.18	151.28	47.24	147.09	45.93
20053	CATUMB_1_60 60.000	BENGUELA	74.22	23.17	94.28	29.44	121.48	37.93	121.76	38.02
20066	B.SUL_60 60.000	BENGUELA	169.94	53.06	183.63	57.34	196.91	61.49	222.54	69.49
20072	CUBAL_60 60.000	BENGUELA	52.54	16.40	53.11	16.58	78.86	24.63	119.84	37.42
20075	BOCOIO_60 60.000	BENGUELA	12.56	3.92	17.91	5.59	69.69	21.76	116.93	36.51
20077	B.FARTA_60 60.000	BENGUELA	0.00	0.00	46.91	14.65	64.93	20.27	69.46	21.69
20079	A.CATUMB_60 60.000	BENGUELA	0.00	0.00	22.13	6.91	50.72	15.84	84.36	26.34
21014	DANGO_60 60.000	HUAMBO	150.72	47.06	224.73	70.17	313.48	97.88	394.64	123.23
21025	UKUMA_60 60.000	HUAMBO	11.56	3.61	17.27	5.39	23.71	7.40	44.54	13.91
21031	CATCH_60 60.000	HUAMBO	43.02	13.43	40.38	12.61	59.25	18.50	86.08	26.88
21036	BAILUNDO_60 60.000	HUAMBO	0.00	0.00	36.04	11.25	57.70	18.02	88.27	27.56
22001	KUITO_60 60.000	BIE	69.77	21.79	103.59	32.35	174.09	54.36	254.15	79.36
22009	ANDULO_60 60.000	BIE	12.33	3.85	27.19	8.49	28.24	8.82	50.33	15.72
22021	CHITEMBO_30 30.000	BIE	0.00	0.00	0.00	0.00	5.50	1.72	18.87	5.89
23002	GABELA_60 60.000	KWANZA SUL	60.93	19.02	88.76	27.71	107.68	33.62	138.80	43.34
23005	A.CH.RNT_60 60.000	KWANZA SUL	35.59	11.11	63.56	19.85	70.93	22.15	97.85	30.55
23011	W.KUNGO_60 60.000	KWANZA SUL	10.77	3.36	17.19	5.37	22.27	6.95	43.43	13.56
23013	CUACRA_60 60.000	KWANZA SUL	14.68	4.58	23.59	7.37	28.14	8.79	29.38	9.17
23018	P_AMBOIM_60 60.000	KWANZA SUL	38.46	12.01	47.89	14.95	95.75	29.90	97.45	30.43
23021	QUIBALA_60 60.000	KWANZA SUL	13.47	4.21	21.85	6.82	34.97	10.92	66.86	20.88
23022	MUSSENDE_110110.00	KWANZA SUL	0.00	0.00	0.00	0.00	9.57	2.99	20.54	6.41
30013	NAMIBE_60_2 60.000	NAMIBE	93.69	29.26	125.99	39.34	174.16	54.38	212.68	66.41
30017	TOMBWA_60 60.000	NAMIBE	35.01	10.93	43.01	13.43	38.12	11.90	45.89	14.33
31018	LUBANG_3_60 60.000	HUILA	67.50	21.08	92.73	28.96	142.21	44.40	198.53	61.99
31030	MATALA_60 60.000	HUILA	18.38	5.74	25.83	8.06	43.68	13.64	64.22	20.05
31044	TCHAMUTE_60 60.000	HUILA	41.02	12.81	46.43	14.50	56.33	17.59	61.63	19.24
31056	KALUKEMB_60 60.000	HUILA	13.34	4.17	25.43	7.94	35.78	11.17	58.70	18.33
31061	QUILENGS_60 60.000	HUILA	11.12	3.47	22.70	7.09	32.69	10.21	54.20	16.92
31303	NOVO_LUB_60 60.000	HUILA	30.14	9.41	41.78	13.05	65.40	20.42	87.16	27.21
31503	CAPLONGO_60 60.000	HUILA	19.80	6.18	25.35	7.91	31.41	9.81	36.35	11.35
31512	CHIPINDO_60 60.000	HUILA	0.00	0.00	30.38	9.49	35.96	11.23	40.80	12.74
32001	CUCHI_30 30.000	K.KUBANGO	17.05	5.32	23.43	7.32	23.98	7.49	24.12	7.53
32004	MENONGUE_60 60.000	K.KUBANGO	69.25	21.62	117.89	36.81	172.45	53.85	214.51	66.98
32016	C_CUANVL_30 30.000	K.KUBANGO	0.00	0.00	0.00	0.00	7.72	2.41	22.31	6.97
32018	MAVINGA_30 30.000	K.KUBANGO	0.00	0.00	0.00	0.00	0.00	0.00	14.34	4.48
33002	CAHAMA_30 30.000	CUNENE	3.18	0.99	8.93	2.79	9.31	2.91	12.81	3.97
33004	XANGONGO_60 60.000	CUNENE	9.73	3.04	15.94	4.98	28.26	8.82	51.06	12.04
33006	ONDJIVA_60 60.000	CUNENE	69.79	21.79	112.12	35.01	162.69	50.80	209.45	69.34
40011	DUNDO_60 60.000	LUNDA NORTE	38.61	12.06	56.51	17.65	95.90	29.94	123.95	38.70
40021	LUCAPA_60 60.000	LUNDA NORTE	24.83	7.75	33.82	10.56	38.96	12.17	50.43	15.75
40031	Xﾁ_MUTBA_110110.00	LUNDA NORTE	33.05	10.32	53.91	16.83	63.63	19.87	85.51	26.70
41021	SAURIMO_60 60.000	LUNDA SUL	77.40	24.17	89.14	27.84	130.45	40.73	171.55	53.57
41041	MUCONDA_30 30.000	LUNDA SUL	0.00	0.00	3.24	1.01	4.04	1.26	9.06	2.83
42000	LUENA_110 110.00	MOXICO	75.20	23.48	77.93	24.33	122.12	38.13	172.14	53.75
42031	LUAU_110 110.00	MOXICO	0.00	0.00	16.28	5.08	17.91	5.59	26.60	8.31
42041	CAZOMBO_30 30.000	MOXICO	0.00	0.00	15.18	4.74	17.45	5.45	25.27	7.89
		Total	5059.60	1579.86	6954.31	2171.48	8957.75	2797.06	10956.37	3421.13

(Source: JICA Survey Team)

7.7.8 The transmission development plan for 2040

We determined the power system model for 2040 based on the 2040 PSSE data offered from RNT. We then applied the model to the power plan and demand assumptions of the JICA Survey Team. At the same time, we conducted power flow calculations and considered the power system plan up to 2040.

In planning the power transmission, we basically prepared double circuit for the routes for the 440 kV and 220 kV transmission lines, the main components of the power system, to meet the N-1 reliability criteria. Note that a different voltage loop system, such as 400 kV and 220V, is operating in the main power system of Angola. If, under such circumstances, an N - 1 contingency occurs on a 400 kV transmission line, an unexpected event could lead to an overload on the 220 kV transmission line. We attempt to avoid such a complex situation by composing a loop system only for the 400 kV system, that with the highest voltage. The 200 kV system, meanwhile, is to be a radial interconnected system.

Currently, many small diesel generators are installed in Luanda and other cities. However, considering the power generation efficiency etc., it is uneconomical, so we will gradually abolish it.

Currently, electric power is supplied to the center of Luanda mainly from the 400/220 kV substations(Viana, Kapary, Catete) using 220 kV T/L. In addition, this system is a loop system of 400/220 kV, with many small DGs connected in the loop.

In 2040, the demand for this area will be more than 4,000MW, which is about four times the current level demand, so it is planned to establish 400/220 kV substation (Bita, Sambizanga) and others several 220/60 kV substations.

In the future, we propose to abolish the DG in order, and introduce CCGT into the 220 kV power system and make the system configuration simple by making it a radial system.

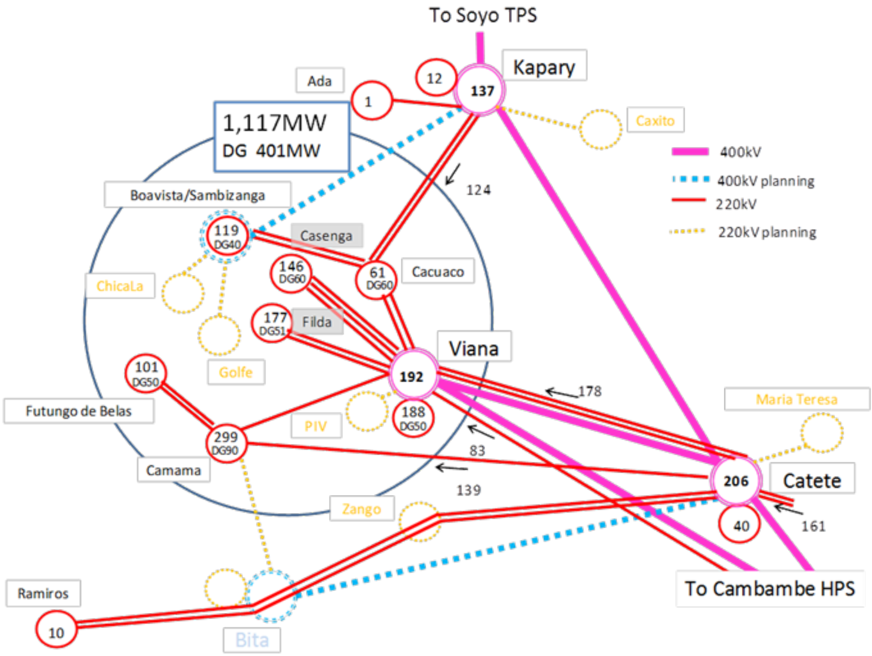


Figure 7-35 Main power system of the center of Luanda in 2017（400 kV, 220 kV）

According to the plan of RNT, Golfe substation (the new 220/60 kV substation) is planned to be connected to the 400/220 kV Viana substation. In this plan, the load will be concentrated on the Viana substation.

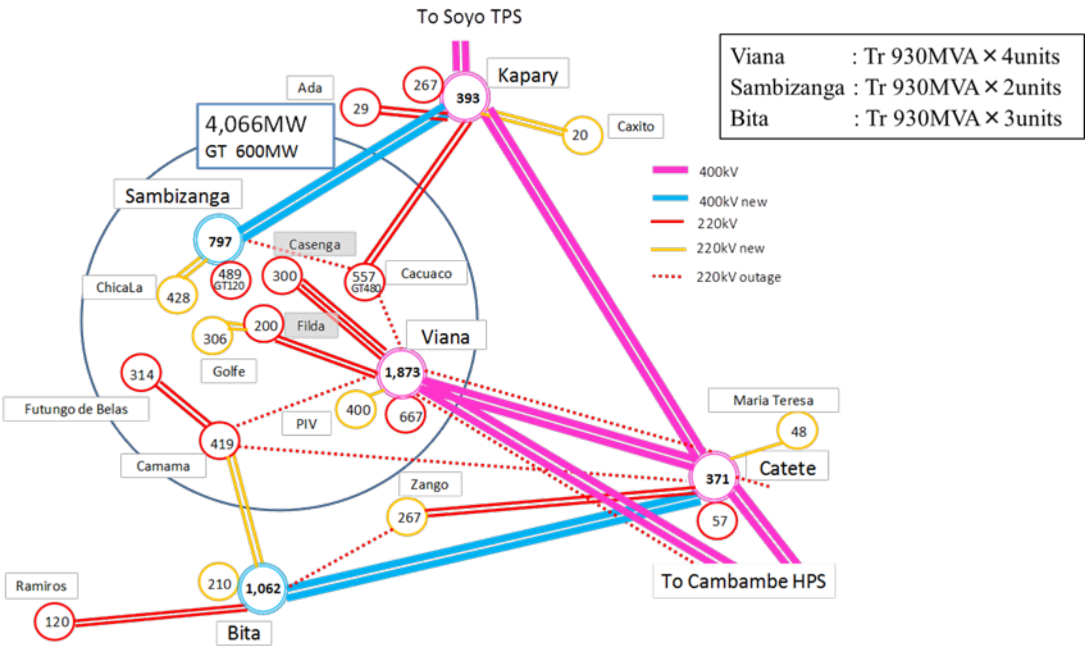


Figure 7-36 Main power system of the center of Luanda in 2040（RNT's draft）

The connection between the Golfe substation to the Sambizanga substation results in a balanced system structure as shown in the figure below.

The distance between the Golfe substation and the Sambizanga substation is about 5 km, but because it is a densely populated residential area, it is considered difficult to construct an overhead power transmission line.

However, according to the RNT, in the future there is also a land readjustment plan in this area, in which case, there is a possibility that it is possible to construction of overhead transmission lines.

Moreover, construction is possible if it is an underground transmission line.

Therefore, JICA survey team adopted this plan as a master plan.

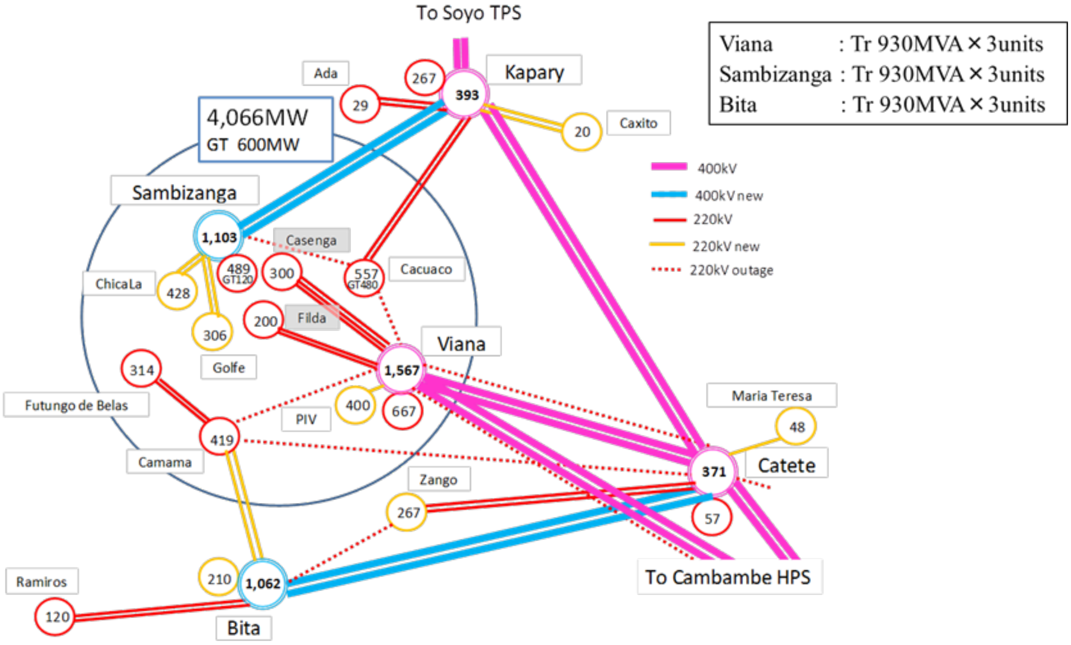


Figure 7-37 Main power system of the center of Luanda in 2040（JICA's draft）

Even in 2040, in the state of two lines, there is no problem in both voltage and load flow, but if it becomes one line, the voltage sensitivity of the bus becomes extremely high as shown in the following table, and It may be verry difficult to operate this network.

Therefore, the three-line configuration is a measure for securing the situation of two lines even in the situation of N-1 (one line stop).

Table 7-21 Sensitivity of 400kV Saurimo Bus

SC Capacity (MVA)	Bus Voltage (kV)	sensitivity (kV/MVA)
75	409.1	
74	407.1	1.8
73	404.3	2.9
72	400.1	4.2
71	Unconvergence	

As a representative measure against high voltage sensitivity, installation of SVC (Static Var Compensator) is conceivable.

The following figure shows the situation when the Capanda = Xa - Mutenba T/L and the Mutenba = Saurimo T/L each become one line in the case where the SVC is installed at the 400 kV bus of the Saurimo substation.

Even if it becomes one circuit line(N-1 contingency), there is no problem situation, indicating that installation of SVC is effective.

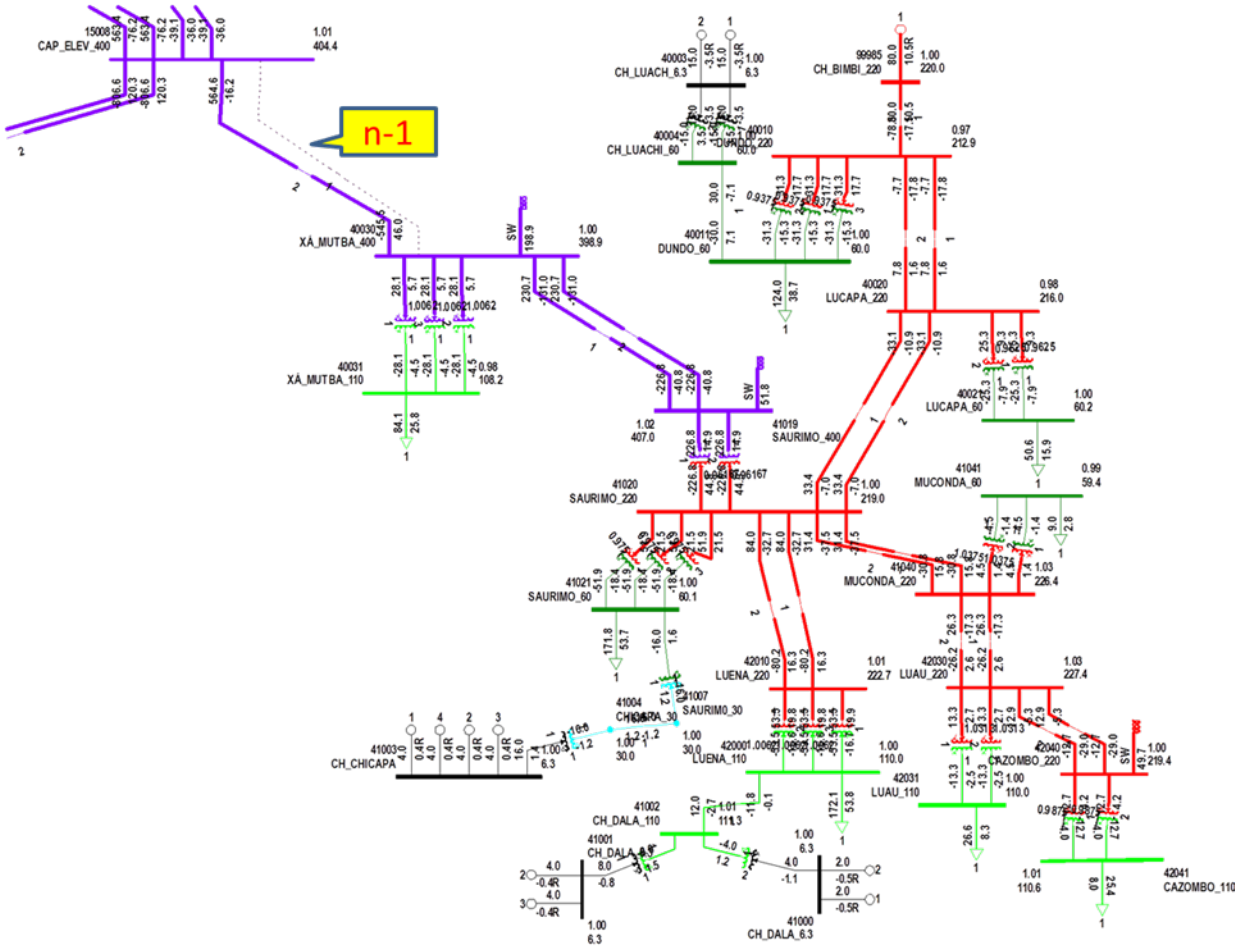


Figure 7-38 Eastern bulk power system calculation result in 2040（Capanda=Xa-Mutenba T/L : N-1）

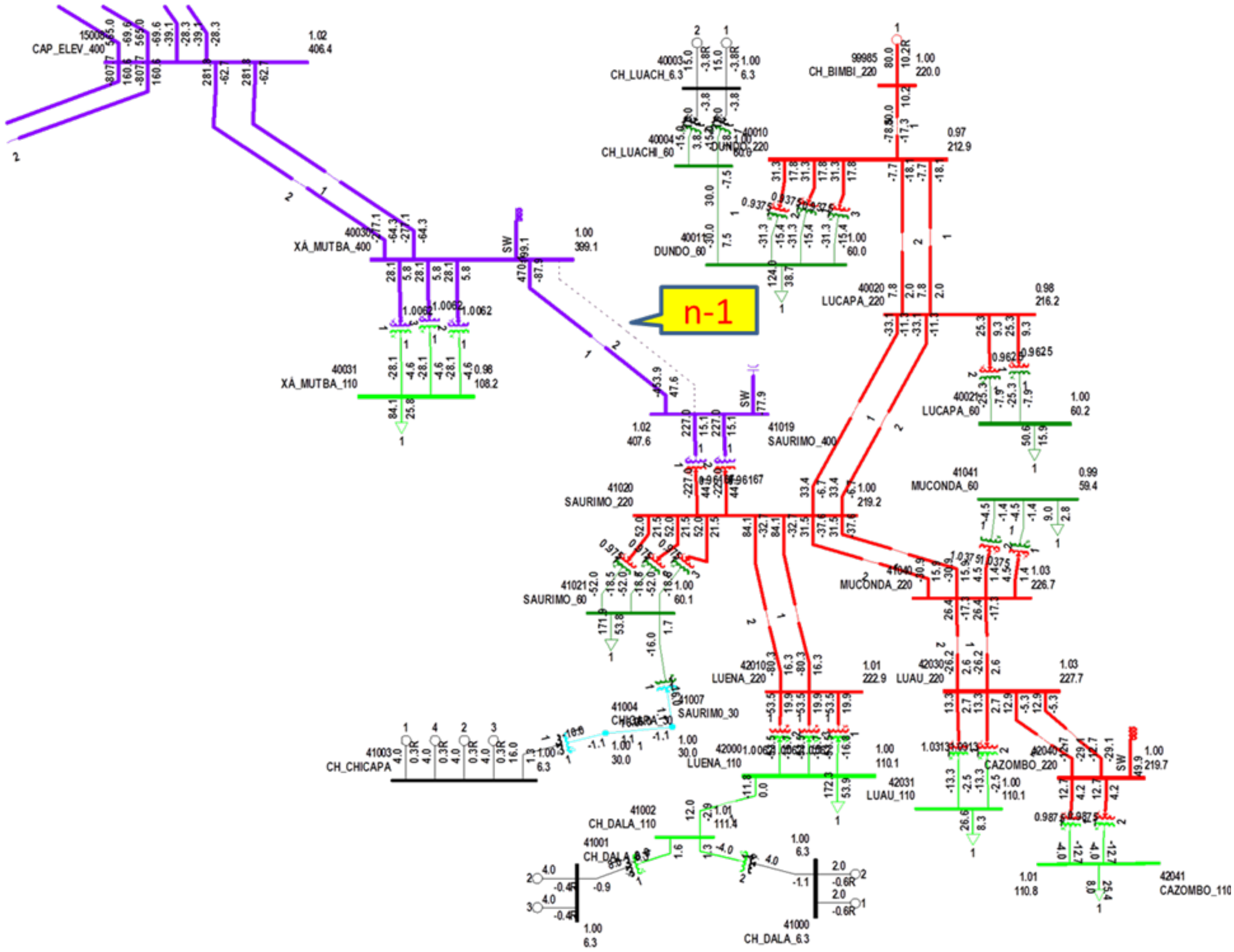


Figure 7-39 Eastern bulk power system calculation result in 2040（Mutenba = Saurimo T/L : N-1）

The following table shows the cost comparison of Statcom type SVC installation and one line enhancement of a 400 kV transmission line (making this Capanda = Xa - Mutenba = Saurimo T/L 3 circuit lines).

Just to be sure, even if two units of SVC are installed as troubleshooting measures, since the cost of installing SVC is significantly lower, JICA survey team proposes a SVC installation plan.

Table 7-22 Cost Comparison

Item	Voltage (kV)	Rating	Unit Cost (MUSD)
Statcom SVC Including bay with transformer & switchgear	400	±150MVA	33
Stactom SVC × 2	400	±150MVA ×2units	66
Capanda =Xa-Xutenba =Sautemo T/L	400	700km ×1cct	546

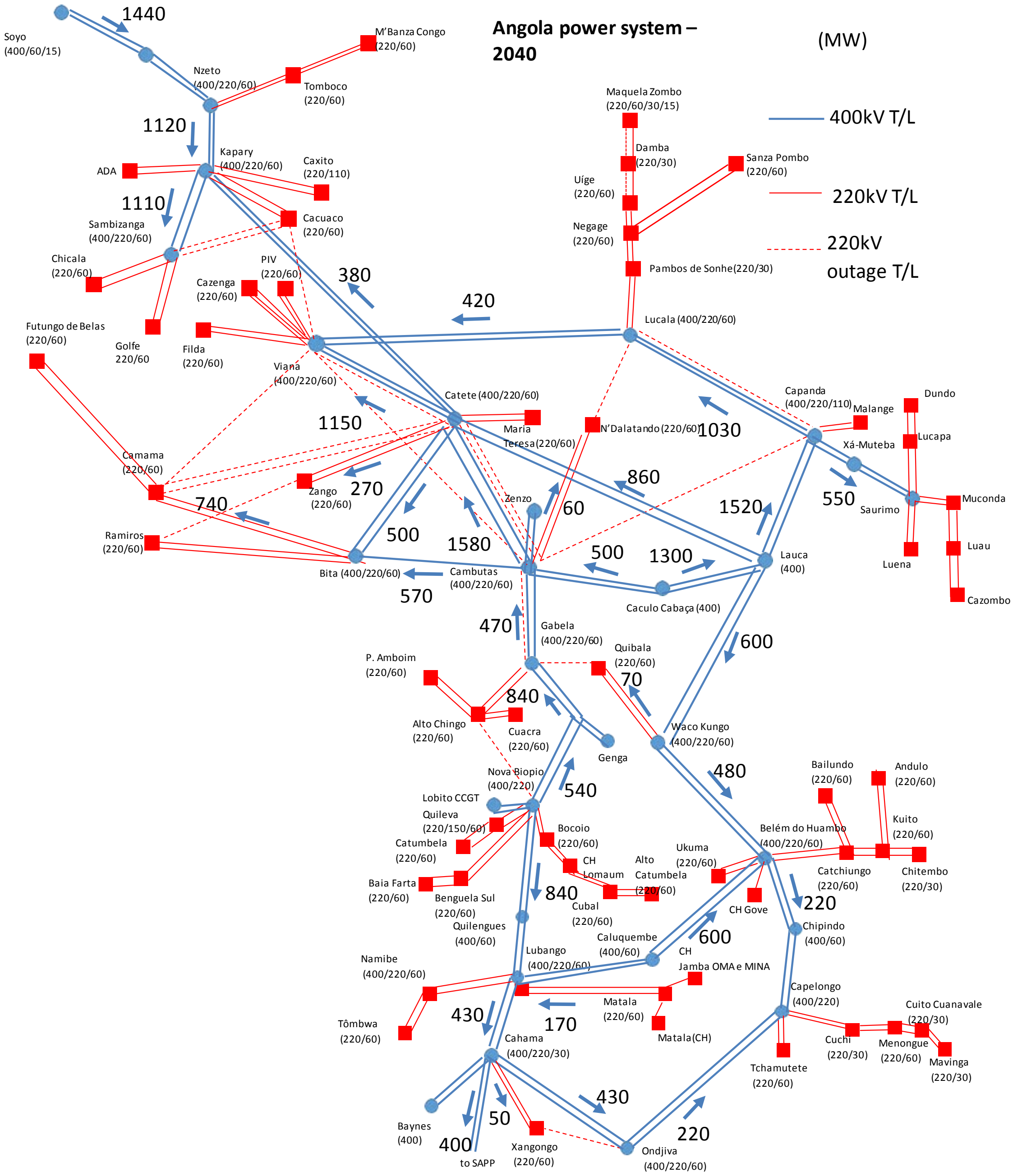


Figure 7-40 Main power system in 2040（400 kV, 220 kV）

(Source: JICA Survey Team)

7.7.9 The evaluation for the power system analysis

PSSE verified that there is no overload with transmission lines and transformers under the n-1 contingency. All of the transmission lines above have capacities of 400 kV, 220 kV and over, and all of the primary transformers have capacities of 220 kV and over (such as 400 kV/220 kV, and 220 kV/60 kV). As mentioned above, the 400 kV system is a loop system, while the 200 kV system is arranged as a radial interconnected system to avoid the operation of a very complicated system consisting of different voltage loop systems of 400 kV and 220 kV. This arrangement makes it possible for the system operator to understand the operating condition of the main system of 400 kV and 220 kV facilities even when the system outages of a system differ from ordinary system outages due to transmission line maintenance, etc.

7.7.10 Validity of distributed installation of CCGT

In that case where CCGT is intensively installed at Soyo, the additional construction of 400 kV transmission lines (approximately 330km) is required between Soyo S/S and KAPARY S/S.

The draft adopted by the JICA Survey Team at this time calls for concentrated CCGT installation not only in Soyo, but also dispersed CCGT installation in LOBITO and NABIBE for securing energy security and avoiding long distances between the transmission lines in place.

The draft values for distributed installations and concentrated installations are shown in Table 7-23.To compare them, there shall be no difference among substation’s demand in this condition. The output of the power plants (Soyo, LOBITO, NABIBIE and other power plants), shown in Table 7-23, is basically the same.

Table 7-23 Transmission losses of each CCGT installed site in 2040

	CCGT Soyo,Lobito,Nabibe Distributed installation (Plan of JICA Survey Team)			CCGT Soyo Concentrated installation		
	CCGT Generation Soyo:600 MW Lobito:1800 MW Nabibe:720 MW			CCGT Generation Soyo:3120 MW Lobito:0 MW Nabibe:0 MW		
Region	Generation (MW)	Demand (MW)	Transmission loss (MW)	Generation (MW)	Demand (MW)	Transmission loss (MW)
NORTE	7075.7	6569.9	159.8	9100.5	6569.9	163.8
CENTRO	3024.0	2313.2	58.0	1224.0	2313.2	67.6
SUL	1438.0	1408.8	67.1	1198.0	1408.8	38.2
LESTE	138.0	664.5	27.8	138.0	664.5	27.8
SAPP	0.0	400.0	6.6	0.0	400.0	6.6
TOTAL	11675.7	11356.4	319.3	11660.5	11356.4	304.0

(Source: JICA Survey Team)

As the comparison of transmission loss in Table 7-23 shows, the draft values for distributed installation and concentrated installation are 319.3 MW and 304.0 MW, respectively. Thus, the transmission loss from the distributed installation is 15.3 MW higher than that from the concentrated one, and totals the equivalent of about 105% of the transmission loss of the concentrated installation draft value. There is no obvious difference between two plans. This comparison is considered one index showing the adequacy of the distributed power plant installation plan in the power system if the viewpoint of avoiding enhancement of long-distance transmission lines and securing energy security are considered.

7.7.11 Consideration for measures to reduce power transmission loss

Figure 7-36 shows the main power system plan for 2040 formulated using data provided PSSE.

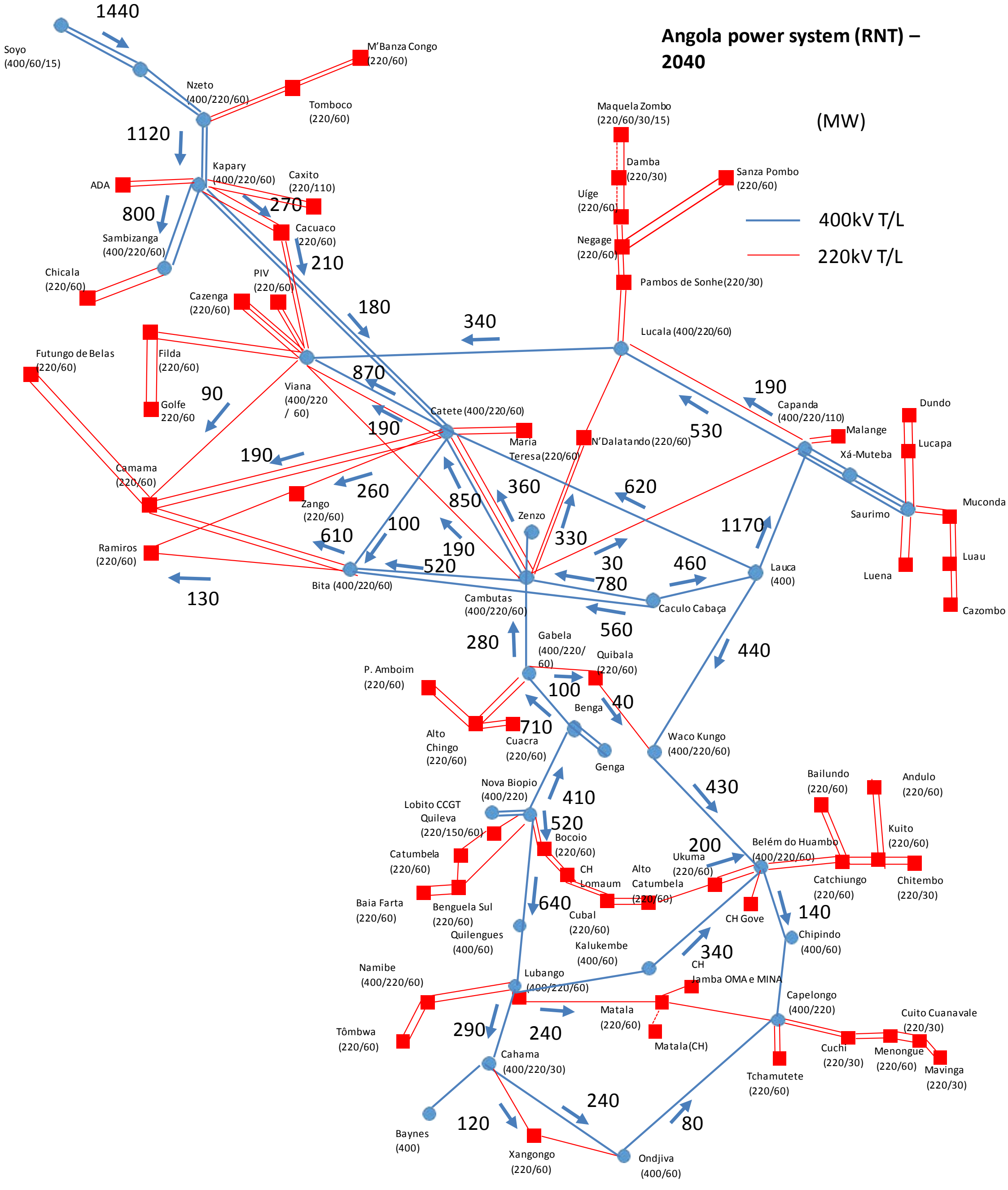


Figure 7-41 RNT's power system plan in 2040（400 kV, 220 kV）

(Source: JICA Survey Team)

Table 7-22 shows the results of a comparison of the transmission loss between the drafts of the JICA Survey Team and RNT. There is no difference in the substation demand condition between the two plans in the comparison. The power plant outputs (Soyo power plant included) are basically the same.

Table 7-24 Transmission losses in 2040

Region	JICA Survey Team's plan			RNT's plan		
	Generation (MW)	Demand (MW)	Transmission loss(MW)	Generation (MW)	Demand (MW)	Transmission loss(MW)
NORTE	7437.0	6569.9	174.0	7524.2	6569.9	213.6
CENTRO	2664.0	2313.2	49.8	2664.0	2313.2	88.9
SUL	1438.0	1408.8	62.4	1438.0	1408.8	70.8
LESTE	138.0	664.5	27.8	138.0	664.5	27.8
SAPP	0.0	400.0	6.6	0.0	400.0	6.6
TOTAL	11677.0	11356.4	320.7	11764.2	11356.4	407.8

(Source: JICA Survey Team)

According to the transmission loss comparison shown in Table 7-24, the values for the RNT and JICA Survey Team drafts are 407.8 MW and 320.7 MW, respectively. Hence, the transmission loss of the JICA Survey Team's draft is 87.1MW less than the RNT's (or approximately 80% of the loss in the RNT draft). This result is one indicator showing the validity of the JICA study team draft.

7.7.12 Annual plan for transmission development system

The following shows the transmission development plans (2025, 2030, and 2035) in the main power system formulated based on the generator plan in Table 7-17 and substation plan in Table 7-20. Basically, the 400 kV transmission line system will have a loop configuration and the 220 kV system will be radial.

PSSE verified that there is no overload with transmission lines or transformers under the n-1 contingency. All of the above transmission lines have capacities of 400 kV, 220 kV and over, and all of the primary transformers have capacities of 220 kV and over (such as 400 kV/220 kV, and 220 kV/60 kV).

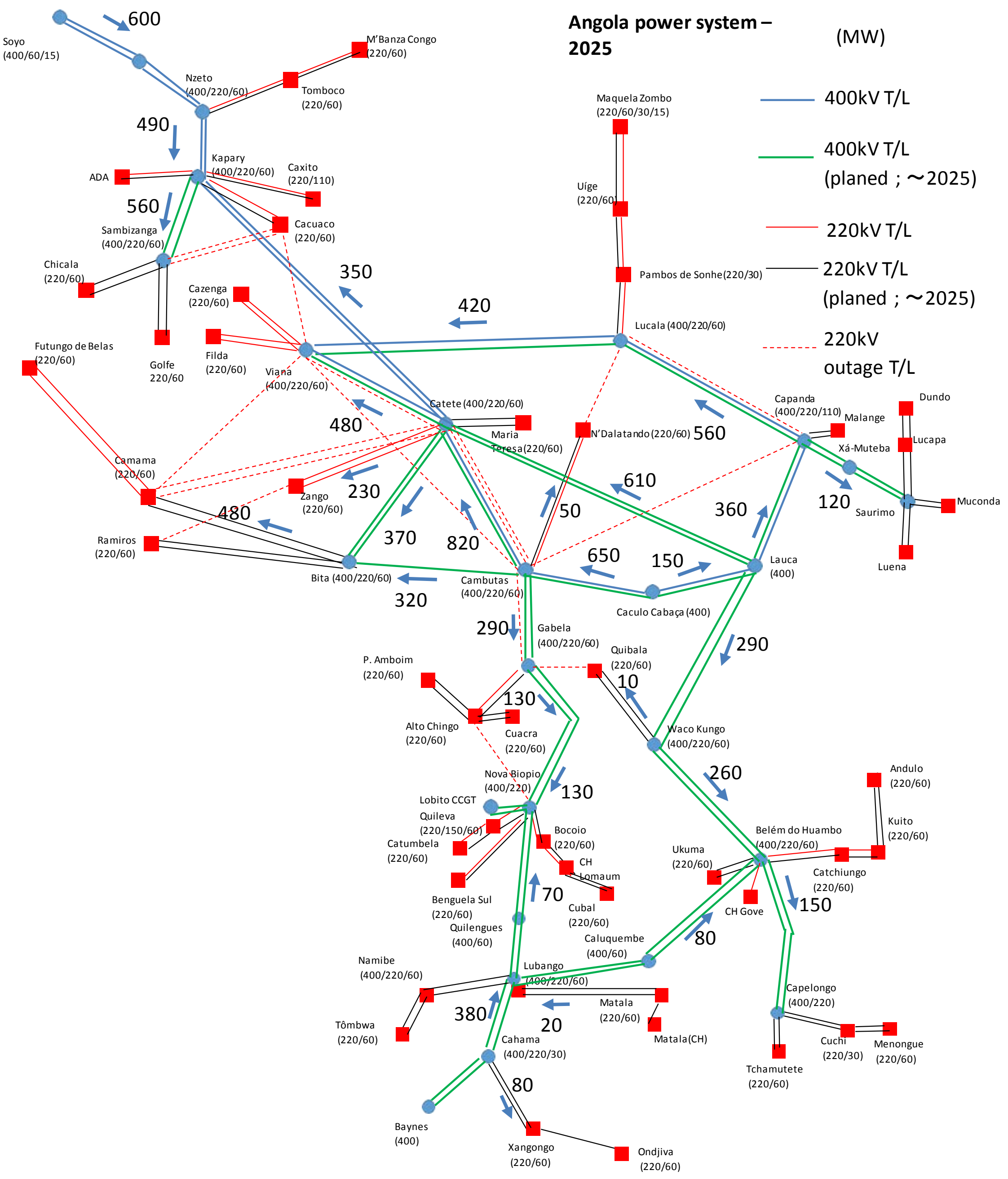


Figure 7-42　Main power system in 2025（400 kV, 220 kV）

(Source: JICA Survey Team)

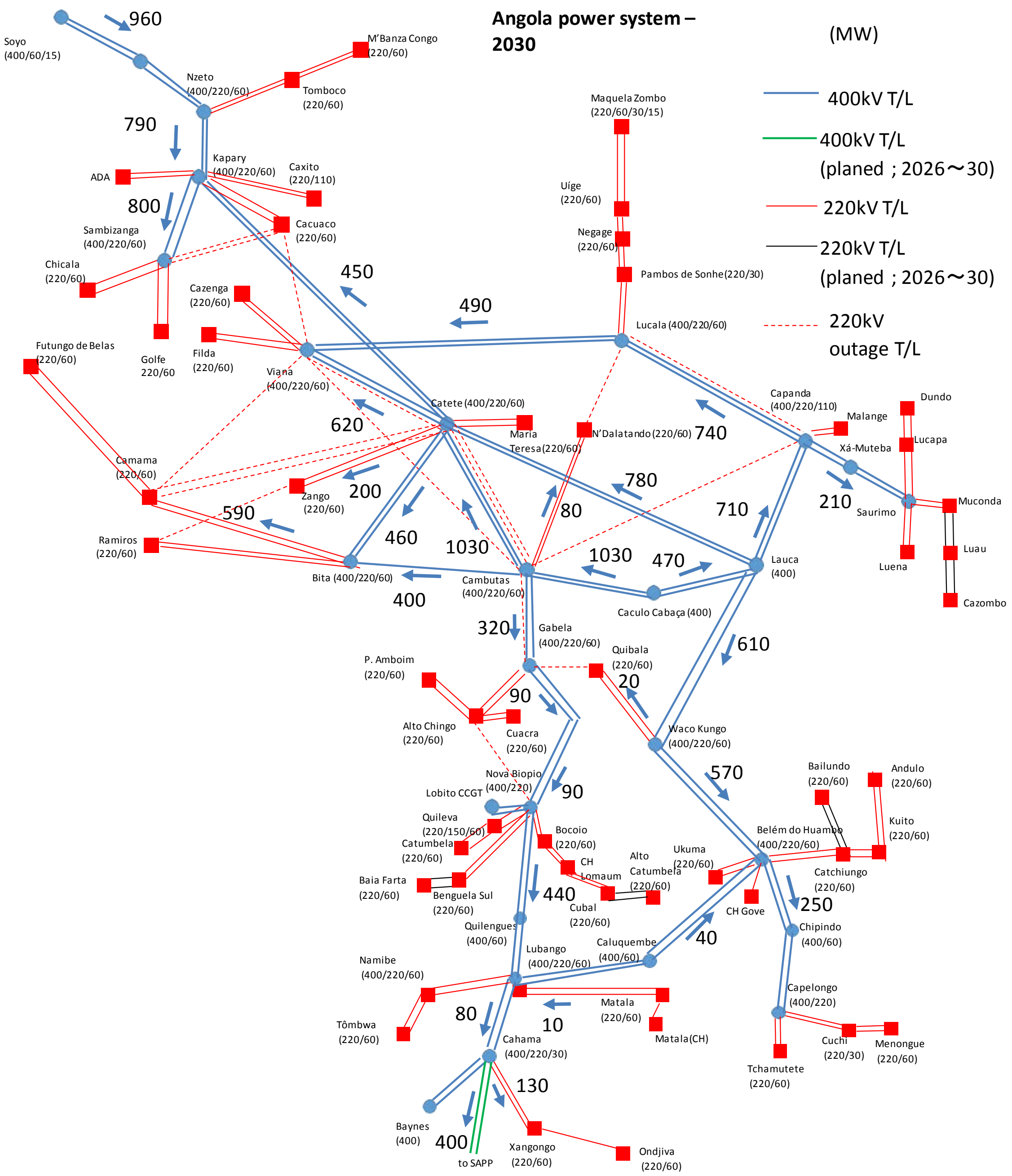


Figure 7-43 Main power system in 2030（400 kV, 220 kV）

(Source: JICA Survey Team)

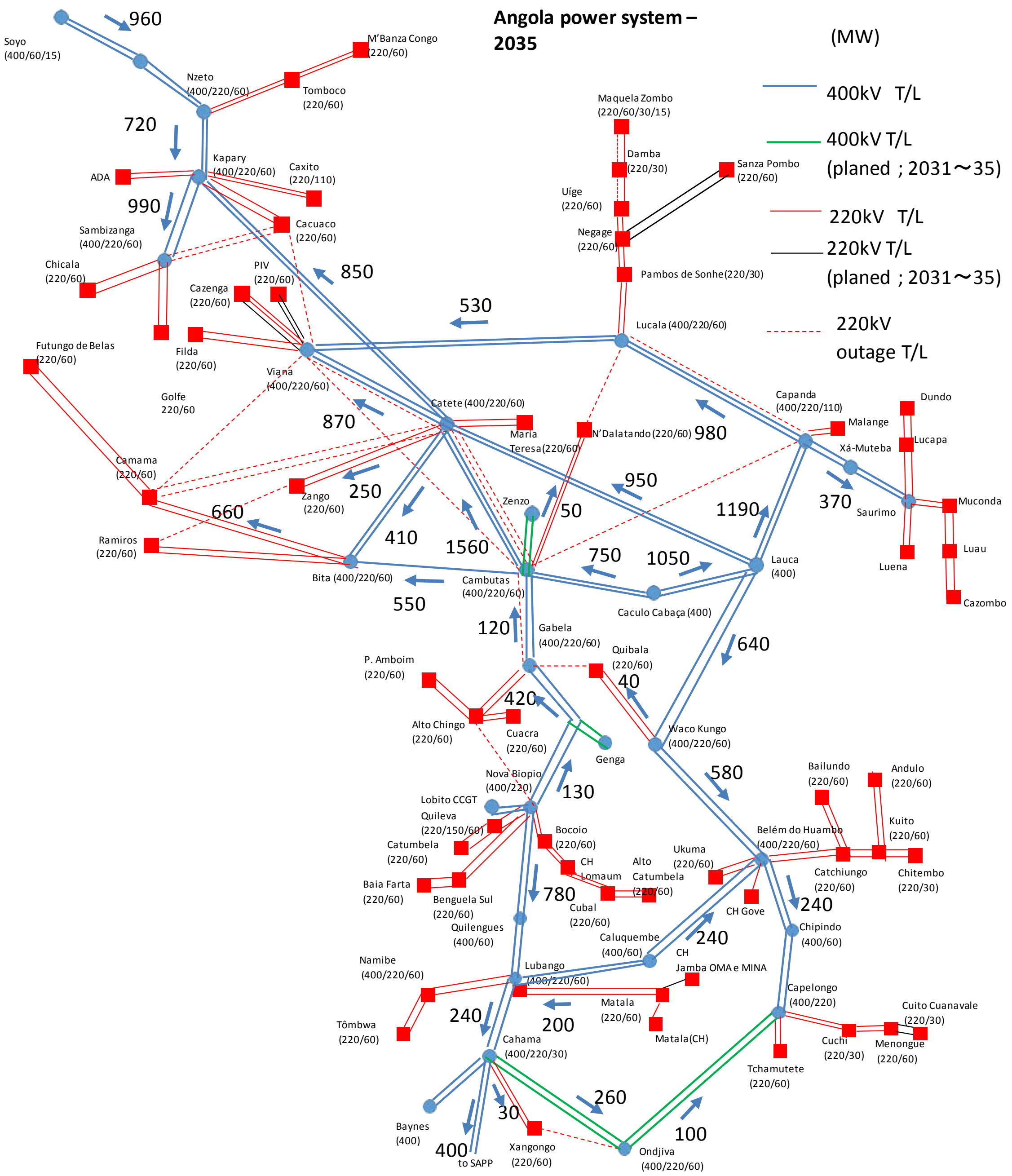


Figure 7-44 Main power system in 2035（400 kV, 220 kV）

(Source: JICA Survey Team)

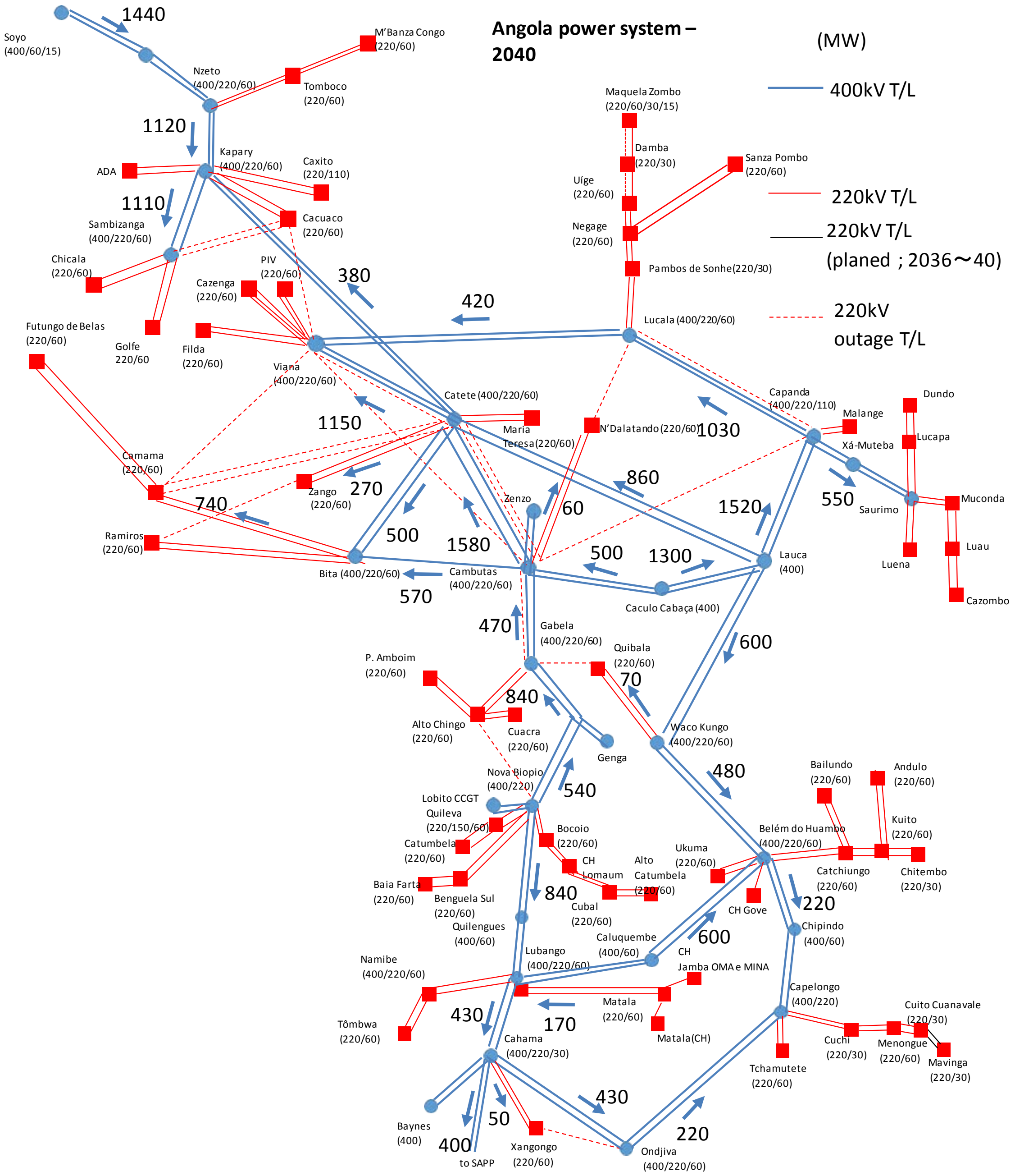


Figure 7-45 Main power system in 2040（400 kV, 220 kV）

(Source: JICA Survey Team)

7.7.13 Required volume of reactive power compensators

The required volume of reactive power compensators of bulk power system, in each voltage class for every five years are shown below.

Table 7-25 Required Volume of Reactive Power Compensators in each Substation

Bus No.	Substation MANE	Bus Voltage to be controlled (kV)	Shunt Reactor (MVA)				Shunt Capacitor (MVA)			
			2025	2030	2035	2040	2025	2030	2035	2040
12118	VIANA	400	0	0	0	0	250	400	450	450
12125	SAMBZANG_400	400	0	0	0	0	50	400	450	450
12141	BITA_400	400	0	0	0	0	50	100	200	250
13004	KAPARY_400	400	0	0	0	0	300	300	450	450
20100	N_BIOPIO_400	400	50	50	50	50	0	0	0	0
23016	W.KUNGO_400	400	350	350	350	350	0	0	0	0
31024	LUBANGO_400	400	300	300	300	300	0	0	0	0
31501	CAPLONGO_400	400	200	200	200	200	0	0	0	0
31510	KALUKEMB_400	400	250	250	250	250	0	0	0	0
33000	CAHAMA_400	400	150	150	200	200	0	0	0	0
33020	ONDJIVA_400	400	–	–	150	150	–	–	0	0
40030	XA_MUTBA_400	400	350	350	350	350	0	0	0	0
41019	SAURIMO_400	400	150	150	150	150	0	0	0	0
10010	M_CONGO_220	220	20	20	20	20	0	0	40	40
11000	UIGE_220	220	0	0	0	0	40	100	180	180
11007	M_ZOMBO_220	220	20	20	20	20	20	20	20	40
11017	S_POMBO_220	220	0	0	0	0	0	0	40	100
11020	DAMBA_220	220	0	0	0	0	0	0	0	0
12002	CAMAMA_220	220	0	0	0	0	100	100	250	250
12005	CAZENGA_220	220	0	0	0	0	60	140	140	180
12132	M_BENTO_220	220	0	0	0	0	120	200	200	200
20065	B.SUL_220	220	0	0	0	0	100	100	100	100
22000	KUITO_220	220	100	100	100	100	0	0	40	180
32003	MENONGUE_220	220	100	100	100	100	0	0	20	100
42040	CAZOMBO_220	220	50	50	50	50	0	0	0	0
	Total		2090	2090	2290	2290	1090	1860	2580	2970
	SVC	400	±150(MVA) at SAURIMO							

7.7.14 Fault Current

The three-phase short circuit fault currents of the 400kV and 220kV buses of the Angola electric power system are shown below.

Calculations are carried out under the following conditions.

- Automatic sequencing fault calculation function of PSSE is used.
- All generators installed in the system in each year are being operated.
- In order to obtain a severe calculation result, a virtual power source of 40 kA was connected to Namibia's international interconnection line..

In each year, the three phase short circuit fault current is within the specified 40kA or less.

Table 7-26 Three-Phase Short Circuit Fault Currents

Bus	Bus Name	Voltage	Fault Current (kA)				Bus Number	Bus Name	Voltage (kV)	Fault Current (kA)			
			2025	2030	2035	2040				2025	2030	2035	2040
10005	SOYO_400	400	10.1	10.6	11.2	11.6	20071	CUBAL_220	220	2.8	3.8	4.3	4.3
10006	SOYO_400_2	400	10.0	10.5	11.1	11.5	20073	CATUMB_220	220	3.4	6.2	8.7	8.8
10007	NZETO_400	400	8.9	9.1	9.6	9.7	20074	BOCOIO_220	220	3.2	4.7	5.6	5.7
10008	NZETO_220	220	9.1	9.2	9.4	9.3	20076	B.FARTA_220	220	−	4.1	5.0	5.1
10010	M_CONGO_220	220	2.4	2.4	2.4	2.4	20078	A.CATUMB_220	220	−	2.9	3.2	3.3
10030	TOMBOCO_220	220	3.6	3.6	3.6	3.6	20100	N_BIOPIO_400	400	7.1	8.6	13.7	15.3
11000	UIGE_220	220	2.0	2.0	2.3	2.4	20110	LOBITO PS	400	6.8	8.1	13.3	15.1
11007	M_ZOMBO_220	220	1.2	1.2	1.3	1.4	21003	GOVE_4_220	220	2.4	2.4	2.6	2.5
11012	NEGAGE_220	220	2.1	2.2	2.5	2.6	21013	DANGO_1_220	220	4.3	4.6	5.6	5.7
11017	S_POMBO_220	220	−	−	1.7	1.8	21021	DANGO_400	400	5.9	6.5	7.7	8.0
11020	DAMBA_220	220	−	−	1.7	1.7	21024	UKUMA_220	220	3.0	3.1	3.4	3.5
12000	CACUACO_220	220	10.7	13.0	15.4	16.4	21030	CATCH_220	220	2.9	3.2	3.5	3.7
12002	CAMAMA_220	220	10.4	10.6	11.9	11.9	21035	BAILUNDO_220	220	−	2.2	2.3	2.3
12005	CAZENGA_220	220	11.3	11.6	13.7	13.8	22000	KUITO_220	220	2.4	2.7	2.8	2.9
12007	FILDA_220	220	13.0	13.5	13.7	13.8	22008	ANDULO_220	220	1.6	1.8	1.8	1.8
12009	VIANA_220	220	18.1	19.0	19.4	19.7	22020	CHITEMBO_220	220	−	1.6	1.7	1.6
12100	CACUACO_GT	220	10.3	12.5	15.0	16.0	23001	GABELA_220	220	10.1	10.4	11.3	11.4
12118	VIANA_400	400	13.8	14.5	15.3	15.6	23004	A.CH.RNT_220	220	5.0	5.1	5.3	5.3
12125	SAMBZANG_400	400	10.1	10.4	11.6	12.3	23010	W.KUNGO_220	220	8.8	9.0	9.4	9.4
12126	SAMBZANGA220	220	13.1	13.4	16.4	17.1	23012	CUACRA_220	220	4.1	4.2	4.4	4.4
12128	SAMBZANGA_GT	220	12.3	12.6	15.3	16.1	23016	W.KUNGO_400	400	7.9	8.2	8.9	9.1
12132	M_BENTO_220	220	7.9	8.0	8.7	8.8	23017	P_AMBOIM_220	220	3.3	3.4	3.5	3.5
12136	CATETE 400	400	17.7	18.6	20.4	20.9	23019	GABELA_400	400	9.7	10.4	13.1	13.3
12137	CATETE_220	220	13.0	13.0	13.4	13.9	23020	QUIBALA_220	220	3.6	3.7	3.8	3.8
12139	RAMIROS_220	220	7.1	7.2	7.8	7.8	23023	BENGA_400	400	−	−	12.6	13.0
12141	BITA_400	400	12.1	12.4	13.2	13.3	23024	GENGA_400	400	7.5	8.0	10.6	10.8
12142	BITA_220	220	13.0	13.2	15.3	15.4	30012	NAMIBE_220	220	2.8	3.1	3.4	9.7
12145	PIV_220	220	−	−	16.8	17.0	30016	TOMBWA_220	220	1.9	2.0	2.1	3.7
12267	ZANGO_220	220	7.0	7.1	7.2	7.3	30112	NABIBE_CCGT	220	−	−	−	10.0
12300	CHICALA_220	220	11.9	12.1	14.5	15.0	31015	MATALA_4_220	220	1.8	1.9	3.6	3.7
12305	GOLF	220	12.0	12.1	14.5	15.1	31024	LUBANGO_400	400	5.5	7.6	9.1	10.4
13004	KAPARY_400	400	14.0	14.6	16.3	17.3	31027	LUBANGO_220	220	5.5	6.6	8.2	8.6
13005	KAPARY_220	220	13.3	16.6	18.8	19.4	31029	MATALA_220	220	1.9	2.0	3.9	4.0
13007	DANDE_220	220	10.3	12.2	13.3	13.6	31031	J_MINA_220	220	1.4	1.5	3.9	4.0
13030	CAXITO_220	220	9.1	10.6	11.4	11.5	31036	J_OMA_220	220	−	0.9	2.3	2.3
14005	CAMBAMBE_220	220	24.3	24.7	26.1	26.1	31043	TCHAMUTE_220	220	1.9	1.8	2.0	2.0
14007	LUCALA_220	220	4.0	3.9	5.4	5.5	31060	QUILENGS_400	400	5.9	7.3	9.5	10.4
14008	LUCALA_400	400	13.0	13.2	13.6	13.7	31300	NOVO_LUB_220	220	7.0	8.7	10.6	13.3
14009	NDALAT_220	220	6.1	6.2	6.2	6.2	31501	CAPLONGO_400	400	3.2	3.3	4.9	5.0
14011	P.SONHE_220	220	2.9	2.9	3.5	3.6	31502	CAPLONGO_220	220	2.8	2.6	3.1	3.0
14016	CAMBUTAS_220	220	27.1	27.6	29.5	29.5	31510	KALUKEMB_400	400	5.2	6.2	7.0	7.4
14017	CAMBUTAS_400	400	21.5	22.2	26.2	26.6	31511	CHIPINDO_400	400	−	4.3	5.6	5.8
14025	CBB_2_1	220	18.4	18.6	19.4	19.3	32000	CUCHI_220	220	1.8	1.8	2.1	2.1
14026	CBB_2_2	220	18.4	18.6	19.4	19.3	32003	MENONGUE_220	220	1.4	1.4	1.6	1.6
14027	CBB_2_3	220	18.4	18.6	19.4	19.3	32015	C_CUANVL_220	220	−	−	1.0	0.9
14028	CBB_2_4	220	18.4	18.6	19.4	19.3	32017	MAVINGA_220	220	−	−	0.8	0.7
14043	M_TERESA_220	220	5.5	5.5	5.5	5.6	33000	CAHAMA_400	400	3.6	6.7	8.0	8.4
14051	LAUCA_400	400	28.6	28.5	31.5	31.7	33001	CAHAMA_220	220	2.6	3.2	3.4	3.5
14053	LAUCA_EC_220	220	3.9	3.9	3.9	3.9	33003	XANGONGO_220	220	1.8	2.1	2.2	2.2
14054	C_CABAﾇA_400	400	28.1	27.2	31.0	31.2	33005	ONDJIVA_220	220	1.1	1.2	3.0	3.0
14071	ZENZO	400	−	−	16.5	16.5	33007	BAYNES_400	400	2.4	3.1	4.5	4.6
14074	CE_GASTﾃO	220	3.0	3.0	3.8	3.9	33020	ONDJIVA_400	400	−	−	5.1	5.2
15004	CAPANDA_220	220	18.0	18.1	18.1	18.0	40010	DUNDO_220	220	1.5	1.5	1.5	1.5
15006	CAP_ELEV_220	220	18.5	18.6	18.6	18.5	40020	LUCAPA_220	220	1.8	1.8	1.8	1.8
15008	CAP_ELEV_400	400	19.0	19.0	20.1	20.2	40030	XA_MUTBA_400	400	3.8	3.9	3.9	3.9
15016	MALANJE_220	220	5.1	5.1	4.8	4.9	41019	SAURIMO_400	400	2.1	2.1	2.0	2.1
20025	KILEV_4_220	220	3.7	6.9	10.3	10.3	41020	SAURIMO_220	220	2.5	2.5	2.6	2.6
20034	LMAUM_3_220	220	2.8	3.8	4.4	4.4	41040	MUCONDA_220	220	1.4	1.4	1.4	1.4
20052	N_BIOP_1_220	220	4.0	6.9	9.7	9.8	42010	LUENA_220	220	1.3	1.3	1.3	1.3
20065	B.SUL_220	220	3.1	5.1	6.8	6.8	42030	LUAU_220	220	1.1	1.2	1.1	1.1
20067	KILEVA_GT	220	3.6	6.9	10.5	10.5	42040	CAZOMBO_220	220	0.8	0.8	0.8	0.8

7.7.15 Summary of the power transmission system development plan up to 2040

The results up to the previous section are compiled into the following project list. The power supply line relation for the transmission lines is shown separately. Here, the standard capacity of the transformer at the 400 kV substation is set to 450 MVA, 930 MVA, and the standard capacity of the transformer at the 220 kV substation is set to 60 MVA, 120 MVA, 240 MVA, and in principle, the development will be carried out in line with this lineup.

Table 7-27 List of 400 kV Substation Projects

Project#	Year of operation	Area	Voltage (kV)	Substation Name	Capacity (MVA)	Cost (MUS$)	Remarks
1	2020	**Cuanza Sul**	400	**Waco kungo**	450	40.5	450 x 1, under construction(China)
2	2020	**Huambo**	400	**Belem do Huambo**	900	51.3	450 x 2, under construction(China)
3	2022	**Luanda**	400	**Bita**	900	51.3	450 x 2, under construction(Brazil)
4	2025	**Cuanza Sul**	400	**Waco kungo**	450	40.5	upgrade 450 x 1
5	2025	**Luanda**	400	**Bita**	450	40.5	upgrade 450 x 1
6	2025	**Zaire**	400	**N'Zeto**	450	40.5	upgrade 450 x 1
7	2025	**Luanda**	400	**Viana**	2,790	96.6	upgrade 930 x 3
8	2025	**Bengo**	400	**Kapary**	450	40.5	upgrade 450 x 1
9	2025	**Huila**	400	**Lubango2**	900	51.3	450 x 2, Pre-FS implemented*
10	2025	**Huila**	400	**Capelongo**	900	51.3	450 x 2
11	2025	**Huila**	400	**Calukembe**	120	32.6	60 x 2
12	2025	**Benguera**	400	**Nova Biopio**	900	51.3	450 x 2
13	2025	**Southern**	400	**Cahama**	900	51.3	450 x 2
14	2025	**Eastern**	400	**Saurimo**	900	51.3	450 x 2, under Pre-FS
15	2025	**Lunda Norte**	400	**Xa-Muteba**	360	38.3	180 x 2, under Pre-FS
16	2025	**Huila**	400	**Quilengues**	120	32.6	60 x 2
17	2025	**Cuanza Sul**	400	**Gabela**	900	51.3	450 x 2
18	2025	**Luanda**	400	**Sambizanga**	2,790	96.6	930 x 3
19	2025	**Malanje**	400	**Lucala**	900	51.3	450 x 2
20	2025	**Chipindo**	400	**Chipindo**	360	38.3	180 x 2
21	2030	**Bengo**	400	**Kapary**	450	40.5	upgrade 450 x 1
22	2030	**Luanda**	400	**Catete**	450	40.5	upgrade 450 x 1
23	2035	**Cunene**	400	**Ondjiva**	900	51.3	450 x 2, Pre-FS implemented*
24	2035	**Luanda**	400	**Bita**	450	40.5	upgrade 450 x 1
25	2035	**Malanje**	400	**Lucala**	450	40.5	upgrade 450 x 1
Total					19,590	1,171.4	

Pre-FS implemented*:Candidate site were selected by USTDA and DBSA.

(Source: JICA Survey Team)

Table 7-28 List of 220 kV Substation Projects (1)

Project#	Year of operation	Area	Voltage (kV)	Substation Name	Capacity (MVA)	Cost (MUS$)	Remarks
1	2018	**Benguela**	220	**Benguela Sul**	240	24.5	120 x 2, under construction(China)
2	2020	**Luanda**	220	**Bita**	240	24.5	120 x 2, under construction(Brazil)
3	2020	**Zaire**	220	**Tomboco**	40	13.7	20 x 2
4	2020	**Malanje**	220	**Capanda Elevadora**	130	18.6	65 x 2, upgrade
5	2021	**Luanda**	220	**Cacuaco**	480	37.5	240 x 2, upgrade
6	2022	**Luanda**	220	**Zango**	360	31.0	120 x 3
7	2022	**Malanje**	220	**Malanje2**	240	24.5	120 x 2
8	2022	**Cuanza Sul**	220	**Waco Kungo**	60	14.8	60 x 1
9	2022	**Cuanza Sul**	220	**Quibala**	120	18.1	60 x 2
10	2022	**Benguela**	220	**Cubal**	120	18.1	60 x 2
11	2022	**Huíla**	220	**Lubango**	240	24.5	120 x 2, Pre-FS implemented*
12	2022	**Huíla**	220	**Matala**	120	18.1	60 x 2, Pre-FS implemented*
13	2022	**Huíla**	220	**Capelongo**	60	14.8	60 x 1
14	2022	**Cuando-Cubango**	220	**Cuchi**	60	14.8	60 x 1
15	2022	**Cuando-Cubango**	220	**Menangue**	240	24.5	120 x 2
16	2022	**Namibe**	220	**Namibe**	240	24.5	120 x 2, Pre-FS implemented*
17	2022	**Namibe**	220	**Tombwa**	120	18.1	60 x 2, Pre-FS implemented*
18	2022	**Lunda Norte**	220	**Lucapa**	60	14.8	60 x 1
19	2022	**Lunda Norte**	220	**Dundo**	120	18.1	60 x 2, under Pre-FS
20	2022	**Lunda Sur**	220	**Saurimo**	120	18.1	60 x 2, under Pre-FS
21	2022	**Uíge**	220	**Uíge**	240	24.5	120 x 2, upgrade
22	2025	**Luanda**	220	**Golfe**	360	31.0	120 x 3
23	2025	**Luanda**	220	**Chicara**	480	37.5	240 x 2
24	2025	**Bengo**	220	**Caxito**	60	14.8	60 x 1
25	2025	**Bengo**	220	**Maria Teresa**	60	14.8	60 x 1
26	2025	**Cuanza Sul**	220	**Porto Amboim**	120	18.1	60 x 2
27	2025	**Cuanza Sul**	220	**Cuacra**	60	14.8	60 x 1
28	2025	**Benguela**	220	**Catumbela**	120	18.1	60 x 2
29	2025	**Benguela**	220	**Bocoio**	120	18.1	60 x 2
30	2025	**Huambo**	220	**Ukuma**	60	14.8	60x 1, Pre-FS implemented*
31	2025	**Huambo**	220	**Catchiungo**	120	18.1	60 x 2, Pre-FS implemented*
32	2025	**Bié**	220	**Andulo**	60	14.8	60 x 1
33	2025	**Huíla**	220	**Nova Lubango**	120	18.1	60 x 2
34	2025	**Huíla**	220	**Caluquembe**	60	14.8	60 x 1
35	2025	**Huíla**	220	**Quilengues**	60	14.8	60 x 1
36	2025	**Huíla**	220	**Tchamutete**	120	18.1	60 x 2, Pre-FS implemented*
37	2025	**Cunene**	220	**Ondjiva**	120	18.1	60 x 2, Pre-FS implemented*
38	2025	**Cunene**	220	**Cahama**	60	14.8	60 x 1, Pre-FS implemented*
39	2025	**Cunene**	220	**Xangongo**	60	14.8	60 x 1, Pre-FS implemented*
40	2025	**Moxico**	220	**Luena**	240	24.5	120 x 2, under Pre-FS
41	2025	**Lunda Norte**	220	**Xa-Muteba**	120	18.1	60 x 2
42	2025	**Luanda**	220	**Viana**	600	44.0	300 x 2, upgrade
43	2025	**Luanda**	220	**Camama**	120	18.1	120 x 1, upgrade
44	2025	**Luanda**	220	**Sambizanga**	240	24.5	240 x 1, upgrade
45	2025	**Kuanza Norte**	220	**N' Dalatando**	80	15.9	40 x 2, upgrade
46	2027	**Moxico**	220	**Cazombo**	60	14.8	60 x 1
47	2027	**Moxico**	220	**Luau**	60	14.8	60 x 1
48	2027	**Lunda Sur**	220	**Muconda**	60	14.8	60 x 1
49	2027	**Bié**	220	**Kuito**	120	18.1	120 x 1, upgrade
50	2030	**Luanda**	220	**Futungo de Belas**	120	18.1	120 x 1, upgrade

Pre-FS implemented*:Candidate site were selected by USTDA and DBSA.

(Source: JICA Survey Team)

Table 7-29 List of 220 kV Substation Projects (2)

Project#	Year of operation	Area	Voltage (kV)	Substation Name	Capacity (MVA)	Cost (MUS$)	Remarks
51	2030	**Uíge**	220	**Negage**	180	21.3	60 x 3
52	2030	**Cabinda**	220	**Cabinda**	240	24.5	120x 2
53	2030	**Cabinda**	220	**Cacongo**	120	18.1	60 x 2
54	2030	**Benguela**	220	**Alto Catumbela**	120	18.1	60 x 2
55	2030	**Benguela**	220	**Baria Farta**	120	18.1	60 x 2
56	2030	**Huambo**	220	**Bailundo**	120	18.1	60 x 2
57	2030	**Huíla**	220	**Chipindo**	60	14.8	60 x 1
58	2031	**Zaire**	220	**M'Banza Congo**	180	21.3	60 x 3, upgrade
59	2032	**Cunene**	220	**Ondjiva**	120	18.1	120 x 1, upgrade
60	2032	**Lunda Sur**	220	**Saurimo**	120	18.1	120 x 1, upgrade
61	2034	**Luanda**	220	**Cacuaco**	240	24.5	240 x 1, upgrade
62	2035	**Luanda**	220	**PIV**	480	37.5	240 x 2
63	2035	**Kuanza Norte**	220	**Lucala**	120	18.1	60 x 2
64	2035	**Uíge**	220	**Sanza Pombo**	120	18.1	60 x 2
65	2035	**Bié**	220	**Camacupa**	60	14.8	60 x 1
66	2035	**Cuando-Cubango**	220	**Cuito Cuanavale**	60	14.8	60 x 1
67	2035	**Luanda**	220	**Cazenga**	120	18.1	120 x 1, upgrade
68	2035	**Bengo**	220	**Kapary**	120	18.1	120 x 1, upgrade
69	2035	**Benguela**	220	**Catumbela**	240	24.5	120 x 2, upgrade
70	2036	**Luanda**	220	**Sambizanga**	240	24.5	240 x 1, upgrade
71	2036	**Uíge**	220	**Maquela do Zombo**	40	13.7	40 x 1, upgrade
72	2036	**Huambo**	220	**Belém do Dango**	240	24.5	240 x 1, upgrade
73	2036	**Lunda Norte**	220	**Dundo**	120	18.1	120 x1, upgrade
74	2037	**Cuanza Sul**	220	**Gabela**	60	14.8	60 x 1, upgrade
75	2038	**Benguela**	220	**Cubal**	240	24.5	120 x 2, upgrade
76	2040	**Cuando-Cubango**	220	**Mavinga**	60	14.8	60 x 1
77	2040	**Malanje**	220	**Malanje2**	120	18.1	120 x 1, upgrade
78	2040	**Huíla**	220	**Caluquembe**	60	14.8	60 x 1, upgrade
Total					11,810	772.4	

(Source: JICA Survey Team)

Table 7-30 List of 400 kV Transmission Line Projects

Project#	Year of operation	Area	Voltage (kV)	Starting point	End point	number of circuit	Power Flow (MVA)	Line Length (km)	Cost (MUS$)	Remarks
1	2020	**Central**	400	**Lauca**	**Waco kungo**	1	307	177	138.1	under construction(China)
2	2020	**Central**	400	**Waco kungo**	**Belem do Huambo**	1	242	174	135.7	under construction(China)
3	2020	**Northern**	400	**Cambutas**	**Bita**	1	580	172	134.2	under construction(Brazil)
4	2022	**Northern**	400	**Catete**	**Bita**	2	504	54	52.9	under construction(Brazil)
5	2025	**Northern**	400	**Cambutas**	**Catete**	1	791	123	95.9	Dualization
6	2025	**Northern**	400	**Catete**	**Viana**	1	579	36	28.1	Dualization
7	2025	**Northern**	400	**Lauca**	**Capanda elev.**	1	518	41	32.0	Dualization
8	2025	**Northern**	400	**Kapary**	**Sambizanga**	2	1130	45	44.1	For New Substation
9	2025	**Northern**	400	**Lauca**	**Catete**	2	868	190	186.2	Changing Connection Plan
10	2025	**Central**	400	**Lauca**	**Waco kungo**	1	307	177	138.1	Dualization
11	2025	**Central**	400	**Waco kungo**	**Belem do Huambo**	1	242	174	135.7	Dualization
12	2025	**Central**	400	**Cambutas**	**Gabela**	2	484	131	128.4	Pre-FS implemented*
13	2025	**Central**	400	**Gabela**	**Benga**	2	848	25	24.5	Pre-FS implemented*
14	2025	**Central**	400	**Benga**	**Nova Biopio**	2	550	200	196.0	Pre-FS implemented*
15	2025	**Southern**	400	**Belem do Huambo**	**Caluquembe**	2	606	175	171.5	Pre-FS implemented*
16	2025	**Southern**	400	**Caluquembe**	**Lubango2**	2	666	168	164.6	Pre-FS implemented*
17	2025	**Southern**	400	**Belem do Huambo**	**Chipindo**	2	264	114	111.7	
18	2025	**Southern**	400	**Chipindo**	**Capelongo**	2	190	109	106.8	
19	2025	**Southern**	400	**Nova Biopio**	**Quilengues**	2	840	117	114.7	Pre-FS implemented*
20	2025	**Southern**	400	**Quilengues**	**Lubango2**	2	772	143	140.1	Pre-FS implemented*
21	2025	**Southern**	400	**Lubango2**	**Cahama**	2	450	190	186.2	Pre-FS implemented*
22	2025	**Eastern**	400	**Capanda_elev**	**Xa-Muteba**	2	590	266	260.7	
23	2025	**Eastern**	400	**Xa-Muteba**	**Saurimo**	2	510	335	328.3	under Pre-FS
24	2027	**Southern**	400	**Capelongo**	**Ondjiva**	2	292	312	305.8	
25	2027	**Southern**	400	**Cahama**	**Ondjiva**	2	442	175	171.5	
26	2027	**Southern**	400	**Cahama**	**Ruacana**	2	409	125	122.5	International Interconnection
Total								3,948	3,654.2	

Pre-FS implemented*:Candidate route were selected by USTDA and DBSA.

(Source: JICA Survey Team)

Table 7-31 220 kV List of Transmission Line Projects

Project#	Year of operation	Area	Voltage (kV)	Starting point	End point	number of circuit	Required Capcity (MVA)	Line Length (km)	Cost (MUS$)	Remarks
1	2020	**Southern**	220	**Lubango2**	**Lubango**	2	360	30	13.5	Pre-FS implemented*
2	2020	**Southern**	220	**Lubango2**	**Namibe**	2	360	162	72.9	Pre-FS implemented*
3	2020	**Southern**	220	**Namibe**	**Tombwa**	2	120	97	43.7	Pre-FS implemented*
4	2020	**Eastern**	220	**Saurimo**	**Lucapa**	2	300	157	70.7	Pre-FS implemented*
5	2020	**Eastern**	220	**Lucapa**	**Dundo**	2	240	135	60.8	Pre-FS implemented*
6	2022	**Northern**	220	**Bita**	**Camama**	2	840	21	9.5	
7	2022	**Northern**	220	**Catete**	**Zango**	2	360	40	18.0	
8	2022	**Northern**	220	**Capanda elev.**	**Maranje**	2	360	110	49.5	
9	2022	**Central**	220	**Gabela**	**Alto Chingo**	1	300	81	29.2	Dualization
10	2022	**Central**	220	**Quibala**	**Waco Kungo**	2	120	92	41.4	
11	2022	**Central**	220	**Lomaum**	**Cubal**	2	360	2	0.9	
12	2022	**Southern**	220	**Lubango**	**Matala**	2	120	168	75.6	Pre-FS implemented*
13	2022	**Southern**	220	**Matala HPS**	**Matala**	1	41	5	1.8	upgarade
14	2022	**Southern**	220	**Capelongo**	**Cuchi**	2	420	91	41.0	
15	2022	**Southern**	220	**Cuchi**	**Menongue**	2	360	94	42.3	
16	2025	**Northern**	220	Sambizanga	**Golfe**	2	360	7	3.2	
17	2025	**Northern**	220	**Kapary**	**Caxito**	2	60	26	11.7	
18	2025	**Northern**	220	**N'Zeto**	**Tomboco**	2	220	5	2.3	For Substattion inserted
19	2025	**Northern**	220	**M'banza Congo**	**Tomboco**	2	220	5	2.3	For Substattion inserted
20	2025	**Northern**	220	**Sambizanga**	**Chicala**	2	480	7	3.2	
21	2025	**Northern**	220	**Catete**	**Maria Teresa**	2	60	51	23.0	
22	2025	**Central**	220	**Alto Chingo**	**Cuacra**	2	60	25	11.3	
23	2025	**Central**	220	**Alto Chingo**	**Port Amboim**	2	120	60	27.0	
24	2025	**Central**	220	**Quileva**	**Nova Biopio**	1	550	18	6.5	Dualization
25	2025	**Central**	220	**Quileva**	**Catumbela**	2	240	8	3.6	
26	2025	**Central**	220	**Nova Biopio**	**Bocoio**	2	120	5	2.3	For Substattion inserted
27	2025	**Central**	220	**Lomaum**	**Bocoio**	2	120	5	2.3	For Substattion inserted
28	2025	**Central**	220	**Belem do Huambo**	**Ukuma**	2	60	66	29.7	
29	2025	**Central**	220	**Belem do Huambo**	**Catchiungo**	2	720	76	34.2	Strengthen
30	2025	**Central**	220	**Catchiungo**	**Kuito**	2	480	85	38.3	Strengthen
31	2025	**Central**	220	**Kuito**	**Andulo**	2	60	110	49.5	
32	2025	**Southern**	220	**Cahama**	**Xangongo**	2	180	97	43.7	Pre-FS implemented*
33	2025	**Southern**	220	**Ondjiva**	**Xangongo**	1	120	97	34.9	Pre-FS implemented*
34	2025	**Southern**	220	**Capelongo**	**Tchamutete**	2	120	98	44.1	
35	2025	**Eastern**	220	**Saurimo**	**Luena**	2	240	265	119.3	Pre-FS implemented*
36	2027	**Eastern**	220	**Saurimo**	**Muconda**	2	180	187	84.2	
37	2027	**Eastern**	220	**Muconda**	**Luau**	2	120	115	51.8	
38	2027	**Eastern**	220	**Luau**	**Cazombo**	2	60	264	118.8	
39	2030	**Central**	220	**Cubal**	**Alto Catumbela**	2	120	47	21.2	
40	2030	**Central**	220	**Catchiungo**	**Bailundo**	2	120	66	29.7	
41	2030	**Central**	220	**Benguela Sul**	**Baia Farta**	2	120	30	13.5	
42	2030	**Northern**	220	**Uige**	**Negage**	2	620	5	2.3	For Substattion inserted
43	2030	**Northern**	220	**Pambos de Sonhe**	**Negage**	2	620	5	2.3	For Substattion inserted
44	2035	**Northern**	220	**Viana**	**PIV**	2	480	7	3.2	
45	2035	**Northern**	220	**Negage**	**Sanza Pombo**	2	120	109	49.1	
46	2035	**Central**	220	**Kuito**	**Camacupa**	2	60	145	65.3	
47	2035	**Southern**	220	**Menongue**	**Cuito Cuanavale**	2	120	189	85.1	
48	2035	**Southern**	220	**Cuito Cuanavale**	**mavinga**	2	60	176	79.2	
Total								3,746	1,667.6	

Pre-FS implemented*:Candidate route were selected by USTDA and DBSA.

(Source: JICA Survey Team)

Table 7-32 List of Power Supply Transmission Line Projects

Project#	Year of operation	Area	Voltage (kV)	Starting point	End point	number of circuit	Generation Capacity (MVA)	Line Length (km)	Cost (MUS$)	Remarks
1	2025	Northern	400	HPP Caculo Cabaça	Cambutas	2	496	54	52.9	under construction(China)
2	2025	Northern	400	HPP Caculo Cabaça	Lauca	2	1326	25	24.5	
3	2025	Northern	400	TPP Soyo 2	Soyo	2	750	5	4.9	
4	2025	Central	400	TPP Lobito CCGT #1	Nova_Biopio	2	750	23	22.5	
5	2025	Northern	220	TPP Cacuaco GT #1	Cacuaco	2	375	5	2.3	
6	2025	Northern	220	TPP Cacuaco GT #2	Cacuaco	2	375	5	2.3	
7	2025	Northern	220	TPP Boavista GT #3	Sambizanga	2	375	5	2.3	
8	2030	Northern	220	HPP Quilengue ⑤	Gabera	2	210	37	16.7	
9	2030	Southern	400	HPP Baynes	Cahama	2	300	195	191.1	
10	2030	Central	220	TPP Quileva GT #4	Quileva	2	250	1	0.5	
11	2030	Central	220	TPP Quileva GT #5	Quileva	2	250	1	0.5	
12	2030	Central	220	TPP Quileva GT #6	Quileva	2	250	1	0.5	
13	2030	Northern	400	TPP Soyo GT #7	Soyo	2	375	5	4.9	
14	2035	Northern	400	HPP Zenzo	Cambutas	2	950	41	40.2	
15	2035	Northern	400	HPP Genga	Benga Switch-yard	2	900	30	29.4	
16	2035	Central	400	TPP Lobito CCGT #2	Nova_Biopio	2	720	23	22.5	
17	2035	Southern	220	HPP Jamba Ya Mina	Matala	1	205	86	31.0	
18	2035	Southern	220	HPP Jamba Ya Oma	HPP Jamba Ya Mina	1	79	37	13.3	
19	2040	Northern	220	HPP Túmulo Caçador	Cambutas	2	453	16	7.2	
20	2040	Southern	220	TPP Namibe CCGT #3	Namibe	2	750	17	7.7	
21	2040	Central	400	TPP Lobito CCGT #4	Nova_Biopio	2	375	23	22.5	
Total								635	499.4	

(Source: JICA Survey Team)

Chapter 8 Review on Private Investment Environment

8.1 Report on private Investment

(1) **'Doing Business 2017' from the World Bank**

First, the JICA Survey Team reviews the 'Doing Business 2017' Report to learn about the business environment of Angola.

The World Bank (WB) publishes a 'Doing Business' report on the ease of doing business based on indicator sets every year. The latest 'Doing Business 2017' report evaluates data such as the days necessary to complete the application process and the required fees. Out of 190 countries covered in a country ranking, Angola ranks 182nd (versus rankings of 25th for Portugal, 74th for South Africa, 137th for Mozambique, and 169 for Nigeria).

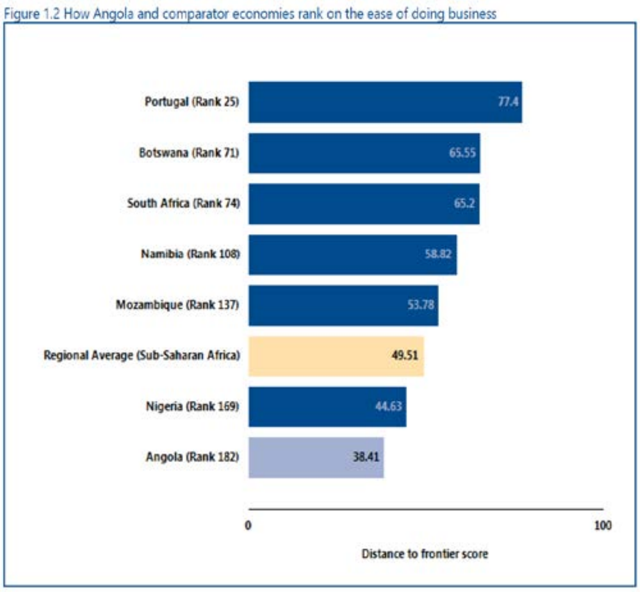
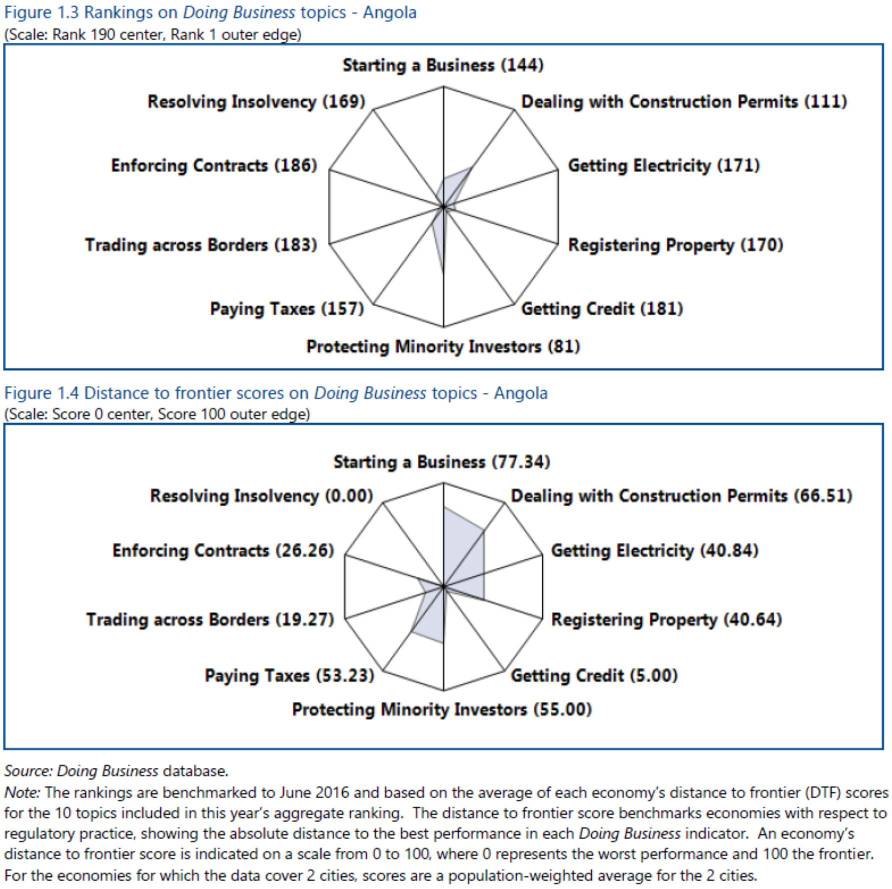


Figure 8-1 Ranking of Angola and other comparator countries

Item by item, Angola ranks 181st in 'Getting Credit,' 183rd in 'Trading across Borders,' 186th in 'Enforcing Contracts,' and 169th in 'Resolving Insolvency.' The rankings are based on the distance to the frontier score for each topic: i.e., the best country on the frontier is scored 100 and the other countries are scored from 0 to 100 according to their absolute distances to the frontier.



(Source: Doing Business database)

Figure 8-2 Ranks and scores for each topic

The JICA Survey Team understands that the problems of Angola concentrate around these low-scored items. The World Bank issued the following explanations in this regard.

- ✓ Credit information systems are not widely used. → Collateral laws or Bankrupcys law are not enacted. Borrower financial credit histories are not shared. Financial statements are not used effectively in providing credit.
- ✓ Contracts are not widely enforced. → no commercial dispute resolution system is established.
- ✓ Liquidation or insolvency systems are not well established. → Angola has not experienced any liquidation or insolvency.

8.2 Review of the Private Investment Environment Report

This section identifies bottlenecks in the private investment environment and summarizes plans to develop a private electric power project.

8.2.1 Private investment environment in Angola

(1) **Private Sector Country Profile: Angola**

The report describes problems in Angola's private investment environment broken down into three factors: the 'institutional factor,' 'economical factor,' and 'other factors.' The problems are summarized in the table below.

The JICA Survey Team reviewed the 'Private Sector Country Profile: Angola in 2012,' the first comprehensive business guidebook on Angola. The profile began with the geographical conditions of the country and then moved onto the recent political conditions, economic conditions, and finally the conditions of the investment environment. In 2015, the African Development Bank published its Portuguese edition. Unlike the 'Doing Business Report' from the World Bank, the contents of the Portuguese edition have not been updated.

The report describes problems in Angola's private investment environment organized into three factors: the 'institutional factor,' 'economical factor,' and 'other factors.' The problems are summarized in the table below.

Table 8-1 Problems in Angola's investment environment

	Problems in the private investment environment
institutional factor	・Laws and contracts tend not to observed. ・Infrastructures such as power and water supply are not properly established. ・It takes much time to obtain approvals for applications.
economical factor	・All daily products are imported by exporting oil. The official foreign currency reserves therefore depend on the oil price. ・No stock market exists. ・A monetary market exists, but is weak and vulnerable. ・Credit evaluations for borrowers are poorly executed. Accounting data that reflect financial conditions is insufficiently used.
other factors	・The labor market for skilled workers is immature.

(Sources: AfDB 'Private Sector Country Profile: Angola' in 2012')

8.2.2 Legal system in Angola

The legal system in Angola is principally based on Portuguese law. Laws, Decrees, and Acts restated to private investment, meanwhile, are being enacted apart from basic laws such as the Civil Law, Labor Law, etc.

The National Bank of Angola (BNA) has a statutory authority to adopt the accounting standards for financial institutions. Especially banks that meet at least one of the criteria in 2015 must adopt IFRS. Other banks also must adopt IFRS issued by IASB but may do so voluntarily from 2016. Many companies other than financial institutions mentioned above do not adopt IFRS. They are said to prepare the financial statements in conformity with the Angolan Accounting Law and the General Accounting Plan (PGC) that was adopted by the Presidential Decree as of 2001.

In this section the JICA Survey Team extracts the laws and regulations it considers important for private investment in Angola, out of those described in the report on the business environment. Note, however, that no laws intended for specific sectors other than the power sector are selected. The new Private Investment Law (newPIL), a law that will be important for private investment, will be reviewed in a later section.

Table 8-2 Names of laws related to the private investment environment

Name	year	contents
Anti money Laundering Law	2010	set up a penalty on Money Laundering
Countering Financial of Terrorism Law No.34/11	2010	Penalty on Public Probity
Public Asset Managing Law, with Presidential Decree	Aug. 2010	for inventory of State Petimnoy, in bidding process
President Decree 177/10	ditto	
New Private Investment Law	May, 2011	New PILwas enacted in 2015.
	→Aug. 2015	ANIPwas establishe in 2003
Exchange Law No.5/97	Jun. 1997	Trade activity : President Decree No.265/10 (Nov. 2010),
		specific rules: BNA's Notice No.19/2012 (Apr. 2012)
Commercial Societes Law Law 01/04	Feb. 2004	defines types of fims

(Sources: AfDB 'Private Sector Country Profile: Angola in 2012')

8.3 Interviews with Japanese companies

8.3.1 Interviews with Japanese Companies in Angola

In October 2017, the JICA Survey Team interviewed three Japanese companies doing business in Angola: Sumitomo Corporation (Sumitomo Syoji), Marubeni, and Toyota de Angola, S.A (Toyota Tusho). Sumitomo Corporation and Marubeni operate Representative Offices in the country, and Toyota de Angola, S.A. is a Joint Stock Company. Sumitomo Corporation is said to have concluded a Minutes of Understanding (MOU) with the Government of Angola for the construction of Japan-made diesel power plants, but the details of the plan are not known.

Issues

① What hardships are they going through in doing business in Angola?

② What bottlenecks are there in Angola's legal system?

③ Is the New Private Investment Law (new PIL) of help in developing new projects?

④ Other

（results）

① Hardships in doing business ・The low oil price binds the foreign reserves of Angola. Private companies are therefore unable to freely remit money outside of Angola. (Nacional Banco of Angola conducts a bid every week and only companies awarded bids are entitled to remit money.) ・ The laws are drafted in Portuguese, the official language, which makes them hard to read and understand.
② Legal bottlenecks ・New Presidential Decrees are being enacted. Actual business follows not the basic laws but the Decrees. ・Interpretation of law varies.
③ Request and opinions on the newPIL ・Laws are enacted, but direct negotiations will prevail.

④ Other

・The monetary market in Angola is weak and provides no good financial products

・Chinese companies doing business in Angola are said to settle their services not by cash but barter for oil. They are therefore immune to the influences of the strict regulations on bank remittance.

8.4 New Private Investment Law

8.4.1 New Private Investment Law (2015)

The New Private Investment Law, a law expected to have strong influence on private investment and project formation in Angola, was approved on August 11, 2015. It was entered into force on the same day that the former private investment law was repealed (Law No.20/11 of May 20, 2011).

A new agency called APITEX (Angolan Investment and Export Promotion Agency) was also formed to promote investments and exports.

An outline of the New Private Investment Law follows.

- ✓ The newPIL no longer includes minimum thresholds for investments. But to qualify for tax benefits and incentives, a foreign investor must invest at least $1 million and a domestic investor must invest at least $500,000.
- ✓ Decisions regarding private investments are in principle taken by the ministers responsible for the main sectors in which the investments are made, or by the Angolan executive (i.e., the President).
- ✓ The New Private Investment Law restricts indirect investment.
- ✓ An investor can be granted certain tax benefits and incentives, albeit no longer automatically.
- ✓ In the electricity and water sectors, the Angolan party should retain an interest of at least 35% in a joint venture.
- ✓ An investor can repatriate dividends, profits, and royalties. Any portion of a repatriated amount exceeding the funds of the company is subject to an additional tax.

8.4.2 Private power project in accordance with the New Private Investment Law

The details of a private electric power project are outlined below.

- ✓ In order to qualify for tax benefits and incentives, a foreign investor must invest at least $1 million and a domestic investor must invest at least $500,000. Negotiations are held directly with the Minister of Energie and Aqua (MINEA) or the Angolan executive (i.e., the President).
- ✓ Any tax incentives are decided and applied through negotiation.
- ✓ A foreign investor forms a joint venture with Angolan individuals or an Angolan company. The Angolan party retains an interest of at least 35% in the joint venture.
- ✓ After paying additional taxes, a foreign investor is eligible to repatriate dividends, profits, and royalties.

At present, the private investment environment in Angola is still underdeveloped. While every country and company recognizes the big potential of Angola, they are still reluctant to go ahead.

A power project by a private sector differs from an ODA project, in general, as no guarantees from the government are obtained. The private sector must therefore bear all of the risks such as the fluctuating prices of fuel and materials, foreign exchange, interest rates, etc. by itself.

Finally, the following are requested when private electric power projects are formed in Angola.

- Every party member observes and acts in accordance with the contract.
- The political system in Angola is stable and assets will not be nationalized.
- A reasonable long-term PPA (Power Purchase Agreement) is concluded. Tariffs are set to adequately secure a certain profit level over the long term.
- Profits earned are allocated in accordance with equity or the contract.
- A foreign investor is free to remit profit and dividends outside of Angola irrespective of the economy of Angola. (※)
- Funds from the monetary market of Angola are preferred: reasonable interest rates (not so high) and longer repayment periods.

※The auction system to settle payments for foreign countries re-started in 2018, with which the winner of the auction is entitled to receive foreign currencies for remittance. However this system seems to work only for a winner so that it does not meet requests from all import companies in Angola.

8.5 Summary and Bottlenecks

- Factors apart from the private investment issues tend to affect candidate projects. As a consequence, there seems to be little incentive to develop private investments overall. The Government needs to promote the observance of contracts and high transparency in appraising and approving projects.
- The lack of actual private investment projects to date leaves Angola with little experience in completing specific PPA agreements. As a result, negotiations and approvals may take longer.

Chapter 9 Long-term Investment Plan

9.1 Premise for fundraising

The progress of power development in Angola is mainly driven by PRODEL, RNT, and ENDE in an environment where private companies lack strong inclination to develop power projects by themselves. Under these circumstances, PRODEL will become a major implementing agency for generation, while ENDE will become the main implementing agency for transmission and distribution.

The JICA Survey Team reviews the financial statements for PRODEL, RNT, and ENDE. Given the apparent difficulty these companies would have in investing more with their own profits, they are likely to request funds from outside.

9.2 Fundraising for investment

First, the JICA Survey Team reviews whether it will be able to raise funds by issuing a bond or taking out a loan in a monetary market of Angola. As for the recent market condition, the official website of Banco Nacional de Angola (BNA) as of October 26, 2017 indicates a loan condition in terms of AOA, with an interest rate of 20.04% and repayment period of 1-3 years. The average interest rates for Treasury Bills with maturities of 91, 182, and 364 days, meanwhile, have been 16.12% (91 days), 23.19% (182 days), and 23.94% (364 days). In 2015 Angola raised $1.5 billion by selling its first Eurobond, offering a yield of 9.5% with a maturity of 10 years. Considering this information, conditions for a non-sovereign bond would be more difficult.

Note: Fitch assigned the bond a “highly speculative” rating of B+ in line with Angola’s sovereign ratings at the time. Angola was rated Ba2 by Moody’s and B+ by Standard & Poor’s and Fitch.

The issue of stock in Angola is improbable, as no stock market exists in the country. Actual fundraising must therefore depend on international monetary intermediaries such as the World Bank (WB), African Development Bank (AfDB), and Japan International Corporation Agency (JICA).

9.2.1 ODA loan

According to the definition of the Development of Co-operation Directorate (DAC), an ODA loan is a loan that includes a grant element of more than 25%. A loan with a greater grant element is advantageous to the borrower or borrowing country. International donor organizations such as the World Bank, AfDB, and JICA are eligible to extend such ODA loans.

Note: The grant element reflects the concessionary nature (i.e., softness) of a loan. The ratio of the grant element rises as the interest rate falls and the repayment period lengthens.

(1) **Loan Conditions Extended by the International Financial Institutions**

The World Bank (WB), European Bank for Reconstruction and Development (EBRD), and African Development Bank (AfDB) are all international financial institutions that provide ODA loans. Among them, however, the AfDB would be more familiar to Angola, a country located in the Sub-Saharan Region. The JICA Study Team visited the official website of AfDB to review the conditions of a Sovereign Guaranteed Loan (SGL) from the bank.

- Currency :USD, EUR, JPY, and others
- repayment period: maximum 20 years (grace: maximum 5 years)
- interest: 6MLIBOR（float）＋Funding Margin＋Lending Margin（60bp）
- principal: equal installments after the end of the grace period (other methods are acceptable)
- front end fee: none
- commission fee: charged
- other: other conditions added depend on the project

Characteristics of an SGL: ① a comparatively long maturity of up to 20 years, including a grace period; ② the borrower can choose a currency out of a few choices; ③ the interest rate is defined as 6MLIBOR (USD, JPY)+ funding margin + lending margin (currently 60bp); ④ a 5-year grace period is extended to the borrower.

According to the official website of AfDB on March 12, 2018, the 6MLIBOR (Fixed Spread Loan in USD), including the lending spread, was set at 1.85%, and the front-end fee was 25bp.

(2) **ODA Loan by JICA**

Japan International Corporation Agency (JICA) provides ODA loans, including Yen loans, under the frameworks of bilateral corporation between Japan and recipient countries. The JICA Study Team visited the official website of JICA on March 12, 2018 to review the loan conditions for Yen loans. According to the website, Angola is classified as an LDC country. The following conditions are applied to LDC countries.

- currency: JPY（Japanese Yen）
- repayment period: 30 year (grace: 10 year)
- interest: 1.0% (fixed), applied after October 17, 2017
- principal: equal installment of 20 years

Characteristics of a Yen Loan: ① long maturity of 30 years, including the grace period; ② JPY currency; ③ low interest rate (1%), ④ payment of principal not required during the grace period.

(3) **Some Remarks on ODA Loan**

Several points must be considered when receiving an ODA loan.

- AfDB can only extend an SGL loan to a regional member country (RMC).

- A guarantee from the Government of Angola is needed when AfDB provides a loan to a project in Angola.
- A certain procedure is required to conclude a JICA Yen Loan. First, the Government of Angola must send an official request for an ODA loan. Next, the Government of Japan appraises the candidate project. Next, the Government of Japan exchanges an E/N with the Government of Angola and finally concludes the L/A. It will actually take at least 2-3 years to conclude the L/A.
- A guarantee from the Government of Angola is needed when JICA provides a loan to a project in Angola.

In a case where the implementing agency does not expect the ODA loan or may not receive the ODA loan, it may request Export Credit from Export Credit Agencies (ECA) in foreign countries as an alternative option. When Angola plans to import plants from Japanese manufacturing companies, it requests export credit from the Japan Bank for International Corporation (JBIC), the ECA of Japan.

The provision of Export Credit needs a guarantee from the Government. An ECA loan is faster than an ordinary ODA loan when the implementation agency successfully obtains the Government's guarantee and commercial banks forming a syndicate with JBIC are ready to provide co-financing. Moreover all OECD member countries, including Japan, are to provide the Export Credit in accordance with '*the Arrangement on Officially Supported Export Credits.'* Consequently, the condition of Export Credit provided by each OECD member country shall be the same.

Meanwhile, historically Angola has been receiving loans or ECAs from the Chinese Export-Import Bank. As a country outside of the OECD, China can provide loans with different loan conditions. When the JICA Study Team visited the official website of the China Export-Import Bank to find the specific loan conditions, no specific loan conditions with figures were disclosed.

Here is the ECA condition JBIC provides as of March 12, 2018, based on information from the official website of JBIC. Commercial Interest Reference Rates (CIRR) is as follows.

- currency: USD ($)
- repayment period: over 8.5 years
- interest: 3.780%
- principal: equal installments or another method
- Beside the interest, the borrower needs to pay an up-front fee as a risk premium. As Angola is classified in Category 6 as of February 2, 2018, Angola needs to pay 12.88% of the up-front fee.
- Candidate borrower (i.e., the implementing agency in Angola) needs to be covered with the insurance issued by NEXI, the Export Insurance Company of Japan, when it requests export credit from JBIC. A visit to the official website of NEXI on March 9, 2018 confirmed that Angola is classified in Category G. The premium calculated with the attached calculation sheet from NEXI is 15.832%.

9.2.2 Typical Loan Conditions

The table below summarizes typical loan conditions for ① an AfDB Loan (AfDB), ② Yen Loan (JICA), ③ commercial loan in Angola, ④ ECA. Each of the foregoing types has its own procedures, appraisal system, and conditions. While it is difficult at this juncture to determine which of the above types is best, a loan with a longer repayment period and lower interest would impose a lighter financial burden.

Note also that the funds are provided with a sub-loan instead of an original loan the implementation agency may lose the merit of the latter.

Table 9-1 Typical Loan Conditions

		type	loan condition
1	AfDB loan (AfDB)	ODA	currency: USD, EURO, JPY and others interest rate: 2.16444% (estimated) (6MLIBOR +fund margin +lending margin(60bp)) maturity: up to 20 years (grace period up to 5 year) principal: equall installments other conditions: commitment fee etc.
2	Yen Loan (JICA)	ODA	currency: JPY interest rate: 1.0% maturity: 30 years (grace period: 10year) principal: equall installments others: −
3	Commercial Loan	commercial loan	currency: AoA interest rate: 20% (estimated) maturity: 3 years principal: − others: −
4	Export Credit	commercial loan	currency: JPY, USD, EURO etc. interest rate: 3.78% (USD, over 8.5 years) maturity: over 8.5 years principal: equall installments other conditions: pay the front-end fee, insurance may be needed.

9.3 Long-term Investment Plan

9.3.1 Summary of the Long-term Investment Plan

The JICA Study Team reviewed the long-term power development plan as of March, 2018. The development plan has two parts: the power development plan to meet the demand forecast and the development plan for the transmission lines and sub-stations.

The table below shows the unit prices necessary to construct power plants, transmission lines, and sub-stations. (The unit prices for hydro and thermal power plants are shown in section 6.3.)

The power development plan up to Year 2040 consists of hydropower projects, thermal power projects (CCGT and GT), transmission line projects (220 kV and 400 kV), and sub-station projects (220 kV and 400 kV). Meanwhile, construction of the renewable energy (wind and solar) facilities will be left to other developers, and power will be purchased from them.

Table 9-2 Unit Prices for Construction

Type		unit capital cost ($/kW)	Note
Hydro power	Large scale	2,700	Average in Angola
	Medium/Small	5,400	ditto
Thermal power	Combined Cycle	1,200	Construction cost of SoyoTPP
	Gas Turbine	650	International price
	Diesel	900	International price
Renewable	Wind	-	Considered in generation cost
	Solar	-	Considered in generation cost
Transmission	220 kV	0.36 mil/ km 0.45 mil/ km	1line 2nd line
	400 kV	0.78 mil./km 0.98 mil/ km	1 line 2nd line
Sub-station	200 kV	0.054*(MVA)+11.58mil	per station
	400 kV	0.024*(MVA)+29.67mil	per station

(1) **Investment in terms of the Commissioning Year**

Following are investment plans by the commissioning year. The total investment comes to 31,548 million USD: hydropower (19,083 million USD), thermal power (6,413 million USD), renewable energy (0 million USD), transmission lines (4,417 million USD) and sub-stations (1,636 million USD).

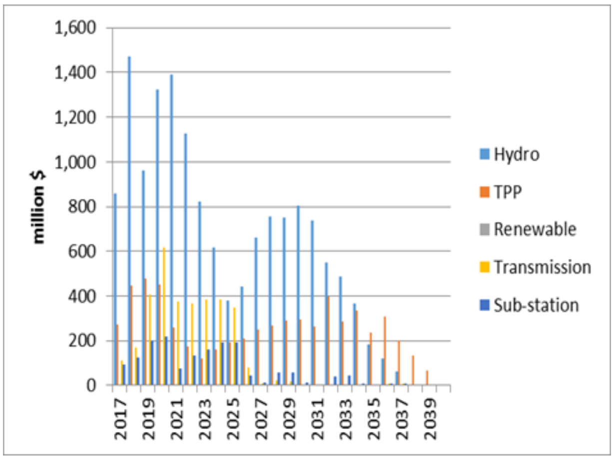
Table 9-3 Long-term Investment Plan up to 2040 (commissioning Year)

(unit: mil. $)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro	0	0	5,589	34	0	0	0	0	5,864	810	0	567	0	0
TPP	300	0	0	0	1,050	531	0	531	81	0	81	450	81	163
Renewable	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transmission	208	0	2	279	0	878	556	2	1,614	0	785	0	0	18
Sub-station	0	25	0	225	0	444	51	0	196	0	426	0	0	18
total	508	25	5,591	539	1,050	1,854	607	533	7,756	810	1,293	1,017	82	199

(unit: mil. $)

	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	total
Hydro	0	2,565	0	0	2,430	0	0	1,223	0	0	19,083
TPP	450	163	325	450	163	450	244	450	0	450	6,413
Renewable	0	0	0	0	0	0	0	0	0	0	0
Transmission	34	0	0	8	6	0	6	0	18	2	4,417
Sub-station	129	0	0	0	103	0	0	0	18	0	1,636
total	613	2,728	325	458	2,701	450	250	1,673	36	452	31,548



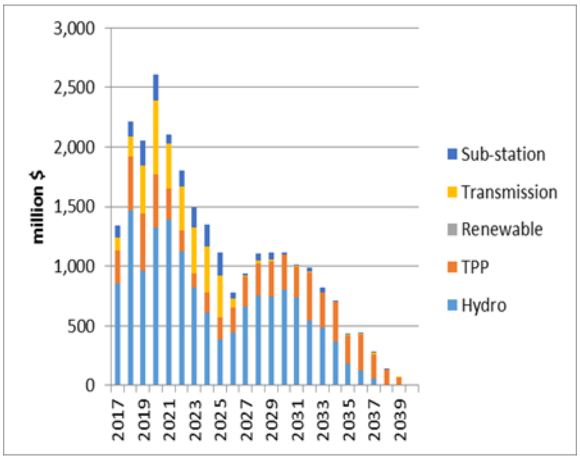


Figure 9-1 Annual Investment up to 2040 (in terms of the Construction Schedule)

The following describes the JICA Study Team's review of the scale of the long-term investment plan. As PRODEL is responsible for generation and RNT is responsible for transmission and sub-stations, the review estimates the size of the investment amounts compared to the sales and net profit levels of PRODEL and RNT in 2016.

Table 9-4 Long-term Investment and 2016 Sales and Net Profit levels of PRODEL and RNT

total investment amount up to 2040	Financial Statement (2016) (b)	(a)／(b)
investment for generation: 26,262 mil. $	PRODEL sales: 1,025 mil. $ (=220,420.7 mil. AOA) net profit: 8.66 mil. $ (=1,862.6 mil. $)	25,6 3,032
investment for transmission & sub-station: 6,187 mil. $	R N T sales：405.9 mil. $ (=87,297.665 mil. AOA) net profit: 20.3 mil. $ (=4,381.762 mil. AOA)	15,2 304,8

※USD is converted using the official exchange rate of Nacional Banco de Angola as of March 12, 2018 ($1=215.064 AOA (T.T.M))

The total investment in hydro and thermal power is 24.9 times the sales of PRODEL in 2016, or 2,944 times the net profit of PRODEL in the same year. The total investment in transmission and sub-stations is 14.9 times the sales of RNT in 2016, or 298.1 times the net profit of RNT in the same year. The investment amounts are so big, neither PRODEL nor RNT seems capable of obtaining the necessary funds with its current retained earnings. Thus, the new investment must be funded through borrowings from financial institutions.

(2) Long-term Investment in terms of the Construction Schedule

The agency implementing the new project will not need all of the funds in the commissioning year. Rather, it will require the funds year by year in accordance with the construction schedule. A standardized construction schedule for each facility is shown below.

Table 9-5 Standardized Annual Construction Schedule during the Construction Period.

	−8	−7	−6	−5	−4	−3	−2	−1
Hydro (Large)	5%	10%	15%	20%	20%	15%	10%	5%
TPP 1 (CC)					25%	30%	30%	15%
TPP 2 (Gas)				15%	25%	20%	15%	25%
Renewable (wind)	no construction but purchase power							
Renewable (solar)								
Transmission (220kV)					5%	40%	45%	10%
Transmission (400kV)					5%	40%	45%	10%
Sub-station (220kV)					5%	40%	45%	10%
Sub-station (400kV)					5%	40%	45%	10%

The total investment amount over the construction schedule is 26,023 million USD, consisting of 14,867 million USD for hydropower projects, 6,113 million USD for thermal power projects, 0 million USD for renewable energy projects, 3,339 million USD for transmission projects, and 1,705 million USD for sub-station projects.

Table 9-6 Long-term Investment Amount up to 2040 (in terms of the Construction Schedule)

(unit: mil. $)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro	857	1,469	962	1,323	1,392	1,127	821	616	382	441	663	756	749	804
TPP	275	448	478	450	259	176	120	161	192	212	249	269	289	294
Renewable	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transmission	113	170	407	752	419	702	765	470	347	78	9	22	17	4
Sub-station	93	124	203	220	77	135	161	190	192	44	14	60	60	13
total	1,337	2,210	2,051	2,745	2,148	2,139	1,868	1,437	1,113	776	935	1,106	1,116	1,114

(unit: mil. $)

	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	total
Hydro	737	548	488	366	183	122	61	0	0	767	**15,634**
TPP	265	398	288	337	239	308	203	135	68	0	**6,113**
Renewable	0	0	0	0	0	0	0	0	0	0	**0**
Transmission	3	6	4	3	3	8	9	3	0	0	**4,314**
Sub-station	5	41	46	10	1	7	8	2	0	0	**1,705**
total	1,010	993	825	716	427	446	281	139	68	767	**27,766**

The following study assumes that the necessary funds will be borrowed in accordance with the annual construction schedule. Depreciation and O&M expenses are incurred after the commissioning year. The interest and principal payments take place in accordance with the repayment schedule.

(3) Presumptions for borrowing

The presumed loans and loan conditions are summarized as follows.

- In other countries, the agency implementing a project generally becomes both the borrower and repayer of the loan. This means that the implementing agency is responsible for repaying the loan. In Angola, however, GAMEK seems to responsible for construction with a loan obtained from an outside party. The newly constructed facility is to be handed over to PRODEL, RNT, or ENDE after commissioning, and the Government of Angola is responsible for repaying the loan. In this case, we cannot clearly discern who will borrow the loan and who will pay it off afterwards.

- It does not appear that PRODEL, RNT, and ENDE will be directly responsible for repaying the loan. This study assumes, however, that the implementing agency will be both the borrower and the repayer. It also assumes that all financial costs related from the borrowings, along with depreciation and O&M costs, will be debited in the financial statements of PRODEL and RNT.
- Considering the current financial conditions of PRODEL and RNT, they are very unlikely to be able to develop new projects with their own retained earnings. Thus, all projects are assumed to be developed through borrowings.
- The following three loans will be available for projects of Angola: (1) a Yen loan extended by JICA, (2) an ODA loan extended by African Development Bank (AfDB), (3) Export Credit extended by JBIC. Over the past few years, ODA agencies have tended to provide ODA loans to hydropower projects, transmission projects, and sub-station projects that have slim prospects for high profitability. Conversely, the agencies are unlikely to provide ODA loans to thermal power projects that have strong prospects for commercial profitability and are expected to be developed as IPP projects.
- The study therefore assumes that the hydropower projects and transmission and sub-station projects will be developed with ODA loans, while the thermal power projects will be developed with ECAs.
- The Yen loan extended by JICA and the ODA loan extended by AfDB are assumed to have upper ceilings of 85% of the total borrowing. This means that the implementing agency must fill the remaining 15% by itself while requesting to borrow 85% of the total investment. Likewise, the Export Credit is also assumed to be capped by a ceiling of 85% of the total investment.
- The study also considers the Interest During Construction (IDC) as part of the total asset after the commissioning year.

Table 9-7 Loan Conditions for Candidate Loans

	type	interest rate	currency	maturity year	grace year	front end fee	reference
Yen Loan	1	1.00%	JPY	30	10	0.20%	up to 85%
AfDB/(WB) loan	2	1.855%	USD	20	5	0.25%	up to 85%
(AfDB FSL USD)							
JBIC ECA USD	3	3.78%	USD	10	0	12.88%	

The total loan amount up to 2040 is 22,120 million USD. The interest, front-end fee, and repayment of principal respectively come to 2,963 million USD, 674 million USD, and 3,936 million USD.

Table 9-8 Borrowings up to 2040 and Financial Expenses

(unit: mil. $)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
loan amount	1137	1878	1743	2333	1826	1818	1587	1222	946	659	794	941	948	947
interest	0	28	54	84	103	120	132	141	148	151	156	163	170	177
f-end fee	0	52	55	56	32	23	16	20	23	24	28	31	33	34
principal	0	38	79	119	141	156	167	180	197	215	236	296	346	428
total	0	118	187	260	276	298	315	341	367	390	420	489	549	639

(unit: mil. $)

	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	total
loan amount	859	844	702	609	363	379	238	118	58	652	**23,601**
interest	109	124	135	145	149	154	155	152	147	140	**3,035**
f-end fee	30	45	32	38	26	34	22	15	7	0	**676**
principal	28	61	86	114	135	161	178	190	195	195	**3,941**
total	166	230	253	297	310	349	355	357	350	335	**7,653**

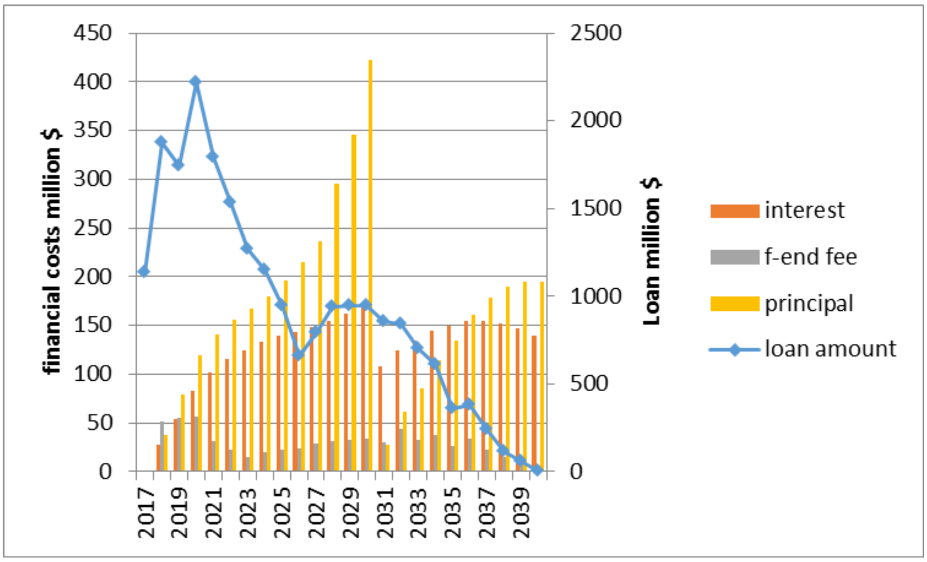


Figure 9-2 Borrowings up to 2040 and Financial Expenses

(4) Presumptions for O&M expense and depreciation

The presumptions after commissioning are as follows.

- New facilities are commissioned on the 1st of January of the commissioning year. Construction of transmission lines to be connected to newly constructed power plant will be completed one year in advance of the commissioning year of the power plant.
- Annual depreciation is calculated by the straight-line method. The residual value is zero.
- The O&M expense for a power plant, a transmission line, and a sub-station is to be calculated based on a certain percentage of the newly constructed asset. The O&M expense for a thermal power plant consists of the O&M expense and cost of fuel consumed at the power plant. The O&M expense for renewable power (wind power and solar power) includes no cost for plant construction, as construction is left to other parties. PRODEL is assumed to purchase power from other parties with a pre-determined power tariff.
- Interest during construction (IDC) is counted as a part of an asset after commissioning. Depreciation and the O&M expense are based on the abovementioned asset.

Table 9-9 Details on Depreciation and IDC

	project period	O&M cost (%)	IDC (%) /100mil.$	construction period (years)
Hydro (Large)	40	1	4.6	8
TPP 1 (CC)	25	3	10.41	4
TPP 2 (Gas)	20	5	11.51	5
Renewable (wind)	20	—	–	3
Renewable (solar)	20	—	–	3
Transmission (220kV)	40	2	2.42	4
Transmission (400kV)	40	2	2.42	4
Sub-station (220kV)	40	2	2.42	4
Sub-station (400kV)	40	2	2.42	4

9.3.2 Long-Run Marginal Cost (LRMC)

(1) **Calculation of the Long-Run Marginal Cost (LRMC)**

The JICA Survey Team hereby calculates a long-run marginal cost (LRMC) in accordance with the '*Internal Rate of Return (IRR) Manual for Yen Loan Projects*' (JBIC). LRMC is calculated as follows.

Long Run Marginal Cost (LRMC) = total project cost × capital recovery factor + O&M expences

capital recovery factor = $r \,/\, (1-(1+r)^{-n})$

r : 10%

n : durable years (hydropower, 40 years; thermal power, 25 years (CCGT) and 20 years (GT))

O&M expense = O&M expense + fuel cost (thermal)

O&M expense: calculated for a certain percent of the total construction cost

Fuel cost: annual fuel cost for thermal power plants

(2) **The Total Investment Cost and LRMC for Generation, Transmission, and Sub-station**

The total Investment Cost and unit cost per kWh shown below indicate the LRMC of the long-term investment plan. The unit cost may vary, but generally stays near 5-6 cents per kWh.

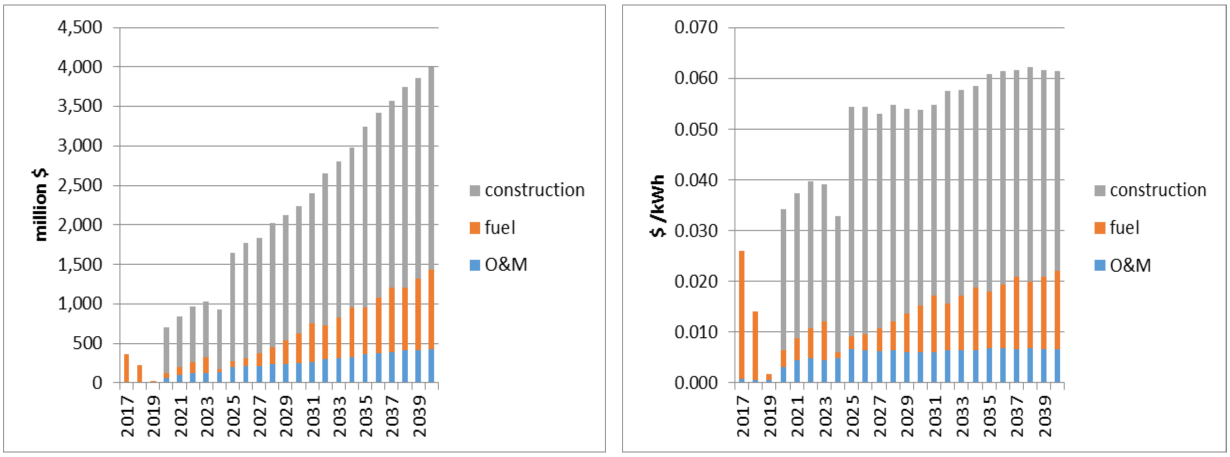


Figure 9-3 Total Annual Cost and Unit Cost for Generation

annual construction cost and unit cost for transmission lines and sub-stations are shown below. Unlike the thermal power plants, the transmission lines and sub-stations have fixed costs (e.g. construction and O&M costs) but no variable costs (e.g., fuel costs). The annual construction cost and unit cost for transmission lines and sub-stations are as follows. The unit cost peaks (1.5 cents/kWh) in 2027 and then falls to 0.8 cents/kWh in ensuing years.

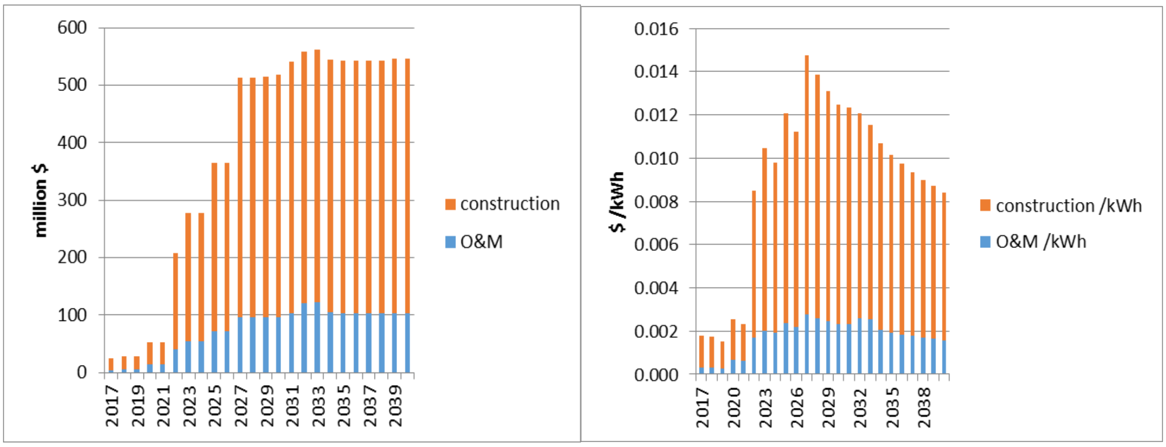


Figure 9-4 Total Annual Cost and Unit Cost for Transmission and Sub-station

(3) **Review on the Proper Tariff**

From here we review how much the incremental cost will rise based on the investment and O&M cost up to 2040, as well as the repayment schedule. (*)The cost consists of the construction cost, O&M cost, and depreciation. Thermal power plants bear fuel costs, as well. The payment of the interest, principal, and IDC will be considered after borrowings.

*: Actual construction cost for each year may fluctuate, depending on the construction schedule and repayment schedules. For this study, however, we adjust the annual cost for each candidate project to an equal level by applying the capital recovery factor.

The results are as follows. The unit price for generation will reach 8.5 cents USD at maximum, while the unit price for transmission and substation will reach 2 cents USD.

Table 9-10 Annual Unit Incremental Cost for Generation (hydro and thermal)

($ /kwh)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
incremental cost /kWh	0.002	0.003	0.003	0.006	0.006	0.013	0.016	0.015	0.019	0.018	0.022	0.021	0.020	0.019

($ /kwh)

type	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	total
incremental cost /kWh	0.018	0.018	0.017	0.016	0.015	0.014	0.014	0.013	0.013	0.012	-

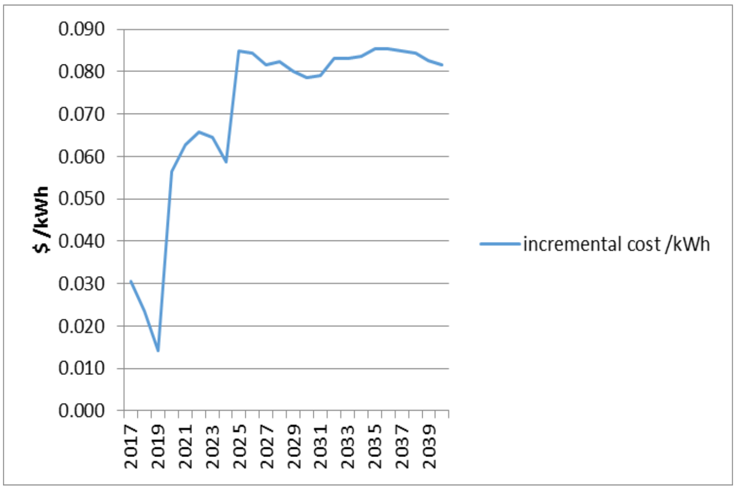


Figure 9-5 Annual Unit Incremental Cost for Generation

Table 9-11 Annual Unit Incremental Cost for Transmission and Sub-station

($ /kWh)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
incremental cost $/kWh	0.002	0.003	0.003	0.006	0.006	0.013	0.016	0.015	0.019	0.018	0.022	0.021	0.020	0.019

($ /kWh)

type	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	total
incremental cost /kWh	0.018	0.018	0.017	0.016	0.015	0.014	0.014	0.013	0.013	0.012	-

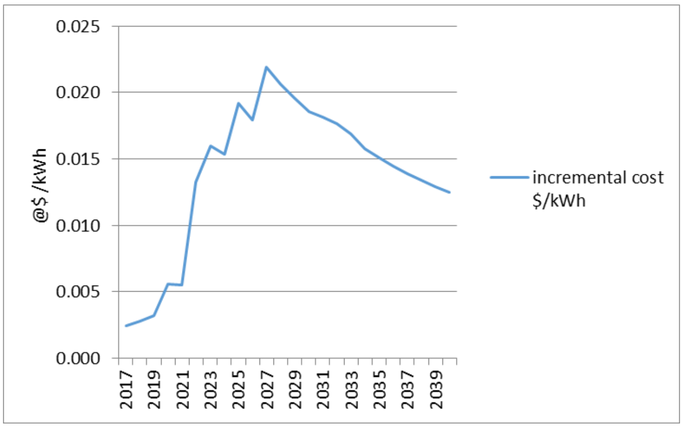


Figure 9-6 Annual Unit Incremental Cost for Transmission and Sub-station

From here we review the current unit revenue prices for PRODEL and RNT to cover the incremental cost as well as the existing cost.

The unit cost for PRODEL in 2016 is 19.86 AOA/kWh, which equals 0.09 $/kWh. The unit cost for RNT in 2016 is 8.15 AOA/kWh, which equals 0.037 $ /kWh.

A guest attending the workshop in 2018 pointed out that PRODEL did not debit the fuel cost. With this factored in, the total cost for PRODEL in 2016 seems to be smaller, as its unit price cost is also smaller than the real unit price cost, reflecting the missing fuel cost.（※）

※A guest attending the workshop held in January 2018 pointed out that PRODEL did not debit the fuel cost in its P/L. The JICA Study Team interpreted this as an indication that PRODEL did not count the fuel cost because it receives the fuel for free. Meanwhile, the JICA Study Team found amounts of 25,152 AOA listed under 'fuel cost' in the 'Other Costs' component of PRODEL's P/L in 2016.This guest must have meant that the fuel was consumed by offices and buildings for administration activities, not by thermal power plants for generation.

Table 9-12 Unit Revenue Price/kWh and Unit Cost Price/kWh

(AOA, AOA/kWh)

	2016	2015
PRODEL		
sales (kWh)	10,929,810,809.00	6,308,876,489.00
@revenue unit price /kWh	20.17	18.49
@cost unit price /kWh	19.74	20.10
R N T		
sales (kWh)	9,348,186,285.76	6,136,127,637.00
@revenue unit price /kWh	9.34	8.93
@cost unit price /kWh	8.45	7.39
ENDE		
sales (kWh)	9,348,186,285.76	5,829,423,620.07
@revenue unit price /kWh	13.59	12.19
@revenue unit price (without subsidy) /kWh	6.27	3.78
@cost unit price /kWh	13.28	13.39

(Source: JICA Survey Team)

Meanwhile, the unit revenue price (generation) derived from the long-term investment is 18.3 AOA, and the total unit cost consisting of the current unit cost and long-term investment cost will be 38.19 AOA, or 0.177 $. Likewise, the unit revenue price (transmission) derived from the long-term investment is 4.3 AOA, and the total unit cost consisting of the current unit cost and long-term investment cost will be 12.45 AOA, or 0.57 $/kWh. (conversion rate: $1=215.064 AOA (T.T.M))

These figures indicate that the unit cost price for PRODEL needs to increase by 15 AOA, starting from the current 23.11 AOA. Likewise for RNT, the unit cost price needs to increase by 3.59 AOA, starting from the current 8.86 AOA.

Table 9-13 Unit Prices and Unit Incremental Costs

	PRODEL	RNT
1. unit revenue price in 2016	@0.09 $ /kWh (=@20.17 AOA/kWh)	@0.043 $ /kWh (=@9.34 AOA/kWh)
2. unit cost price in 2016	@0.09$ /kWh (=@19.74 AOA/kWh)	@0.039 $ / kWh (=@8.45 AOA/kWh)
3. incremental cost based on the long-term investment	@0.085$/ kWh (=@18.3 AOA/kWh)	@0.02$/ kWh (=@4.3 AOA/kWh)
4.. Total cost (2+3)	@0.175 $/kWh (=@38.04AOA/kWh)	@ 0.059 $/kWh (=@12.75 AOA/kWh)
5. increase of tariff (unit cost of investment／current unit cost)	17.9 AOA (1.92)	3.41 AOA (1.51)

※USD is converted using the official exchange rate of Nacional Banco de Angola as of March 12, 2018 ($1=215.064 AOA (T.T.M))

Following is a summary of the current power tariffs (announced in the national gazette as of December 2015). ENDE collects the sales revenue with these tariffs.

Table 9-14 Summary of Power Tariffs as of December 2015

voltage	type	reference	calculation formula
Low Voltage	Domestic	contracted power: 1.3 kVA contracted power: 3.0 kVA	～120kWh：@2.46 AOA/kWh ～200kWh：@3.00 AOA/kWh
	Public lighting	supplied less than 1KV	T=（1.80×d＋4.73×W） AOA
	General and Special Domestic	contracted power: 3.0 kVA～9.9 kVA	Single phase：T=(3.10×d×pc＋6.53×W) AOA Three phase：T=(4.20×d×pc＋7.05×W) AOA
	Commercial and Industry	commercial: industry:	T=(4.20×d×pc＋7.05×W) AOA T=(4.20×d×pc＋7.053×W) AOA
Middle Voltage	Commercial and Industry	voltage: less than 30 kV	T=(538.93×P＋5.88×W) AOA
		voltage: more than 30 kV	T=(538.93×P＋5.13×W) AOA
High Voltage	Industry and Distributors	industry: more than 30 kV	T=(598.36×P＋4.70×W) AOA
		distributor: more than 30 kV	T=(598.36×P＋4.70×W) AOA

d：days passed after issuance of the bill

pc：contracted power (kVA)

P：maximum power (KW) recorded at 15-minute meter

W：power (kWh) consumed

T：sales calculated with the formula (AOA)

The characteristics are as follows:

- Domestic in Low Voltage (contracted power: up to 3.0 kVA) is based on a gradual increase of prices. Consumed power per kWh is divided into two stages: up to 120 kWh and 120 kWh to 200 kWh. The unit price goes up from 2.46 AOA /kWh to 3.0 AOA /kWh.
- The unit price for General and Special Domestic (contracted power: more than 3.0 kVA) is double that of Domestic in Low Voltage (contracted power: up to 3.0 kVA). The calculation assumes that the amount the customer pays rises as the customer uses more power. The customer also has to pay more when the customer takes more days to pay the electricity bill.
- The formula for Commerce and Industry in Middle Voltage and in High Voltage considers the number of days (d) passed. The bill gets bigger as more days pass.
- Sales of Commerce and Industry in Middle Voltage and in High Voltage do not increase in proportion to the number of days (d). Rather, the figure increases with P (the maximum power (KW)) and W (power (kWh) consumed).
- The current level of tariff per kWh is around 7 AOA, while the unit cost price calculated with the accounting figures of ENDE is 13.28 AOA. The unit cost price calculated with the accounting figures of ENDE is double that of the current tariff. This reflects the national policy not to impose a high tariff on Angolan nationals, and to compensate the loss with subsidies.
- The tariff of ENDE shall generally include all costs of PRODEL and RNT, and the investment- related costs of the long-term investment plan is to to be added to the existing costs for distribution. In line with this approach, the incremental cost of the long-term investment is 0.232 $ (=50.64 AOA). In this sense, decision-making on the subsidy shall be separated from the calculation of the necessary revenue and cost.

※Table 9-13 The incremental unit cost of the long-term investment consists of one component coming from PRODEL and one component coming from RNT.

@0. 175 $ /kWh＋@ 0.057 $ /kWh＝＠0.232 $ /kWh
When expressed in AOA,
@38.19 AOA /kWh＋＠12.45 AOA /kWh＝＠50.64 AOA /kWh

9.3.3 Recommendations on the Optimal Financial Strategy

(1) **Recommendations**

(a) Price Hike

As stated in the section 9.3.2, the unit cost caused by the investment up to 2040 is estimated at 0.175$ for generation and 0.057$ for transmission and sub-station. These estimates imply that the tariff must be raised to meet the increasing cost.

(b) Review of the candidate loans

Considering the current financial condition of PRODEL and RNT, it will be difficult for both to go on investing solely with their own retrained earnings. The study therefore assumes that both will depend on borrowing, and explains the candidate loan conditions available. Note, meanwhile, that some loans will need government guarantees and data on the project cycles and time by which the loans must be received.

(c) Proper Equity Ratio

If the agency implementing the project goes on borrowing, the equity ratio will decrease. A decreasing equity ratio would be unfavorable from a financial viewpoint, as it would increase the default risk. In this case, equity must be injected at the proper time. A 20-30% of equity ratio is generally favorable, though there seems to be no standard for a proper equity ratio in the power sector.

The table below shows the total assets, total equity, and equity ratios for PRODEL and RNT in 2016. The equity ratios for PRODEL and RNT were higher than 40% in 2016, which would be. If both companies go on investing solely with borrowing, their equity ratios will decrease: PRODEL (47.0%→3.8%) and RNT (41.1%→5.3%).

Table 9-15 Equity Ratios with Long-term Investment

accounting data in 2016 (equity ratio)	total investment up to 2040	total asset＋total investment （equity ratio）
PRODEL total asset: 2,838 million $ （47.0%）	26,262 million $	29.100 million $ (4.6%)
RNT total asset: 1,150 million $ （41.1%）	6,187 million $	7,337 million $ (6.4%)

(2) **Conclusion**

(a) Price Hike

The key implementing agencies in the Power Sector of Angola are PRODEL (generation), RNT (transmission and sub-station), and ENDE (distribution). ENDE receives a subsidy, which helps to lessen the financial burden for Angolan nationals.

The long-term investment plan consists of the generation development plan and transmission and the sub-station development plan. The plan requires increases in the unit revenue prices for PRODEL and for RNT, while direct tariff increases will not necessarily be required for ENDE. Revenue and expenditure will have to be calculated in each sector, but this might not lead to a higher tariff. This calculation of revenue and expenditure will be necessary even if a subsidy is provided to the distribution sector.

(b) Decision of the borrowings

As each financial institution has its own project-formation cycle and appraisal procedure, the implementation agency will select the financial institutions that are to be requested to provide loans. Taking the example of a project-formation cycle of JICA, the implementation agency may also request a grant to complete an Implementation Report (I/P) in the process of a project cycle.

If the candidate project needs a guarantee from the Government, the implementation agency has to pass through a step-by-step approval process within the Government. This implies that the Government of Angola sets up an official approval procedure internally.

(c) Maintain a Proper Equity Ratio

Compulsive injection of equity to a new project would be useful to maintain a certain equity ratio. An implementing agency for a new power project in India, for example, is requested to raise funds with a ratio of 70% (borrowing) and 30% (equity). In India, either the Central Government or the State Government provides equity to the implementing agency out of the budget or the long-term borrowing.

In fact, both the Central Government and the State Government in India are suffering from a red-ink budget and would be hard-pressed to provide equity from the start. The Government often provides funds to the implementing agency as long-term borrowing at the beginning but waives the liability if the implementing agency meets certain conditions. Thus, the implementing agency is finally able to keep a certain equity ratio by changing the status of the long-term liability into equity in future. (*)

*: India’s ‘*Accounting for Government Grants and Disclosure of Government Assistance*’ Accounting Standard (IND AS20) defines a forgivable loan. This standard allows the Government, the lender of the loan, to waive repayment under certain prescribed conditions. In this context, a certain prescribed condition would be one that allowed the borrower of the loan to complete the construction on schedule. Important conditions for the implementing agency are a possible future cancellation of the borrowing at the beginning and the ability to convert the liability into equity.

Chapter 10 Economic and Financial Analysis

10.1 Financial Analysis of RNT・PRODEL・ENDE

The JICA Survey Team received financial statements for RNT, PRODEL, and ENDE. While the financial statements in 2015 and in 2014 are now available for all three companies, the Profit and Loss Statement for ENDE is only available in 2017 (January to June). To keep consistency among the three companies, the JICA Survey Team only analyzes the statements of 2015 and 2014.

Two types of the financial statements are prepared: the first in the national currency (AOA) and the other in USD converted at the official rate as of 25 April, 2018. ($1= 270.68 AOA)

10.1.1 RNT

(1) **Financial Analysis of RNT**

The financial statements of RNT report figures in units of 1000 AOA.

(a) P/L

Operating Income in 2016 consisted of Sales (82,297 million AOA), other operating income (4,489 million AOA), and other. The main component of Costs in 2016 was the cost of goods (67,206 million AOA). Gross profit totaled 8,293 million AOA after deducting financial costs (-859 million AOA) and Corporate income tax (2,145 million AOA). Finally, RNT posted net profit 4,381 million AOA for the Year (2016).

Table 10-1 Profit and Loss Statement (P/L)

unit: 1000 AOA

	2016	2015
Operating Incomes	*87,297,665*	*54,811,737*
Sales	82,791,700	51,450,377
Provision of service	16,760	22,478
Other operating profits	4,489,205	3,338,882
Operating Costs	*79,004,626*	*45,341,594*
Changes in inventories of finished goods and work in progress	0	0
Works capitalized	0	0
Cost of goods sold and the materials consumed	67,206,922	37,787,871
Personnel costs	4,391,321	3,127,136
Amortizations	4,614,278	3,392,712
Other operationa costs and loss	2,792,105	1,033,875
Gross Profit	*8,293,039*	*9,470,143*
Financial costs	-859,334	-1,463,938
Subsidies and affiliate company results	0	0
Non-operating costs / income	-906,109	-579,007
Profit before Tax	*6,527,596*	*7,427,198*
Corporate income tax	2,145,834	2,228,159
Net Profit	*4,381,762*	*5,199,039*
Extraordinary results	0	0
Corporate income tax	0	0
Net Profit of the Year	4,381,762	5,199,039

(unit: 1000 USD)

	2016	2015
Operating Incomes	*322,598*	*202,550*
Sales	305,947	190,129
Provision of service	62	83
Other operating profits	16,589	12,338
Operating Costs	*291,952*	*167,555*
Changes in inventories of finished goods and work in progress	0	0
Works capitalized	0	0
Cost of goods sold and the materials consumed	248,355	139,641
Personnel costs	16,228	11,556
Amortizations	17,052	12,537
Other operationa costs and loss	10,318	3,821
Gross Profit	*30,646*	*34,996*
Financial costs	-3,176	-5,410
Subsidies and affiliate company results	0	0
Non-operating costs / income	-3,348	-2,140
Profit before tax	*24,122*	*27,446*
Corporate income tax	7,930	8,234
Net result from ordinary activities		
Extraordinary results	0	0
Corporate income tax	0	0
Net profit of the year	*16,192*	*19,212*

Table 10-2 Balance Sheet (B/S)

unit: 1000 AOA

	2016	2015
ASSETS		
Non Current Asset	*134,179,383*	*125,647,314*
Tangible fixed assets	134,178,838	125,646,596
Intangible fixed assets	545	718
Investments in subsidiaries and associates	0	0
Other financial assets	0	0
Other non-current Assets	0	*0*
Current Asset	*113,274,311*	*62,235,687*
cash	68,243	203,990
Accounts receivable	101,955,502	53,566,640
cash and bank deposits	7,805,495	5,476,676
Other current assets	3,445,071	2,988,381
TOTAL ASSETS	**247,453,694**	**187,883,001**
EQUITY AND LIABILITY		
Equity	*101,884,053*	*102,548,357*
Equity		
Capital	11,579,155	11,579,155
Reserve	81,182,631	86,228,695
Retained earnings	4,740,507	-458,532
Net profit for the year	4,381,760	5,199,039
Total Equity	101,884,053	102,548,357
Non-current Liability	*14,616,216*	*16,851,862*
Medium and long-term loan	0	0
Deferred taxes	0	0
Provisions for pensions	0	0
Provisions for other risks	0	*0*
Other Non-liquid liability	14,616,216	***16,851,862***
Current Liability	*130,953,425*	*68,482,782*
Accounts payable	123,646,573	66,368,651
Short-term loan	4,832,965	0
Current part of medium and long-term loans	0	0
Other current liability	2,473,887	2,114,131
Total Liabilities	145,569,641	85,334,644
TOTAL EQUITY AND LIABILITY	**247,453,694**	**187,883,001**

(unit: 1000 USD)

	2016	2015
ASSETS		
Non current asset	*495,844*	*464,315*
Tangible fixed assets	495,842	464,312
Intangible fixed assets	2	3
Investments in subsidiaries and associates	0	0
Other financial assets	0	0
Other non-current Assets	0	0
Current Asset	*418,592*	*229,985*
cash	252	754
Accounts receivable	376,765	197,949
cash and bank deposits	28,844	20,238
Other current assets	12,731	11,043
TOTAL ASSETS	914,436	694,300
EQUITY AND LIABILITY		
Equity	*376,501*	*378,955*
Equity	0	0
Capital	42,789	42,789
Reservs	300,001	318,648
Retained earnings	17,518	-1,694
Net profit for the year	16,192	19,212
Total Equity	376,501	378,955
Non-current Liability	*54,013*	*62,274*
Medium and long-term loan	0	0
Deferred taxes	0	0
Provisions for pensions	0	0
Provisions for other risks	0	0
Other Non-liquid liability	54,013	62,274
Current Liability	*483,923*	*253,070*
Accounts payable	456,921	245,258
Short-term loan	17,860	0
Current part of medium and long-term loans	0	0
Other current liability	9,142	7,813
	0	0
Total Liabilities	537,935	315,344
TOTAL EQUITY AND LIABILITY	914,436	694,300

(b) B/S

Tangible assets in 2016 (134,178 million AOA) were the biggest component of non-current assets. Accounts payable in 2016 were the biggest component of current assets (101,955 million AOA), exceeding operating income for the year.

(c) C/F

Cash Flow from Operating Activities in 2016 was 446 million AOA, although RNT paid 18,881 million AOA to extraordinary items. Cash Flow from Investment in 2016 went into the red due to investment in subsidies and payment to tangible fixed assets. Meanwhile, RNT borrowed a loan of 4,649 million AOA, as net cash for the year was 2,328 million AOA. Finally, cash and cash equivalents at the end of that year totaled 7,805 million AOA.

Table 10-3 Cash Flow Statement (C/F)

(unit: 1000 AOA)

	2016	2015
Cash Flow from Operational Activities		
Receipt from customers	26,038,515	1,709,371
Payments to suppliers	46,224,491	1,121,398
Payment to employees	0	1,572,087
Cash flow from operation	-20,185,976	-984,114
Other receipts related to operational activities		39,916
Interest paid	1,750,305	
Cash Flow from Extraordinary items	-18,435,671	-944,198
Payments with extraordinary items	18,881,692	10,430,988
Cash Flow from Operating activities	***446,021***	***-11,375,186***
Cash Flow from Investment Activities		
Receipt from:		
Tangible fixed assets		
Intangible fixed assets	0	
Financial investment		
Investment to subsidy	2,235,645	20,188,370
Interest and similar income		
Dividends		
Total receipts	2,235,645	20,188,370
Payment to:		
Tangible fixed assets	4,448,443	
Intangible fixed assets	0	
Financial investment		
Subsidy to investment		3,336,508
Total payment	4,448,443	3,336,508
Cash Flow before Extraordinary	***-2,212,798***	***16,851,862***
Cash Flow from Financial Activities		
Receipts from:		10,241,186
Capital increase, supplementary paymants and own share sales		
Damage coverage		
Loan obtained	4,649,741	
Subisidy and donations		
Total receipts	4,649,741	0
Payment to:		0
Capital decrease, supplementary provisions		
Purchase of shares		
Loan obtained		
Depreciation of leasing contracts		
Interest and similar interest	554,144	
Total payment	554,144	
Cash Flow from Financial Activities	**4,095,597**	**0**
Net Cash Increase and its	***2,328,819***	***5,476,676***
Cash and its Equivalents at the Beginning of the Year	5,476,676	0
Cash and its Equivalents at the End of the Year	**7,805,495**	**5,476,676**

(unit: 1000 USD)

	2016	2015
Cash Flow from Operational Activities		
Receipt from customers	96,222	6,317
Payments to suppliers	170,817	4,144
Payment to employees	0	5,809
Cash flow from operation	-74,595	-3,637
Other receipts related to operational activities	0	148
Interest paid	6,468	0
Cash Flow from Extraordinary items	-68,127	-3,489
Payments with extraordinary items	69,775	38,546
Cash Flow from Operating activities	1,648	-42,036
Cash Flow from Investment Activities		
Receipt from:		
Tangible fixed assets		
Intangible fixed assets	0	0
Financial investment		
Investment to subsidy	8,262	74,604
Interest and similar income		
Dividends		
Total receipts	8,262	74,604
Payment to:		
Tangible fixed assets	16,439	
Intangible fixed assets	0	
Financial investment		
Subsidy to investment		12,330
Total payment	16,439	12,330
Cash Flow before Extraordinary	-8,177	62,274
Cash Flow from Financial Activities		
Receipts from:		37,845
Capital increase, supplementary paymants and own share sales		
Damage coverage		
Loan obtained	17,183	
Subisidy and donations		
Total receipts	17,183	0
		0
Payment to:		
Capital decrease, supplementary provisions		
Purchase of shares		
Loan obtained		
Depreciation of leasing contracts		
Interest and similar interest	2,048	
Total payment	2,048	
Cash Flow from Financial Activities	15,135	0
Net Cash Increase and its Equivalents	8,606	20,238
Cash and its Equivalents at the Beginning of the Year	20,238	0
Cash and its Equivalents at the End of the Year	**28,844**	**20,238**

(d) Conclusion

The major financial ratios were as follows.

The net profit margin in 2016 was 5.0 %, which was quite good. Return on Assets (ROA) in 2016 was quite small, falling to 1.8%, because accounts receivables were quite big compared to operating income. The current ratio, an indicator of financial stability, was 0.82, which was less than 1.0. The average collection (days) in 2016 was 426 days because the outstanding accounts receivables were bigger than operating income.

Table 10-4 Major financial ratios

	2016	2015
net profit margin	5.0%	9.5%
return on assets (ROA)	1.8%	2.8%
current ratio	0.86	0.91
asset turnover	0.35	0.29
average collection (days)	426	357

10.1.2 PRODEL

The financial statements of PRODEL report figures in units of 1000 AOA.

(a) P/L

The major component of operating income in 2016 was sales (42,255 million AOA). Other operating income consisted of subsidies (178,182 million AOA). More than 70% of the operating costs were costs of goods (164,235 million AOA). Gross profit was positive, though subsidies and affiliates and corporate income tax followed. Net profit for the Year in 2016 was 1,862 million AOA.

One guest attending the workshop held in January 2018 pointed out that PRODEL did not debit the fuel cost on its financial statement. The JICA Study Team found that PRODEL's Financial Statement in 2016 debited 25,152,000 AOA of fuel cost as 'Other Costs.' This guest must have meant that PRODEL consumed the fuel for administrative purposes in offices or buildings.

Table 10-5 Profit and Loss Statement (P/L)

unit: 1000 AOA

	2016	2015
Operating Incomes	*220,420,796*	*116,631,357*
Sales	42,238,471	25,655,726
Services rendered	0	0
Other operating profits	178,182,325	90,975,631
Operating Costs	*215,757,239*	*126,819,841*
Changes in inventories of finished goods and work in progress	0	0
Works capitalized	0	0
Cost of goods sold and the materials consumed	164,235,499	98,320,782
Personnel costs	10,401,554	7,146,216
Amortizations	15,055,711	11,246,853
Other costs and operating Loss	26,064,475	10,105,990
Gross Profit	*4,663,557*	*-10,188,484*
Financial results	1,297,742	-431,536
Subsidies and affiliate company results	-192,245	0
Non-operating costs / income	66,470	-83,047
Profit before tax	*5,835,524*	*-10,703,067*
Corporate income tax	0	0
Net result from ordinary activities	*5,835,524*	*-10,703,067*
Extraordinary results	0	11,033,610
Corporate income tax	-3,972,868	-99,357
Net profit of the year	1,862,656	231,186

(unit: 1000 USD)

	2016	2015
Operating Incomes	*814,539*	*430,997*
Sales	156,087	94,808
Provision of service	0	0
Other operating profits	658,452	336,190
Operating Costs	*645,351*	*389,741*
Variation in the finished product and in the process of manufacturing		
Work for the company itself	0	0
Cost of goods sold and the raw materials and supplies consumed	606,913	363,333
Personnel costs	38,438	26,408
Amortizations		
Other costs and Operating Loss		
Gross Profit	*17,233.63*	*-37,650.34*
Financial results	4,796	-1,595
Results from Subsidiaries and associated companies		
Non-operating results		
Profit before tax	*21,564*	*-39,552*
Taxes on income		
Net result from ordinary activities		
Extraordinary results		
Taxes on income		
Net profit of the year	***6,883.23***	***854.32***

Table 10-6 Balance Sheet (B/S)

unit: 1000 AOA

	2016	2015
ASSETS		
Non current assets	*417,084,219*	*415,089,591*
Tangible fixed assets	416,818,944	414,632,071
Intangible fixed assets	0	0
Investments in subsidiaries and associates	265,275	457,520
Other Financial Assets	0	0
Other non-liquid Assets	0	*0*
Current Asset	*193,269,597*	*61,714,599*
Cash	253,823	108,125
Accounts receivable	55,128,687	30,760,705
cash and bank deposits	17,870,497	26,635,522
Other current assets	120,016,590	4,210,247
TOTAL ASSET	**610,353,816**	**476,804,190**
EQUITY AND LIABILITY		
Equity	*286,949,652*	*309,013,298*
Share capital	233,910,935	233,910,935
Reserves	45,095,506	75,761,981
Retained earnings	6,080,555	-890,804
Result o travel	1,862,656	231,186
Results for the year	286,949,652	309,013,298
Total Equity	286,949,652	309,013,298
Non-current liabilities	*3,000,000*	*3,000,000*
Medium and long-term loan	3,000,000	3,000,000
Deferred taxes		
Provisions for pensions		
Provisions for other risks		
Other non-liquid liability		
Current liabilities	*320,404,164*	*164,790,893*
Accounts payables	311,917,639	149,893,665
Short-term loan	5,046,446	7,241,186
Current part of medium and long-term loans	3,000,000	0
Other current liability	440,079	7,656,042
Total Liability	323,404,164	167,790,893
Total EQUITY AND LIABILITY	**610,353,816**	**476,804,191**

(unit: 1000 USD)

	2016	2015
ASSETS		
Non current assets	*1,541,286*	*1,533,915*
Tangible fixed assets	1,540,305	1,532,224
Intangible fixed assets	0	0
Investments in subsidiaries and associates	980	1,691
Other Financial Assets	0	0
Other non-liquid Assets	0	0
Current Asset	*714,205*	*228,059*
Cash	938	400
Accounts receivable	203,722	113,673
cash and bank deposits	66,038	98,428
Other current assets	443,507	15,558
TOTAL ASSET	**2,255,491**	**1,761,974**
EQUITY AND LIABILITY		
Equity	*1,060,389*	*1,141,922*
Share capital	864,390	864,390
Reserves	166,645	279,969
Retained earnings	22,470	-3,292
Result o travel	6,883	854
Results for the year	1,060,389	1,141,922
Total Equity	1,060,389	1,141,922
Non-current liabilities	*11,086*	*11,086*
Medium and long-term loan	11,086	11,086
Deferred taxes		
Provisions for pensions		
Provisions for other risks		
Other non-liquid liability		
Current liabilities	*1,184,016*	*608,965*
Accounts payables	1,152,655	553,914
Short-term loan	18,649	26,759
Current part of medium and long-term loans	11,086	0
Other current liability	1,626	28,292
Total Liability	1,195,102	620,051
Total EQUITY AND LIABILITY	**2,255,491**	**1,761,974**

(b) B/S

Almost all of the non-current assets in 2016 were tangible assets (416,818 million AOA). Accounts payable in 2016 were 311,917 million AOA, exceeding accounts receivables. There was also a middle-term borrowing in 2016 (3,000 million AOA).

(c) C/F

Cash Flow from Operating Activities in 2106 went into the red (-69,075 million AOA) because payments to suppliers were much bigger than receipts and other incomes. Cash Flow from Investment Activities in 2016 was 49,988 million AOA because receipts from subsidy exceeded those to subsidy. Cash Flow from Financial Activities in 2016 mainly consisted of loans. (11,046 million AOA). Moreover, PRODEL received 151 million AOA as income from exchange rates.

As a result, net cash decreased -8,916 million AOA for the year and cash and cash equivalents at the end of the year totaled 17,870 million AOA.

Table 10-7 Cash Flow Statement (C/F)

unit: 1000 AOA

	2016	2015
Cash Flow from Operational Activities		
Receipt from customers	12,516,975	*2,052,676*
Payments to suppliers	-127,095,520	-142,521,055
Payment to employees	-12,539,480	-5,495,466
Cash flow from operation	**-127,118,025**	**-145,963,845**
Other receipts related to operational activities	58,042,079	104,933,775
Cash Flow from Operating activities	**-69,075,946**	**-41,030,070**
Payments with extraordinary items	0	0
Total cash flow from operating	***-69,075,946***	***-41,030,070***
Cash Flow from Investment Activities		
Receipts from subsidy	75,736,210	62,150,986
Investment to subsidy	-25,747,442	-11,033,610
Cash Flow from Investing Activities	***49,988,768***	***51,117,376***
Cash Flow from Financial Activities		
Receipts from loans	11,046,446	10,241,186
Payment to loans	-876,230	0
Cash Flow from Financial Activities	**10,170,216**	**10,241,186**
Net Cash Increase and its	**-8,916,962**	**20,328,492**
Income / loss from exchange rates	151,938.00	6,307,029.00
Cash and its Equivalents at the Beginning of the Year	26,635,522	0
Cash and its Equivalents at the End of the Year	**17,870,498**	**26,635,521**

(unit: 1000 USD)

	2016	2015
Cash Flow from Operational Activities		
Receipt from customers	46,255	7,585
Payments to suppliers	-469,667	-526,670
Payment to employees	-46,338	-20,308
Cash flow from operation	-469,750	-539,392
Other receipts related to operational activities	214,488	387,770
Cash Flow from Operating activities	-255,262	-151,622
Payments with extraordinary items	0	0
Total cash flow from operating	-255,262	-151,622
Cash Flow from Investment Activities		
Receipts from subsidy	279,874	229,672
Investment to subsidy	-95,147	-40,773
Cash Flow from Investing Activities	184,728	188,898
Cash Flow from Financial Activities		
Receipts from loans	40,821	37,845
Payment to loans	-3,238	0
Cash Flow from Financial Activities	37,583	37,845
Net Cash Increase and its Equivalents	-32,952	75,122
Income / loss from exchange rates	561	23,307
Cash and its Equivalents at the Beginning of the Year	98,428	0
Cash and its Equivalents at the End of the Year	**66,038**	**98,428**

(d) Conclusion

The major financial ratios were as follows.

The net profit margin in 2016 was positive, albeit small (0.8%). Given the low net profit margin, Return on Assets (ROA) in 2016 was also small (0.6%). The current ratio, an indicator of financial stability, was 0.6, which was less than 1.0. The average collection (days) in 2016 was 91 days, which was quite good compared to the other two corporations.

Table 10-8 Major financial ratios

	2016	2015
net profit margin	0.8%	0.2%
return on assets (ROA)	0.6%	0.1%
current ratio	0.6	0.4
asset turnover	0.68	0.70
average collection (days)	91	96

10.1.3 ENDE

The financial statements of ENDE originally reported figures in units of AOA. To keep consistency with the statements of the other corporations (PRODEL and RNT), the financial statements are analyzed on a 1000 AOA basis.

(a) P/L

Major operating income in 2016 consisted of subsidies in process (68,414 million AOA), as well as electricity power sales (48,336 million AOA) and other. The biggest portion of operating costs was subsidized and consumed raw materials (82,436 million AOA), followed by personnel expenses (17,209 million AOA). Gross profit was positive, though ENDE incurred both financial loss (-7,024 million AOA) and non-operating loss (-12,193 million AOA). Finally, the net profit for the Year in 2016 was -16,318 million AOA.

Table 10-9 Profit and Loss Statement (P/L)

(unit: 1000 AoA)

	2016	2015
Operating Incomes	*127,058,787*	*71,032,092*
Electricity Power sales	48,336,107	18,818,779
Subsidiy on Prices	68,414,297	49,009,948
Provision of services	8,782,110	2,097,476
Other operating income	1,526,272	1,105,888
Operating Costs	*124,164,811*	*78,075,986*
Costs of goods sold and materials		
Susidized and consumed raw materials	82,436,761	49,187,316
Personnel expences	17,209,246	13,953,362
Amortizations	8,769,867	6,115,252
Other costs operating losses	15,748,938	8,820,057
Gross Profit	*2,893,976*	*-7,043,894*
Financial incomet/ loss	-7,024,058	-1,496,678
Non-operating income / loss	-12,193,406	-14,234,891
Profit before Tax	*-16,323,488*	*-22,775,464*
Income tax	0	0
Profit after Tax	*-16,323,488*	*-22,775,464*
Extraordinary income/ loss	4,536	-27,877
Net Profit	***-16,318,952***	***-22,803,341***

(unit: 1000 USD)

	2016	2015
Operating Incomes	*469,530.79*	*262,490.73*
Electricity Power sales	178,620	69,543
Subsidiy on Prices	252,817	181,110
Provision of services	32,453	7,751
Other operating income	5,640	4,087
Operating Costs	*458,836*	*288,521*
Costs of goods sold and materials		
Susidized and consumed raw materials	304,635	181,766
Personnel expences	63,595	51,563
Amortizations	32,408	22,598
Other costs operating losses	58,198	32,593
Gross Profit	*10,694*	*-26,029.88*
Financial incomet/ loss	-25,957	-5,531
Non-operating income / loss	-45,059	-52,603
Profit before Tax	*-60,322*	*-84,164.04*
Income tax	0	0
Profit after Tax	*-60,322*	*-84,164*
Extraordinary income/ loss	17	-103
Net Profit	*-60,304.77*	*-84,267.06*

Table 10-10 Balance Sheet (B/S)

(unit: 1000 AoA)

	2016	2015
ASSETS		
Current Assets	*288,265,058*	*244,428,283*
Inventory	6,016,839	5,191,603
Accounts receivables	267,923,682	233,226,179
Cash and equivalents	12,112,350	4,760,025
Other current assets	2,212,187	1,250,476
Non-Current Assets	*183,090,288*	*191,098,017*
Fixed tangible assets	149,990,427	152,888,383
Fixed intangible assets	11,287,254	11,503,474
Other finaicial assets	17,699,466	17,986,697
Other non-current assets	4,113,142	8,719,462
Total Assets	*471,355,346*	*435,526,300*
LIABILITIES AND NET ASSETS		
Current Liabilities	*216,587,284*	*164,213,403*
Accounts payables	167,799,183	116,401,463
Short term loans	5,102,112	1,102,112
Other current liabilities	43,685,989	46,709,828
Non-Current Liabilities	*9,700,757*	*9,926,640*
Mid and long-term loans	169,412	395,294
Provisions for pension funds	9,416,453	9,416,453
Provisions for other risks and charges	114,892	114,892
Total Liabilities	226,288,041	174,140,043
EQUITY & CAPITAL		
Equity & Capital	*245,067,305*	*261,386,257*
Capital	284,194,598	284,194,598
Retained earnings	-22,808,341	0
Incomes from the related period	-16,318,952	-22,808,341
Equity & Capitals	245,067,305	261,386,257
Total Liabilities and Net Assets	**471,355,346**	**435,526,300**

(unit: 1000 USD)

	2016	2015
ASSETS		
Current Assets	*1,065,250*	*903,256*
Inventory	22,235	19,185
Accounts receivables	990,080	861,860
Cash and equivalents	44,760	17,590
Other current assets	8,175	4,621
Non-Current Assets	*676,589*	*706,180*
Fixed tangible assets	554,272	564,981
Fixed intangible assets	41,711	42,510
Other finaicial assets	65,406	66,468
Other non-current assets	15,200	32,222
Total Assets	***1,741,838***	***1,609,436***
LIABILITIES AND NET ASSETS		
Current Liabilities	*800,373*	*606,831*
Accounts payables	620,082	430,148
Short term loans	18,854	4,073
Other current liabilities	161,436	172,611
Non-Current Liabilities	*35,848*	*36,683*
Mid and long-term loans	626	1,461
Provisions for pension funds	34,797	34,797
Provisions for other risks and charges	425	425
Total Liabilities	*836,221*	*643,514*
EQUITY & CAPITAL		
Equity & Capital	*905,617*	*965,922*
Capital	1,050,208	1,050,208
Retained earnings	-84,286	0
Incomes from the related period	-60,305	-84,286
Equity & Capitals	*905,617*	*965,922*
Total Liabilities and Net Assets	***1,741,838***	***1,609,436***

(b) B/S

Accounts receivables were prominent in current assets, and accounts payables were prominent in current liabilities. Outstanding accounts receivables and payables in 2016 were 267,923 million and 167,799 million AOA, respectively. Accounts receivables far exceeded the operating income for the year, so the collection (days) was 770 days. The total billed amounts during the year 2015 to June 2017 are: 52,621,339,094.34 AOA for Law Voltage and 35,046,795,121.71 AOA for Medium Voltage. Meanwhile ENDE collected during the same period 38,292,121.097 AOA for Law Voltage and 20,138,340,323 AOA for Medium Voltage. It means that collection rate for Law Voltage is 72.7% but that for Medium Voltage is 57.4%. It seems that the bill collection of Medium Voltage is harder than that of Law Voltage. As a result, some accounts receivables of Medium Voltage have gone bad. One possible reason for the gap was the practice of crediting bills to clients without necessarily collecting in some cases. Uncollected receivables accumulated, as some receivables were no longer collected. The same thing happened with accounts payables.

(c) C/F

Cash Flow from Operating Activities in 2016 was negative because payments to suppliers and payments to employees were bigger than receipts from clients. Cash flow from Investment Activities was negative (-1,936 million AOA). Cash Flow from Financial Activities included 26,708 million AOA of allocations to Exploration and Contributions. Moreover, ENDE borrowed 5,000 million AOA. Cash Flow from Financial Activities made up the losses for Cash Flow from Operating Activities and Cash Flow from Investment Activities.

Table 10-11 Cash Flow Statement (CF)

(unit: 1000 AoA)

	2016	2015
Cash Flow from Operational	*-19,750,661*	*-1,703,503*
Cash flow from operation	*-11,557,392*	*1,866,526*
Cash receipts from clients	36,938,612	16,532,900
Cash payments to suppliers	-32,928,684	-4,507,034
Payment to employees	-15,567,320	-10,159,340
Profits tax	-272,885	-137,051
Cash flow before other operational activi	*-7,791,191*	*-3,331,305*
Other receipts from operational activities	609,652	0
Other paymentes from operational activities	-8,400,844	-3,331,305
Cash flow before nonstandard items	-129,193	-101,672
Receipts from nonstandard items	27,094	50,420
Payments from nonstandard items	-156,287	-152,093
	0	0
Cash Flow from Investment Activiti	*-1,936,745*	*-2,039,147*
Receipts from:	*880,317*	*241,319*
Tangible fixed assets	3,753	2,081
Financial investments	0	0
Interests	876,563	239,237
Payments to	*-2,817,062*	*-2,280,466*
Fixed tangible assets	-2,817,062	-2,280,466
Fixed intangible assets	0	0
Casf flow from Financial Activities	***29,039,731***	***4,334,991***
Receipts from	*31,708,536*	*4,645,763*
Loans	5,000,000	0
Allocations to Exploration and Contributions	26,708,536	4,645,763
Payments to	*-2,668,804*	*-310,772*
Loans	-1,225,882	-169,412
Interests	-1,442,922	-141,360
	0	0
Net Cash Increase or Decrease of the Ye:	7,352,325	592,341
Cash and Equivalent at the Beginning of the Year	4,760,025	0
Impact of the Addition of Cash Balances and its Equivalent from Winded -up ENE and EDEL	0	4,167,684
Cash and its Equivalent at the End of the Year	12,112,350	4,760,025

(unit: 1000 USD)

	2016	2015
Cash Flow from Operational Activities	*-72,986*	*-6,295*
Cash flow from operation	-42,709	6,898
Cash receipts from clients	136,502	61,095
Cash payments to suppliers	-121,684	-16,655
Payment to employees	-57,527	-37,543
Profits tax	-1,008	-506
Cash flow before other operational activities	-28,791	-12,310
Other receipts from operational activities	2,253	0
Other paymentes from operational activities	-31,044	-12,310
Cash flow before nonstandard items	-477	-376
Receipts from nonstandard items	100	186
Payments from nonstandard items	-578	-562
Cash Flow from Investment Activities	*-7,157*	*-7,535*
Receipts from:	3,253	892
Tangible fixed assets	14	8
Financial investments	0	0
Interests	3,239	884
Payments to	-10,410	-8,427
Fixed tangible assets	-10,410	-8,427
Fixed intangible assets	0	0
Casf flow from Financial Activities	***107,313***	***16,019***
Receipts from	117,175	17,168
Loans	18,477	0
Allocations to Exploration and Contributions	98,698	17,168
Payments to	-9,862	-1,148
Loans	-4,530	-626
Interests	-5,332	-522
	0	0
Net Cash Increase or Decrease of the Year	27,170	2,189
Cash and Equivalent at the Beginning of the Year	17,590	0
Impact of the Addition of Cash Balances and its Equivalent from Winded -up ENE and EDEL	0	15,401
Cash and its Equivalent at the End of the Year	*44,760*	*17,590*

(d) Conclusion

The major financial ratios were as follows.

The net profit margin in 2016 was negative (-12.8%). Return on Assets (ROA) in 2016 was small, falling to -3.5%, because accounts receivables were big due to the far bigger total assets versus operating income. The current ratio, an indicator of financial stability, was 1.33 because current assets were bigger than current liabilities. The average collection (days) in 2016 was 770 days, which was bigger than 1 year (365 days).

Table 10-12 Major financial ratios

	2016	2015
net profit margin	-12.8%	-32.1%
return on assets (ROA)	-3.5%	-5.2%
current ratio	1.33	1.49
asset turnover	0.27	0.16
average collection (days)	770	1,198

10.2 Analysis of Financial Soundness and Sustainability

10.2.1 Analysis of a unit revenue price per kWh

The JICA Study Team calculated a unit revenue price and unit cost price. Appropriate actual data for generation, transmission, and distribution were unavailable, which compelled the Survey Team to use the generation data shown in the '*Activity Report* 'issued by ENDE. As the revenue of ENDE consists of subsidies on prices as well as ordinary power sales, the Survey Team calculated two types of unit revenue prices: one without a subsidy on price and one with a subsidy on price.

The unit revenue price of PRODEL in 2016 was 4.43 AOA, which was far less than the unit cost price. For the other two companies, the unit revenue price and unit cost price were almost the same or the unit cost price was bigger than the unit revenue price. These figures suggest that none of the three companies have been maintaining appropriate profitability. The unit revenue price without a subsidy of ENDE in 2016 was 5.23 AOA, which was less than half of the unit cost price.

Finally the JICA Survey Team calculated the unit cost necessary to deliver electricity to the final users in Angola. The calculation assumes that the power purchased by Angolan nationals is generated by PRODEL, transmitted through the trunk-lines and sub-stations of RNT, and distributed by ENDE. Then the calculation divides the sum of all of the operational costs of PRODEL, RNT and ENDE by sales (kWh). The result is 44.81 AOA (=0.166 USD).

Table 10-13 Unit Revenue Prices and Unit Cost Prices

(AOA, AOA/kWh)

		2016	2015
PRODEL			
	sales (kWh)	10,929,810,809.00	6,308,876,489.00
	@revenue unit price /kWh	20.17	18.49
	@cost unit price /kWh	19.74	20.10
R N T			
	sales (kWh)	9,348,186,285.76	6,136,127,637.00
	@revenue unit price /kWh	9.34	8.93
	@cost unit price /kWh	8.45	7.39
ENDE			
	sales (kWh)	9,348,186,285.76	5,829,423,620.07
	@revenue unit price /kWh	13.59	12.19
	@revenue unit price (without subsidy) /kWh	6.27	3.78
	@cost unit price /kWh	13.28	13.39
Total cost of PRODEL, RNT and ENDE			
	sales (kWh)	9,348,186,285.76	5,829,423,620.07
	@total cost unit price /kWh in AOA	*44.81*	*42.93*
	@total cost unit price /kWh in USD	0.208	0.200

※ USD1= 215.064 AOA based on the official announcement of Banco Nacional de Angola, as of March 12, 2018

10.2.2 Bill Collection

Next, the JICA Survey Team calculated how many days each company needs to collect receivables, from a viewpoint of profitability. In 2014 and 2015, RNT and ENDE took more than 1 year (365 days) to collect receivables, while PRODEL collected receivables in around 90 days. ENDE took an especially long time, more than 1,000 days, to collect receivable in 2015.

ENDE offers an explanation for this issue in its Activity Report: "ENDE sets the goal of collecting from 70% to up to 85% of billed amounts." If a collection-day extends beyond 365 days, some of the accounts receivables go bad, making further collection almost impossible. This, in turn, makes it necessary to increase the collection rate further. At the same time, ENDE must review whether or not outstanding accounts receivables go bad.

Table 10-14 Collection (days) for Bills (days)

days	2016	2015
PRODEL	91	96
RNT	426	357
ENDE	770	1,198

10.2.3 Financial Soundness

(1) **Current ratio**

The current ratio is a financial indicator used to assess insolvency, especially short-term debt against current assets, including cash and high liquidity, to current liabilities. The current ratio should generally be higher than 2.0.

The low current ratios of the three companies, all below 2.0, reveal their poor solvency and financial soundness. The current ratio of ENDE in 2016 was 1.33, the highest among the three. This ratio, however, was calculated with very high accounts receivables. ENDE therefore needs to review accounts receivable more fully to see whether or not these assets are to become uncollectable.

Table 10-15 Current Ratio

	2016	2015
PRODEL	0.60	0.37
RNT	0.82	0.81
ENDE	1.33	1.49

(2) **Debt Equity Ratio**

The debt equity ratio is a financial indicator used to assess soundness against liabilities. The current debt equity ratios for all three companies exceeded 0.4.

The liabilities for the three companies are limited to short-term borrowings or middle-term borrowings at present, and there are no long-term borrowings. If these companies start borrowing to meet the long-term power development plan, the debt equity ratio will clearly decrease in the long run. These companies will have to either keep certain amounts of profit every year to transfer to retained earnings or periodically increase their capital to maintain their debt equity ratios at a certain level.

Table 10-16 Debt Equity Ratio

	2016	2015
PRODEL	0.47	0.65
RNT	0.41	0.55
ENDE	0.52	0.60

10.3 Review of the Financial Condition of PRODEL, RNT and ENDE

10.3.1 Tariff

As stated in the section 9.3.2, the unit prices of PRODEL and RNT are not big enough to cover the incremental cost derived from the future investment. Both companies need to raise the power tariff or inject a subsidy to cover the incremental cost.

Table 10-17 The Unit Incremental Cost Derived from the Long-term Investment

	PRODEL	RNT
1. unit revenue price in 2016	@0.09 $ /kWh	@0.043 $ /kWh
	(=@20.17 AOA/kWh)	(=@9.34 AOA/kWh)
2. unit cost price in 2016	@0.09$ /kWh	@0.039 $ / kWh
	(=@19.74 AOA/kWh)	(=@8.45 AOA/kWh)
3. incremental cost based on the long-term investment	@0.085$/ kWh	@0.02$/ kWh
	(=@18.3 AOA/kWh)	(=@4.3 AOA/kWh)
4.. Total cost (2+3)	@0.175 $/kWh	@ 0.059 $/kWh
	(=@38.04AOA/kWh)	(=@12.75 AOA/kWh)
5. increase of tariff (unit cost of investment／current unit cost)	17.9 AOA (1.92)	3.41 AOA (1.51)

10.3.2 Cost Structure

The JICA Study Team's review of the financial statements of PRODEL, RNT and ENDE failed to turn up any financial trends, as the statements were available for only two years. Some studies by JICA in other countries, however, were able to find the proper profit margins. In its '*Project Master Plan Study on the Electricity Sector in the Democratic Socialist Republic of Sri Lanka,*' for example, JICA calculated the Return on Asset (ROA) necessary for investment and profit margin that covered the decreasing generation of hydropower plants in the dry season. ※

※ A review of a series of past financial statements of the Ceylon Electricity Board (CEB) in the '*Project Master Plan Study on the Electricity Sector in the Democratic Socialist Republic of Sri Lanka*' (2018) determined that CEB needed an ROA of 5% to generate retained earnings and a profit margin of 3-7.5% to curb the impact of decreasing generation of hydropower plants in the dry season.

10.3.3 Borrowing

The liabilities of PRODEL, RNT and ENDE RNT are currently limited to short-term or middle-term liabilities. There are no long-term liabilities. If the three companies depend solely on borrowing, the credibility of each company will decline commensurately with the decreases in its equity ratio. In order to maintain a proper equity ratio, funds should be raised from a mixture of borrowings and equity, or from a forgivable loan, the approach followed India.

10.3.4 Regulation on the fiscal budget and the tariff

- All of the accounting data must be kept for use for the calculation of their tariffs.
- The net profit of ENDE went into the red in 2016 and a subsidy was received to compensate for the loss. Meanwhile, PRODEL and RNT went into the black.
- While amount of subsidy ENDE receives is important, the calculation of the unit cost for the generation, transmission and sub-station will be unaffected.

10.3.5 Some Financial Issues to be considered

It seems that no rating firms have ever rated PRODEL, RNT, and ENDE so far. From here we summarize several important considerations.

(1) **Improvement of profitability**

No financial institution would extend a loan to an implementing agency with low profitability. Hence, the implementing agency needs to improve its profitability. While it may not be possible to raise tariffs to cover all costs, it will be important to encourage efforts to improve profitability.

(2) **Financial Soundness**

(a) Current Ratio

All three corporations have big receivables stemming from their apparently big current ratios. Yet some portion of the receivables went bad. The implementing agencies need to review the receivables and try to collect them faster.

(b) Return on Equity (ROE)

If an investment is extended solely by borrowing, it will push Return on Equity (ROE) down. As continuous borrowing may lead to an ultimate default, overdependence on borrowing is discouraged. A proper capital injection would therefore be necessary from a financial viewpoint.

10.3.6 Other issues

(1) **Accounting and disclosure**

- The time will come to compare the fuel costs of different thermal power plants, which includes the ones developed by the private investor. This will require disclosure of information on how much fuel cost the implementing agency consumes (though this may not be disclosed in the financial statement of PRODEL).
- In order to access the financial condition of PRODEL, RNT and ENDE, a review must be conducted to determine how the three newly established corporations (PRODEL, RNT and ENDE) took over or did not take over the assets when they were first established. Alternatively, the report from the Audit Firm could be reviewed, if necessary.

(2) **Analysis on the fiscal condition of the Government of Angola**

The JICA Study Team reviewed the financial conditions of the three corporations in the power Sector. If Angola plans to develop power projects through borrowing, it needs to consider the fiscal condition of the Government of Angola as well as the three corporations of Angola.

As stated in the Chapter 9, borrowings from JICA, JBIC, and AfDB need government guarantees. Borrowings guaranteed by the government surely increase the General Government Gross Debt. As the rate of the Gross Debt in Angola has already reached a high level, failure to undertake a new guarantee may seriously impede long-term power development. （※）

※The power sector in Vietnam faces the same problem. The ratio of General Government Gross Debt already reached the upper ceiling of 65% in 2017. Consequently the Government of Vietnam is reluctant to undertake a new guarantee. Meanwhile, the Government of Vietnam is said not to provide government guarantees to new power project exceptionally. Rather the Government encourages the Electricity of Vietnam (EVN), the biggest utility power company in Vietnam, to raise funds by itself and raise the power tariff.

According to recent macro indices of Angola, the GDP in 2017 was 124.21 billion USD and the Rate of General Government Debt has reached 65.35% (=81.066 billion USD), starting from 44.3% in 2010. The total investment amount up to 2040 will reach 31,548 million USD, the equivalent of 25% of the 2017

GDP. If the Government of Angola goes on undertaking government guarantees, the total debt will almost reach Angola's 2017 GDP. This would not be favorable for the long-term sustainability of the country.

Table 10-18 GDP and General Government Gross Debt of Angola

	2010	2011	2012	2013	2014	2015	2016	2017
GDP (billion USD)	82.53	104.12	113.92	124.91	126.73	102.62	96.34	124.21
General Government Gross Debt (%)	(44.3)	(33.8)	(29.9)	(32.9)	(40.7)	(64.6)	(79.8)	(65.3)

(Source: IMF World Economic Outlook 2018)