Chapter 7 Interconnection Plan

7.1 Formulation policy

Power interchange through international interconnections is important from the perspective of energy security, that is, assuring an efficient supply of energy. It is also vital for stimulation of the power market economy through import of power with a unit generation cost lower than that of domestically generated power and sale of surplus power to other countries, as well as the accompanying stimulation of the regional economy.

However as noted in connection with the Generation Development Planning in the previous chapter, Zambia's supply and demand balance will not significantly depend on power interchange through international interconnections. This is because positioning of power supplied through international interconnections (mainly imported power) as a major component of the supply-demand balance would make Zambia's energy security dependent on power sources in other countries, that is, their energy security. As such, it would negate the meaning of the master plan in Zambia, which operates and maintains large-scale hydropower sources and is eager for continued introduction of hydropower and various other power sources. Considering Zambia's vision to join the group of middle-income countries, its objective would be to satisfy the majority of demand with power generated within its borders and to supply any deficit of reserve power (here referring mainly to the spinning margin and part of the standby reserve power) from other countries through international interchange. Zambia will also participate in strategic power sales and in the regional power market economy when there is surplus power.

Geographically, Zambia is situated in the center of SAPP. In the SAPP, it has exports and wheels power mainly to South Africa, which is the biggest power consumer in SAPP. Zambia also wheels power generated in the southern SAPP countries to northern ones such as Tanzania, which has an adverse supply-demand balance. Therefore Zambia must be a strong backbone for SAPP, through its possession and continued reinforcement of trunk transmission lines linking the northern and southern halves of SAPP.

Zambia's investment in transmission has the addede benefit of supporting rural electrification by extending the grid and reinforcing capacity.

The treatment of the interconnection plan in this chapter will not go into the details of contracts (partner countries, contract schemes, etc.) but instead discuss power import required by Zambia and its possible power export. This is because SAPP is yet to develop into fully fledged competitive market.

7.2 Formulation method

Figure 7.1 shows the flow of formulation of the study. The power demand forecast and generaton development plan presented in the preceding chapters provided the basis for calculation of the possible power export and requisite power import by Zambia.

Another major factor here alongside the amount of electrical energy (in terms of GWh) is the amount power (in terms of MW), meaning the amount of peak demand that cannot be supplied, i.e., the facility surplus shortage in the time period when the peak demand occurs. Naturally, load curtailment (through means such as load shedding) must be performed for that portion of the peak demand which cannot be met. Therefore, the Study Team made calculations for imported power in addition to the amount of electrical energy import and export.

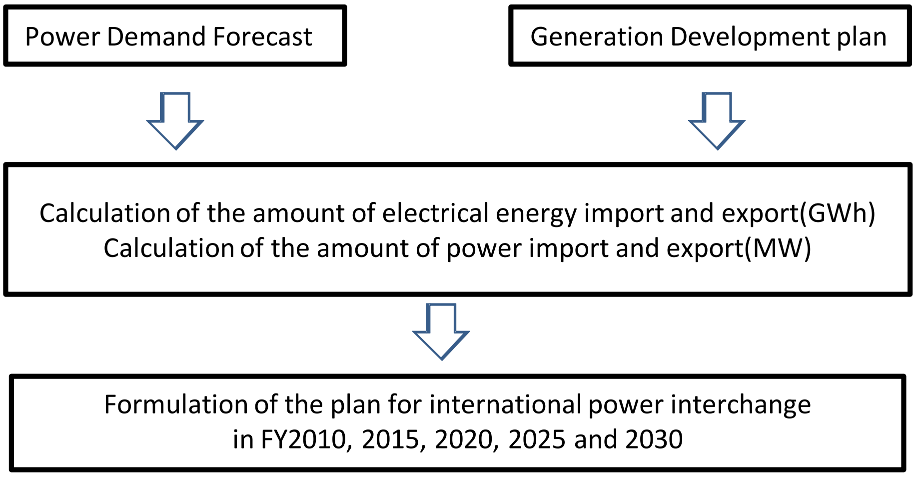

Figure 7.1 Flow of formulation of the international power interchange plan

7.3 Results of calculation of the amount of electrical energy import and export

The following discusses the amount of electrical energy import and export in Scenario 1-1

Figure 7.2 shows the results of the rough calculation in the case of ordinary water level years for hydropower generation in Scenario 1-1 of the generation development plan, in the base case of the power demand forecast. In this case, the generated output would continue to be short, and require import of 4,650 GWh in fiscal 2012. The requisite import would decline with the startup of the Maamba coal-fired power station (200 MW) and Kariba North Extension power station (360 MW) in fiscal 2014. In fiscal 2019, the supply and demand would be balanced with the startup of the Kafue Gorge Lower power station (750 MW). With the startup of large-scale hydropower stations at Devil's Gorge (500 MW) and other locations along the Zambezi in succeeding years, Zambia would become capable of exporting power in amounts up to 8,255 GWh.

Figure 7.3 shows the results of calculations made for the cases of wet and dry years in Scenario 1-1 in the base demand forecast case, in addition to those for ordinary water years. Even in the case of continued wet levels, Zambia would have to import power over fiscal years 2011 - 2016. In that of continued dry levels, the supply-demand balance would greatly worsen and necessitate import almost every year. The startup of the large-scale hydropower plants on the Zambezi at Mpata Gorge (543 MW) and Devil's Gorge (500 MW) is vital for development of an export capability.

Figures 7.4 - 7.6 show the calculation results in each of the three demand forecast cases (high, low, and base) and each water level case (ordinary - Figure 7.4, wet - Figure 7.5, and dry - Figure 7.6).

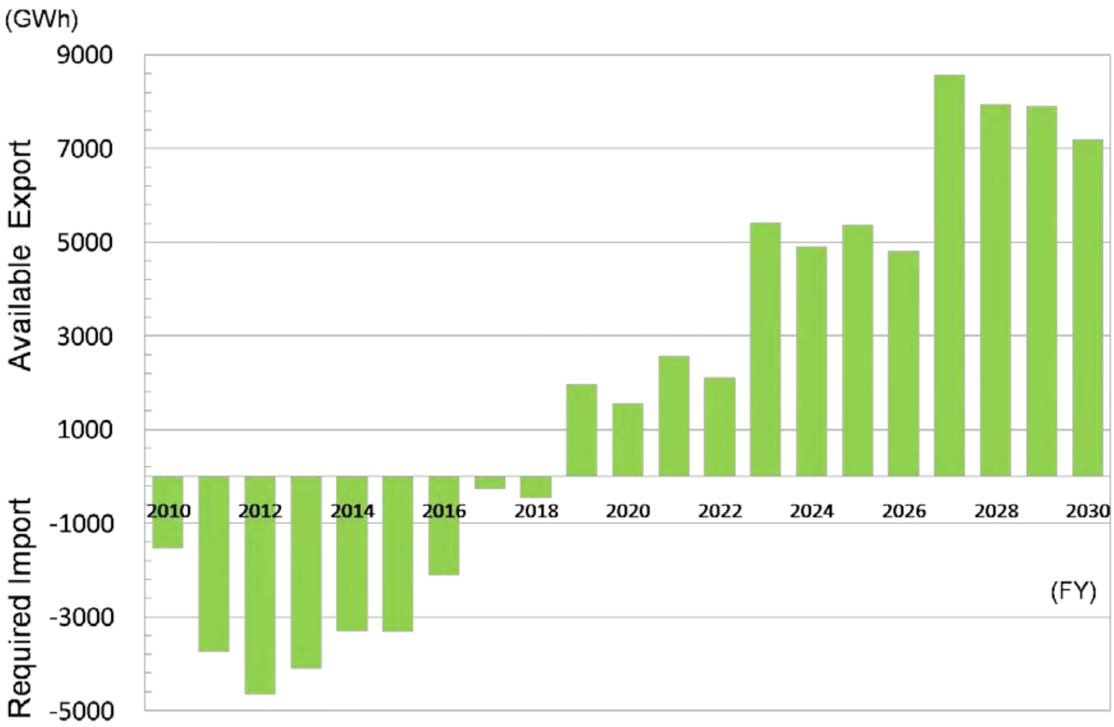

Figure 7.2 Approximate amount of electrical energy import and export in ordinary years (Base case, Scenario 1-1)

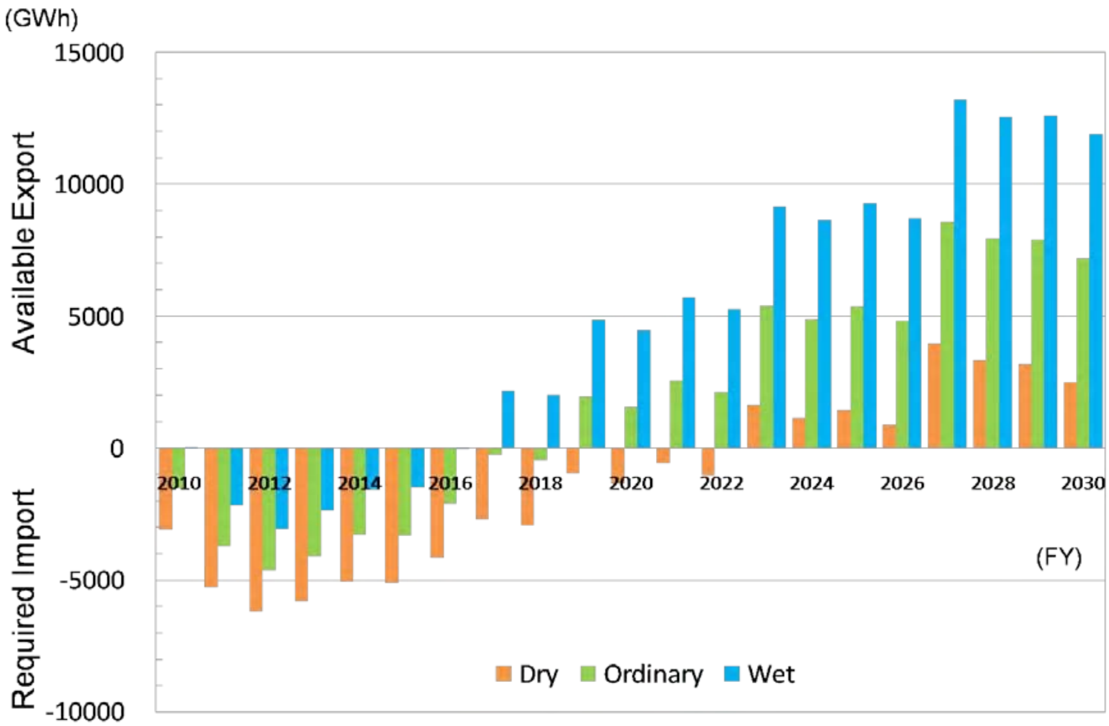

Figure 7.3 Comparison of amounts of electrical energy import and export at wet, ordinary, and dry levels (Scenario 1-1)

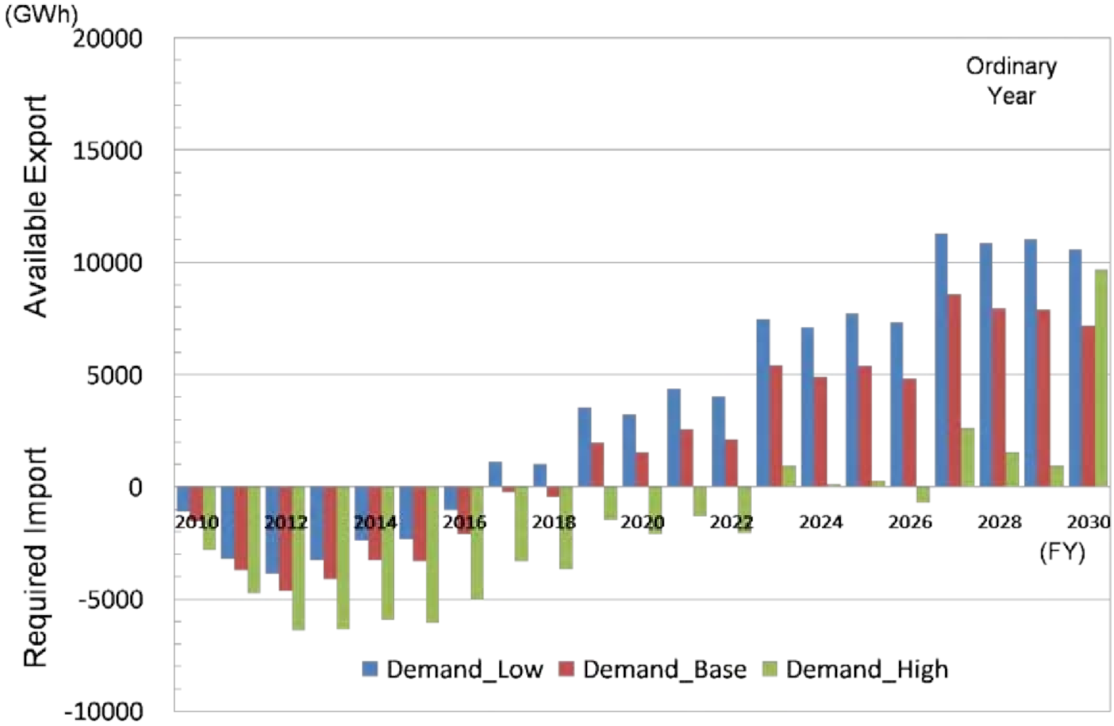

Figure 7.4 **Comparison of amounts of electrical energy import and export based on the power demand forecast (Ordinary level, Scenario 1-1)**

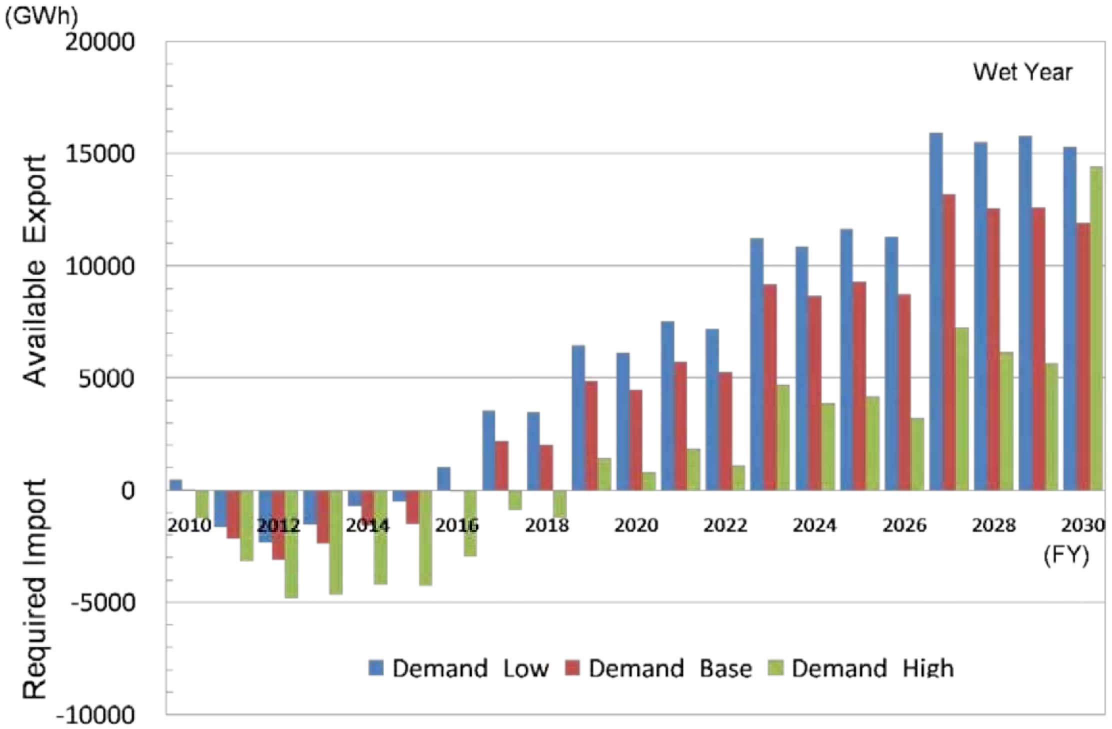

Figure 7.5 **Comparison of amounts of electrical energy import and export based on the power demand forecast (Wet level, Scenario 1-1)**

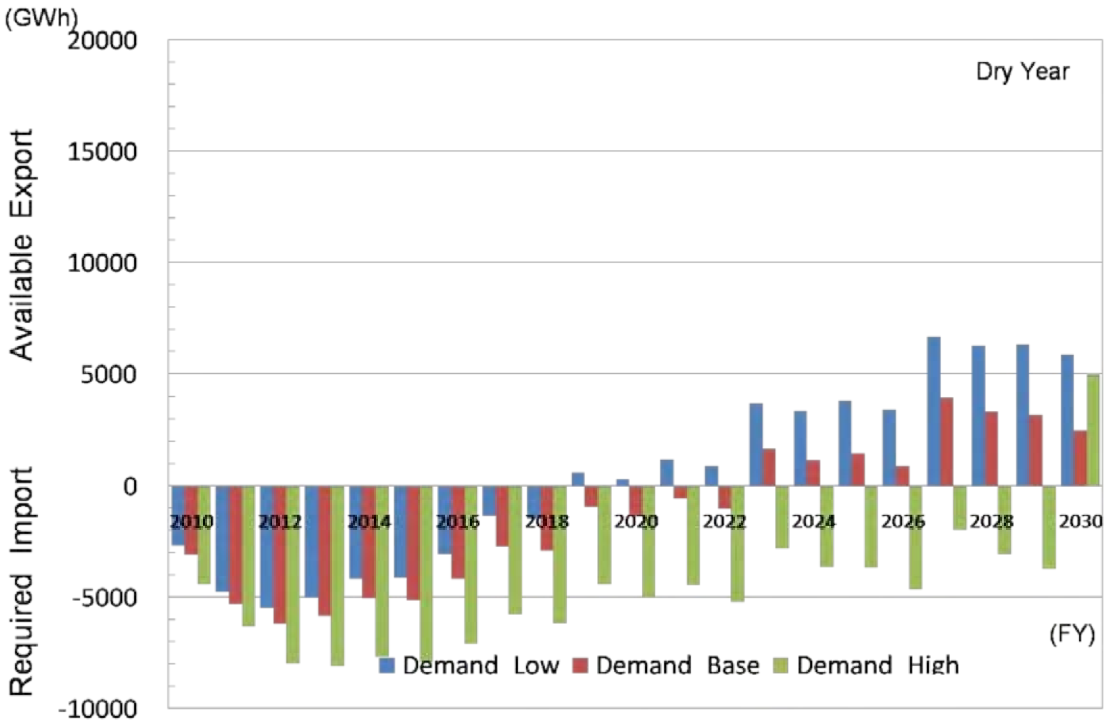

Figure 7.6 Comparison of amounts of electrical energy import and export based on the power demand forecast (Dry level, Scenario 1-1)

The following discusses the amount of electrical energy import and export in development Scenario 1-2

Figure 7.7 shows the results of the rough calculation of the amount of electrical energy import and export in ordinary years for hydropower generation in the base demand forecast case in Scenario 1-2 of the generation development plan. As in the case of Scenario 1-1, the supply would be insufficient in the immediately succeeding years, but the input of a coal-fired power station in fiscal 2016 would support the base power and dramatically reduce the extent of supply shortage. Thereafter, a supply surplus could be steadily maintained through effective supply of base power by successive input of coal-fired power stations.

Figure 7.8 shows the calculation results for wet and dry levels in addition to ordinary ones in the base demand forecast case in Scenario 1-2. It best manifests the effects of thermal power station introduction, and indicates that there would be no supply shortage beginning in fiscal 2016.

Figures 7.9 - 7.11 show the calculation results in each of the three demand forecast cases (high, low, and base) and each water level case (ordinary - Figure 7.9, wet - Figure 7.10, and dry - Figure 7.11). It should be noted that, beginning in fiscal 2016, there would constantly be a surplus of about 2,000 GWh in the base case even in years with dry levels. This figure is equivalent to the yearly amount of power generated by one of the candidate coal-fired power stations, and would constitute a sufficient level of reserve power.

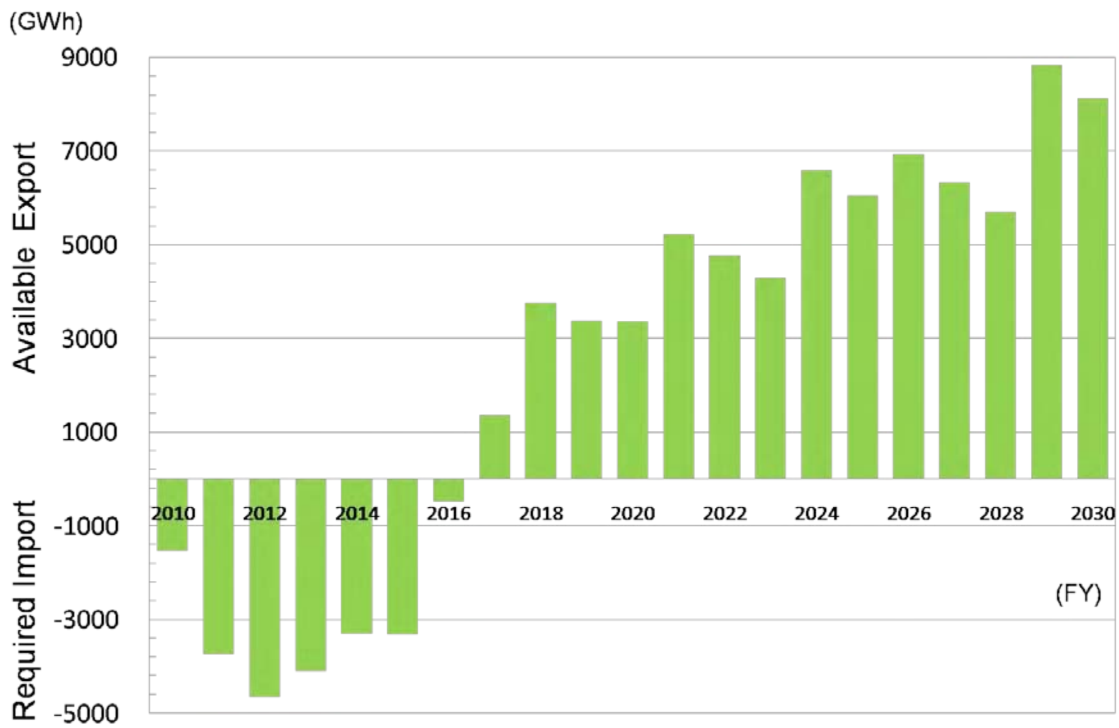

Figure 7.7 Approximate amount of electrical import and export in ordinary years (Base case, Scenario 1-2)

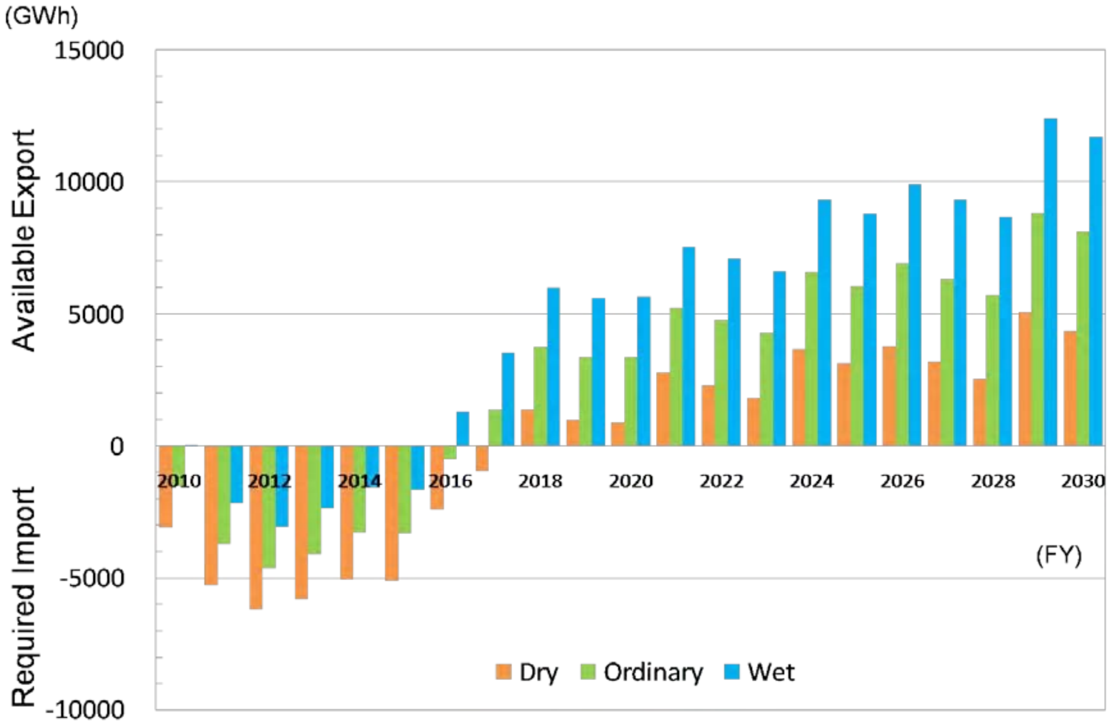

Figure 7.8 Comparison of amounts of electrical energy import and export at wet, ordinary, and dry levels (Scenario 1-2)

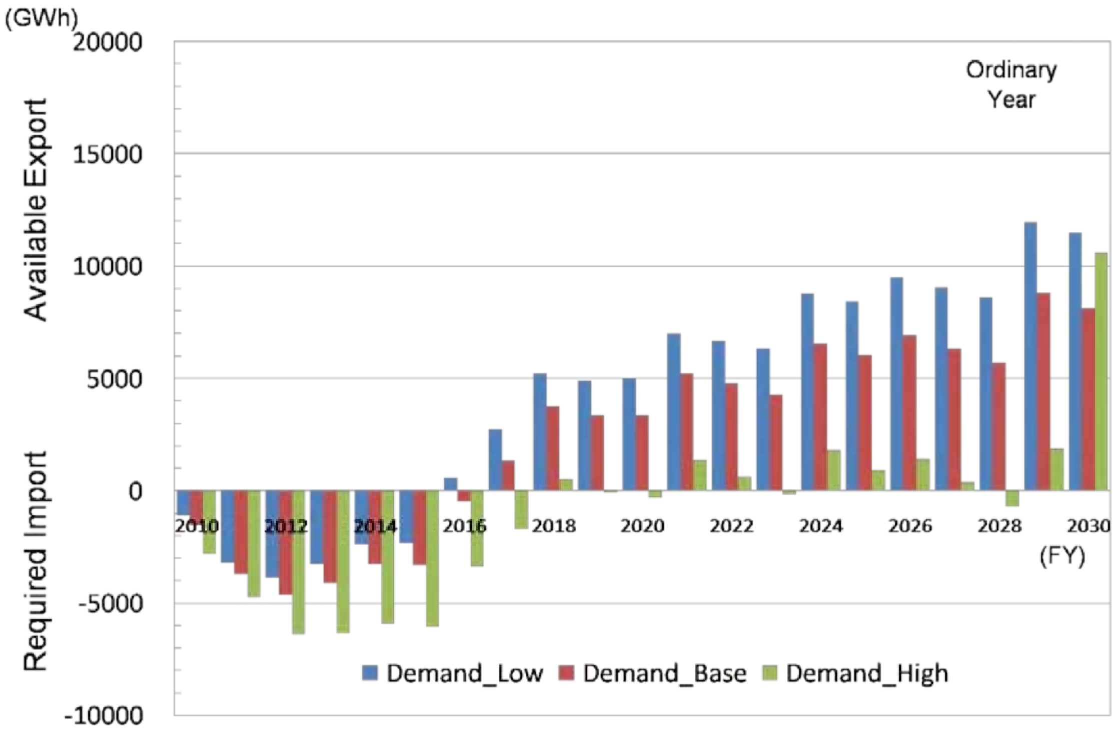

Figure 7.9 Comparison of amounts of electrical energy import and export based on the power demand forecast (Ordinary level, Scenario 1-2)

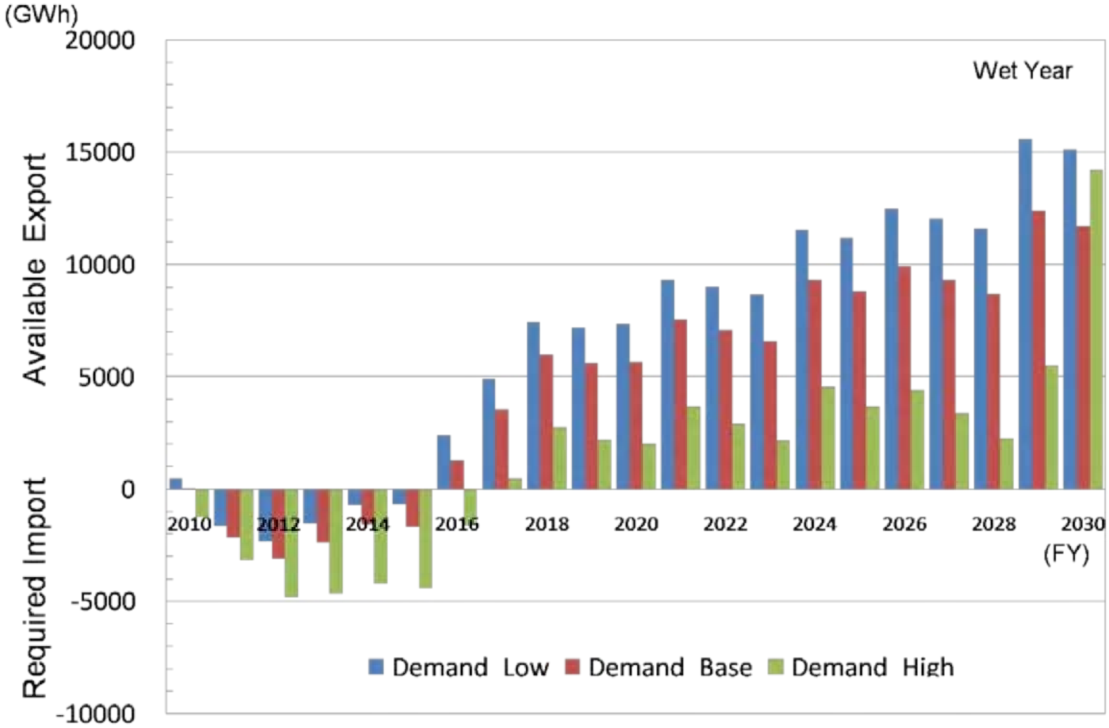

Figure 7.10 Comparison of amounts of electrical energy import and export based on the power demand forecast (Wet level, Scenario 1-2)

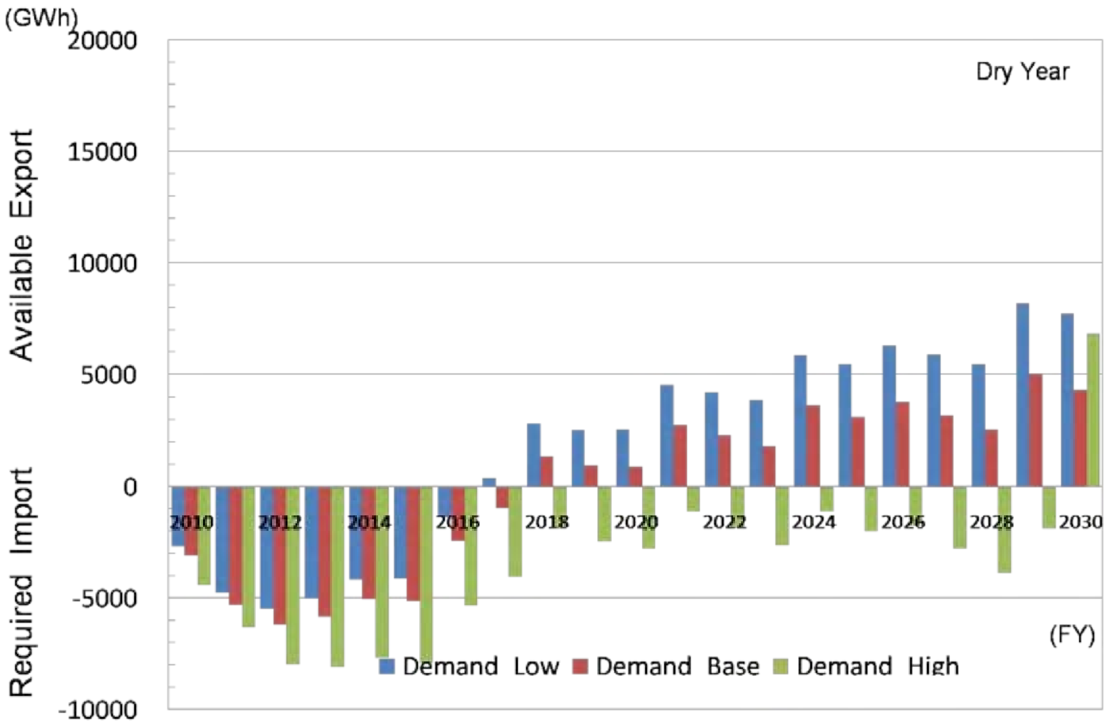

Figure 7.11 Comparison of amounts of electrical energy import and export based on the power demand forecast (Dry level, Scenario 1-2)

7.4 Results of calculation of power import and export (MW)

To estimate the need for power import, the Study Team made a comparison of the forecast peak demand and the available generation capacity. The results are shown in Figure 7.12.

The available generation capacity was calculated in accordance with the following assumptions.

* Coal-fired thermal power units will each operate with 80 percent of capacity factor..
* The reservoir -type hydropower units will each operate with 100 percent of capacity factor.
* The run-of-river hydropower units will each operate with 60 percent of capacity factor due to their dependence on the prevailing water level.

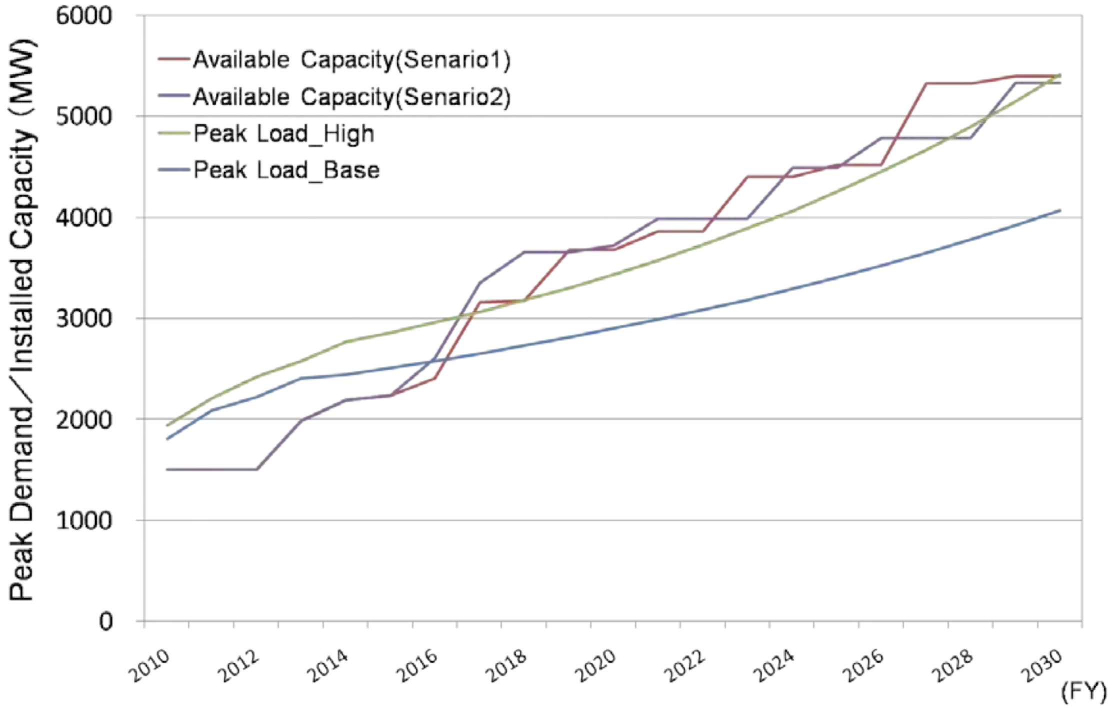

Figure 7.12 Correlation between forecast peak demand(MW) and available generation capacity

This figure shows the following observations can be made about the period beginning in fiscal 2017.

* In the base case, Zambia could retain a margin in the range of 800 - 1,300 MW in both generation development plan scenarios. This range amounts to possession of a power reserve of over 20 percent every fiscal year, and indicates a high level of system stability.
* In the high case demand forecast scenario, the reserve capability would be extremely slim in certain fiscal years, but would generally remain in the range of 5 - 8 percent.

In other words, beginning in fiscal 2017, Zambia would probably be fully capable of exporting power for response to peak demand.

7.5 International power interchange in the future

Tables 7.1 - 7.3 summarize the results of the rough calculation of electrical energy and power import and export (MW and TWh) described in the preceding sections.

Table 7.1 Results of calculation of power and electrical energy import and export (Demand forecast : Base case)

Import and Export			2010	2015	2020	2025	2030
Export	Power(MW)				700	1000	1300
	Electrical Energy (TWh)	Wet			4.4/5.6	9.2/8.8	11.9/11.7
		Ordinary			1.5/3.3	5.3/6.0	7.2/8.1
		Dry			-/0.9	1.4/3.1	2.4/4.3
Import	Power(MW)		300	300			
	Electrical Energy (TWh)	Wet	0.2/0.2	1.5/1.6			
		Ordinary	1.5/1.5	3.3/3.3			
		Dry	3.1/3.1	5.1/5.1	1.3/-		

Note: Figures to the left of the / slashes are for Scenario 1-1, and those to the right, for Scenario 1-2.

Table 7.2 Results of calculation of power and electrical energy import and export (Demand forecast : High case)

Import and Export			2010	2015	2020	2025	2030
Export	Power(MW)				700	1000	1300
	Electrical Energy (TWh)	Wet			4.4/5.6	9.2/8.8	11.9/11.7
		Ordinary			1.5/3.3	5.3/6.0	7.2/8.1
		Dry			-/0.9	1.4/3.1	2.4/4.3
Import	Power(MW)		300	300			
	Electrical Energy (TWh)	Wet	0.2/0.2	1.5/1.6			
		Ordinary	1.5/1.5	3.3/3.3			
		Dry	3.1/3.1	5.1/5.1	1.3/-		

Note: Figures to the left of the / slashes are for Scenario 1-1, and those to the right, for Scenario 1-2.

In light of the figures in these tables, the matter which must be accorded top priority in studies by Zambia is the identity of a source for procurement of the shortage of power and electrical energy over the immediately following years

The study of imported power on the assumption that there will be ordinary levels in fiscal 2010 as shown in Table 7.1 found a requisite power of 300 MW and requisite energy of 1.5 TWh. Division of the latter figure by the number of hours per year yields a figure of 171 MW (1.5 TWh / 8,760 h). As this is lower than 300 MW, Zambia would have to consider the option of importing power to meet the peak in addition to the import contracted for base power. The same calculation on the assumption that the fiscal 2010 water level would be dry yields a figure of 353 MW (3.1 TWh / 8,760 h). This would raise the possibility of response to peak demand within the context of contracts for power import for base demand. Table 7.3 shows the results of the examinations concerning shortage of power and electrical energy.

Table 7.3 Study of shortage of imported power and electrical energy

Required Volume			2010	2015	2020	2025	2030
Base Case	Requisite peak capacity (MW)		300	300			
	Requisite power	Wet	Base(100) Peak(200)	Base(200) Peak(100)			
		Ordinary	Base(200) Peak(100)	Base(300)			
		Dry	Base(400)	Base(600)	Base(300)		
High Case	Requisite peak capacity (MW)		300	300			
	Requisite power	Wet	Base(200) Peak(100)	Base(600)			
		Ordinary	Base(400)	Base(700)	Base(300)		
		Dry	Base(600)	Base(900)	Base(600)	Base(300)	

Note: "Base" refers to contracts for base power, and "Peak", to contracts for peak power. Figures in parentheses indicate the amounts of power to be contracted in MW.

Because the shortage would come in the immediately succeeding years, it would presumably be difficult for Zambia to develop new partners for supply of the shortages of power and electrical energy. Therefore, the study here was restricted to South Africa and the Democratic Republic of the Congo (DRC), with which Zambia currently has transactions.

For the routes for power reception, the Study Team selected the interconnection with the DRC (interconnection capacity of 600 MW[18]) and the interconnection with South Africa via Zimbabwe (Kariba South Route, interconnection capacity of 300 MW[19]).

The figures for interconnection line capacity noted above were obtained by multiplying the result of calculation using PSS/E, the system analysis simulation tool, by a fixed safety coefficient.

A study must be made to determine whether or not the DRC (SNEL) and South Africa (ESKOM) are actually capable of supplying the amounts of power. In this connection, Table 7.4 shows related figures taken from a project report that was supported by the World Bank.

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18 This figure indicates the capacity of supply through a double-circuit 220kV transmission line and single-circuit 330kV transmission line.

19 This figure indicates the capacity of supply through a double-circuit 330kV transmission line. The capacity appears to be heading for increase along with construction of the central corridor, but the feasibility of this project is still uncertain, and this prospective increase was consequently excluded from consideration. There is also a reception route via Namibia (the ZIZABONA Project), but this was also excluded from consideration due to uncertainty about its operation.

Table 7.4　　　　　P rospects for power import from the DRC and South Africa

Country	Interconnection Capacity (MW)	Exportable power (MW)		
		2010	2015	2020
DRC	600	179	326～3740	55～3620
South Africa	300	Impossible	Impossible	Impossible or up to 1215
Ref.:Zimbabwe	(300)	Impossible	Impossible or up to 648	Impossible or up to 826

(Source) Prepared by the Study Team with data taken from the interim draft final report of the SAPP Regional Generation and Transmission Plan Study, 2008

It would be impossible to import the requisite power from South Africa. The Study Team considered the prospect of supply from Zimbabwe (ZESA) using the same interconnection, but the power exports by that country show great fluctuation. The DRC is consequently the only possible supplier. Although it would be unable to export the entire requisite amount in fiscal 2010, it would be able to do so in fiscal 2015. Therefore, the conclusion of a firm-type long-term transaction contract with the DRC should enable Zambia to build a more advantageous relationship.

Regarding exported power, the Study Team did not select a certain form of contract or transaction-partner country. The reason is that the present plans for development of power sources and transmission lines among SAPP countries may not be implemented on schedule due to factors such as shortage of funds and stagnation of private-sector investment. It may also be noted that, for extensive power interchange, the level of transaction prices ranks alongside infrastructural conditioning as an item of the greatest concern. This level depends largely on the future course of power tariffs in the related countries. The Study Team therefore advises Zambia to monitor the future situation in SAPP countries and engage in power transactions when the time is right. For the time being, Zambia could retain exported power as power reserve (standby reserve) to heighten the reliability of its own supply or have it make a contribution through power sales.

Chapter 8　Transmission Development Plan

8.1　Current state of the transmission system in Zambia

Figure 8.1 presents a chart of the transmission system in Zambia.　This system is marked by the following characteristics.

(1)　Trunk transmission lines

These consist mainly of 330kV lines.　The power flows from the large-scale hydropower stations in the south (such as Kariba North and Kafue Gorge) toward the Copperbelt area, and the voltage tends to fall as the flow proceeds north.　SCADA data for the Luano substation in 2008 show that the 330kV bus voltage was not up to the standard (330kV plus or minus 5 percent) in about 40 percent of the time periods per year.

(2)　Load transmission lines

These consist mainly of 66kV lines.　In the northeastern and western areas, most are long-distance single-circuit lines, and do not meet the N-1 rule in many locations.　Because power is transmitted over distances in excess of 100 km by 66kV lines, voltage drops greatly at the line ends.　According to 2008 SCADA data for the Kasama substation, the 66kV bus voltage did not meet the standard (66kV plus or minus 5 percent) in more than one-third of the time periods per year.

For these reasons, it is consequently vital to find measures to keep voltage stability in the Zambian transmission system.　In response, the formulation of the transmission plan emphasized this point.

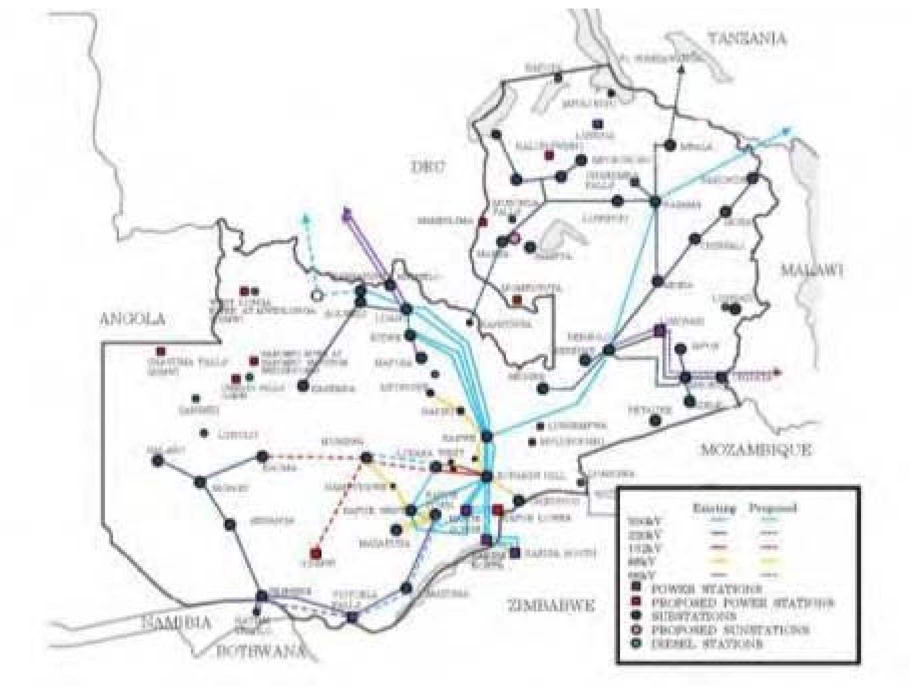

Figure 8.1　　Transmission system in Zambia

8.2 Criteria applied in formulation of the transmission development plan

Table 8.1 shows the criteria applied in formulation of plans for transmission development in Zambia. It may be added that the standard formulated by the power transmission and development authority in Zambia follow the Grid Code determined by the ERB. It was decided to follow this standard in the preparation of this plan as well. The N-1 rule, which is used as the standard criteria around the world, and is also applied in Zambia. In areas with a low demand density such as the northeastern and western ones, however, this criterion cannot be met because the transmission lines have only one circuit. Although this situation is unavoidable when there are only limited finances available for promoting rural electrification (RE), areas covered only by single-circuit transmission lines should be reduced as far as possible into the future. For this purpose, the Study Team formulated the plan with a view to a phased shrinkage of areas not up to the N-1 rule.

Table 8.1 Criteria applied in formulation of the transmission development plan

Item	Criteria
Station Bus Voltages	Steady state: +/-5% of the nominal value
	Contingency conditions: +/-10% of nominal value
Equipment Loading	Steady state: Within Rated Current of equipment
	Short time overload: 20% above Rated Current for 20 minutes maximum
System Operation Security	System should stand a single contingency
System Stability	System stability (voltage and angle) is to be maintained following a single contingency outage after a permanent line to ground fault on any transmission line or transformer. For single circuit supply arrangements, the criterion will be relaxed.
Power Factor	0.95 (for transmission planning)
Frequency	With SAPP Interconnection: 49.95 - 50.05 Hz range 90% of the time
	Isolated Case: above 49 Hz

In formulation of the transmission plan, the Study Team also made demand forecast at each substation based on the demand forecast presented in Chapter 5 and the current level of demand at each substation. The results are shown in Table 8.2 and this methodology is represented in Appendix.

Table 8.2 Results of the demand forecast at substations

Peak Demand (MW)

Substation	2008	2010	2015	2020	2025	2030
Kalabo	1	1.1	1.6	1.8	2.4	3.1
Mongu	3	3.4	4.7	5.4	7.2	9.4
Senanga	1	1.1	1.6	1.8	2.4	3.1
Sesheke	1	1.1	1.6	1.8	2.4	3.1
Zambezi	5	5.6	7.8	9	12	15.7
Kazunlula	4	4.5	6.3	7.2	9.6	12.5
Vincria Falls	15	16.9	23.5	27.1	35.9	47
Maamba	5	5.6	7.8	9	12	15.7
Muzuma	10	11.3	15.6	18.1	23.9	31.3
Nampundwe	12	13.5	18.8	21.7	28.7	37.6
Mazabuka	38	42.8	59.4	68.7	91	106.6
Monze	4					12.5
Kafue Town	30	33.8	46.9	54.2	71.8	94
Mapepe	14	15.8	21.9	25.3	33.5	43.9
Water Works1	30	33.8	46.9	54.2	71.8	94
Water Works2	40	45	62.6	72.3	95.8	125.3
Coventry Street	15	16.9	23.5	27.1	35.9	47
Coventry Street	80	90	125.1	144.6	191.5	250.6
Coventry Street	25	28.1	39.1	45.2	59.9	78.3
Lusaka West	70	78.8	109.5	126.5	167.6	219.3
Roma	100	112.5	156.4	180.7	239.4	313.3
Chirundu	1	1.1	1.6	1.8	2.4	3.1
Chongwe	7	7.9	10.9	12.6	16.8	21.9
Fig Tree	6	6.8	9.4	10.8	14.4	18.8
Kabwe	27	30.4	42.2	48.8	64.6	84.6
Kapiri Muposi	12	13.5	18.8	21.7	28.7	37.6
Mpongwe	6	6.8	9.4	10.8	14.4	18.8
BRKHL	13	14.6	20.3	23.5	31.1	40.7
Cosak	50	3	78.2	81.9	87.8	96.7
Chisenga	24	31	41.5	43.4	46.6	51.3
Chambishi	25	3	39.1	40.9	43.9	48.3
Solwezi	10	11.3	15.6	16.3	17.5	19.3
Kabundi	16	18	25	26.2	28.1	30.9
Stadium	70	78.8	109.5	114.6	123	135.4
Avenue	53	94.6	117.9	123.4	132.4	145.8
Bancroft	77	106.6	180.4	188.9	202.6	223.1
Bancroft North	20	22.5	31.3	32.8	35.2	38.7
Kansanshi	90	101.3	140.8	147.4	158.2	174.1
Lumwana1	30	33.8	46.9	49.1	52.7	58
Lumwana2	15	16.9	23.5	24.6	26.4	29.1
Chambishi	10	11.3	15.6	16.3	17.5	19.3
Kansuswa	12	13.5	18.8	19.7	21.1	23.2
Mufulira	57	64.1	89.2	93.4	100.2	110.3
Kankoyo	34	2	2	2.1	2.2	2.5
Mufulira West	6	6.8	9.4	9.8	10.6	11.6
C.S.S.(Kitwe)	24	27	37.5	39.3	42.1	46.4
Turf	14	15.8	21.9	22.9	24.6	27.1
Kitwe	35	39.4	54.7	57.3	61.4	67.6

Substation	2008	2010	2015	2020	2025	2030
Mill	32	36	50.1	52.4	56.3	61.9
Nkana	26	29.3	40.7	42.6	45.7	50.3
Mindola	35	2	54.7	57.3	61.4	67.6
Fikondi	5	5.6	7.8	8.2	8.8	9.6
Chibulma	8	9	12.5	13.1	14	15.5
Maposa	1	1.1	1.6	1.7	1.8	2
Pamodzi	28	31.5	43.8	45.9	49.2	54.2
Depot Road	18	20.3	28.2	29.5	31.7	34.9
Skyways	43	48.4	67.3	70.5	75.6	83.2
Ndola Refinery	2	2.3	3.1	3.2	3.5	3.8
Mushili	5	5.6	7.8	8.2	8.8	9.6
Bwana Mukubwa	11	12.4	17.2	18	19.3	21.3
Baluba	13	14.6	20.3	21.3	22.8	25.1
Maclaren	1	1.1	1.6	1.7	1.8	2
Irwin	1	1.1	1.6	1.7	1.8	2
Roan	10	11.3	15.6	16.3	17.5	19.3
Luanshya Minic	16	18	25	26.2	28.1	30.9
Stoke	1	1.1	1.6	1.7	1.8	2
Serenje	1	1.1	1.6	1.8	2.4	3.1
Mfuwe	5	5.6	7.8	9	12	15.7
Chipata	7	7.9	10.9	12.6	16.8	4.9
Azele	2	2.3	3.1	3.6	4.8	6.3
KANON	6	6.8	9.4	10.8	14.4	18.8
KAOMB	7	7.9	10.9	12.6	16.8	21.9
Mpika	3	3.4	4.7	5.4	7.2	9.4
Chinsali	1	1.1	1.6	1.8	2.4	3.1
Isoka	1	1.1	1.6	1.8	2.4	3.1
Nakonde	1	1.1	1.6	1.8	2.4	3.1
Mbala	4	4.5	6.3	7.2	9.6	12.5
Kasama	4	4.5	6.3	7.2	9.6	12.5
Luwingu	2	2.3	3.1	3.6	4.8	6.3
Mansa	2	2.3	3.1	3.6	4.8	6.3
Kawambwa Tea	2	2.3	3.1	3.6	4.8	6.3
Mporokoso	2	2.3	3.1	3.6	4.8	6.3
Frontier	26	29.3	40.7	40.7	40.7	40.7
Kaoma		3.8	5.4	7.0	9.2	12.0
Chavuma		0.3	0.4	0.6	0.8	1.0
Kabompo		2.2	3.1	4.1	5.3	7.0
Mufumbwe		1.3	1.8	2.3	3.1	4.0
Mwinilunga		1.9	2.7	3.5	4.6	6.0
Zambezi		2.2	3.1	4.1	5.3	7.0
Lukuku		2.2	3.1	4.1	5.3	7.0
Mbereshi		2.2	3.1	4.1	5.3	7.0
Nchelenge		2.6	3.6	4.7	6.1	8.0

The plan formulation also considered the influence of international power interchange. Because the transmission system must deliver a stable function even in the case of international interchange, the Study Team analyzed and studied each of two cases: a base case (without international interchange) and an interconnecting case (the condition thought to be the toughest for the Zambian system). Table 8.3 shows the cases analyzed.

Table 8.3 Conditions of international power interchange in transmission plan

<table>
<tr><th rowspan="2">Year</th><th colspan="2">Base Case</th><th colspan="2">Interconnecting Case</th></tr>
<tr><th>Import</th><th>Export</th><th>Import</th><th>Export</th></tr>
<tr><td>2015</td><td rowspan="4">0</td><td rowspan="4">0</td><td>-Sesheke 200MW</td><td>-Nakonde 200MW</td></tr>
<tr><td>2020</td><td rowspan="3">-Sesheke 200MW
-Victoria Falls 200MW</td><td rowspan="3">-Nakonde 400MW</td></tr>
<tr><td>2025</td></tr>
<tr><td>2030</td></tr>
</table>

In Zambia, power sources are concentrated in the south, and power consequently always flows from the south to the north. As a result, a further magnification of this flow by import of power from Namibia and export of power to Tanzania would be the toughest condition for the Zambian system. The case of international interchange was therefore postulated as shown in Table 8.3. Power import from the DRC would supress the flow from south to north, and therefore alleviates the burden on the system in the aspects of both thermal capacity and voltage stability. Similarly, import from Kariba South would curb the flow between Victoria Falls and Lusaka, and therefore also be more advantageous than import from Namibia.

8.3 Transmission development plan in the scenario 1-1

The results of the demand forecast and power development plan served as the basis for formulation of the transmission plan in Zambia in the base scenario (Scenario 1-1). The formulation included a power flow analysis and study of N-1 rule.

In formulation of the transmission plan, the Zambian power system was divided into five regional areas, and the plan was prepared with consideration of the attributes of each area. Figure 8.2 shows this division. Furemore, stability analysis was studied in Zambian system and the result of this represented in Appendix.

To make the transmission development plan, the Zambian power system was divided into the following and considered the feature of each area.

- North-east area
- West area
- South area
- Lusaka area
- Copperbelt area

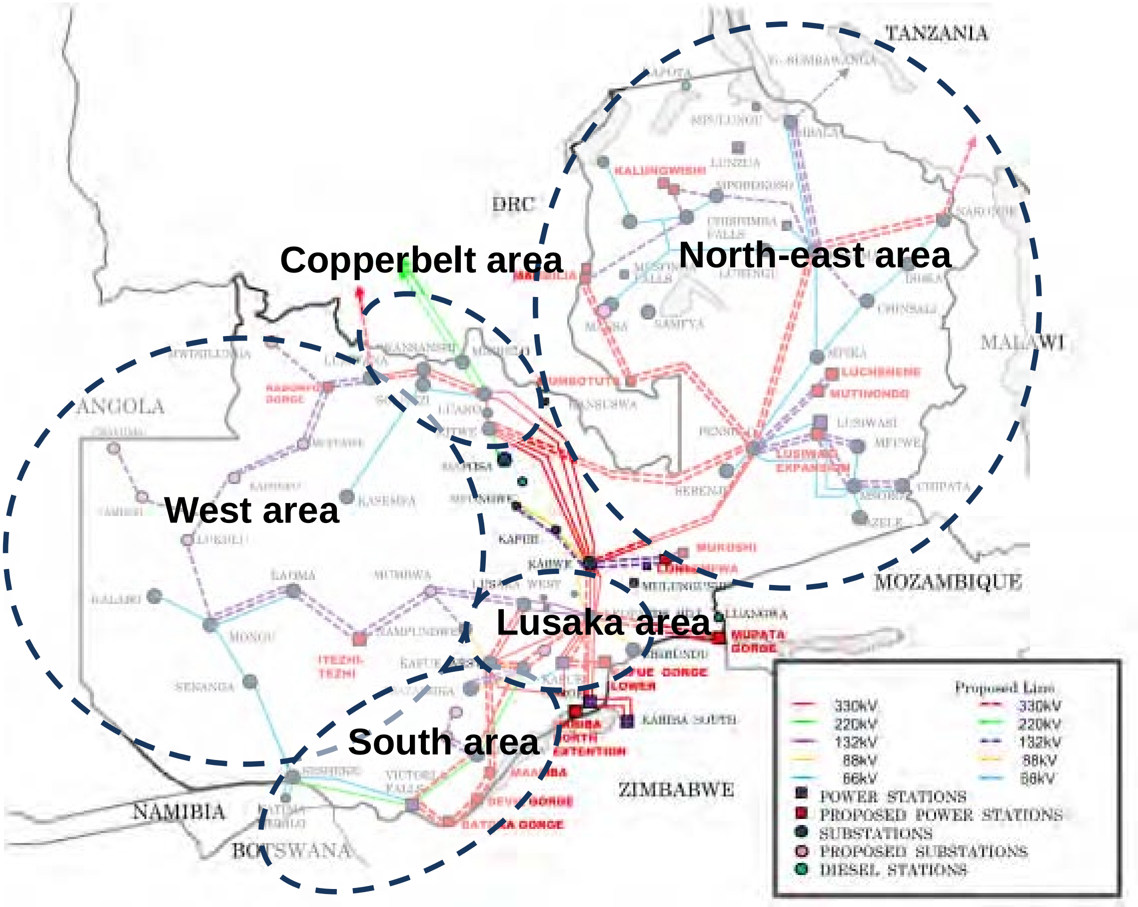

Figure 8.2 Division of regional areas applied in transmission plan formulation

The following sections present the attributes of each area and an outline of the development plan corresponding with them.

8.3.1 North-east area

In this area, there are plans for construction of a large-scale hydropower station near the border with the DRC, and for installation of international interconnection line with Tanzania and Malawi. The characteristics of the power system are as follows.

- The area is already covered by the 66kV transmission line.
- Most of the 66kV transmission lines run for a distance of more than 100 km, with a very steep voltage drop.
- The demand density is low, and the substation load is limited in size.
- At present, the system does not meet the N-1 rule.
- The candidate sites for large-scale hydropower stations are Mambilima, Mumbotuta, Kundbwika, and Kabwelume.

In this area, the major problem is the voltage stability on 66kV power lines. To resolve it, the

Study Team decided to reinforcement of the system in this area through installation of 132kV and 330kV lines. In addition, 330kV transmission lines must be installed for supply of power from the large-scale hydropower stations (Mambilima and Mumbotuta) and for the interconnection with Tanzania. Effective use of these transmission lines would be vital for stabilizing the voltage in this area.

The formulation of the transmission development plan for this area took account of these factors. It may be outlined as follows.

(a) International interconnections

Two international interconnection lines are planned for this area. One is the interconnection line with Tanzania, and the other, with Malawi. The plans for each are described below.

・ Interconnection line with Tanzania (Pensulo-Kasama-Nakond-Tanzania)

There are currently plans for an interconnection with Tanzania in 2013 for eventual interchange of 400 MW of power with Tanzania and Kenya. Considering the transmission distance and the magnitude of the power flow, the interconnection line would have to be made with 330kV line. It would also function as the point of interconnection between EAPP and SAPP, and play a vital role in the SAPP system further in the future. As such, it must have a two-circuit structure to meet N-1 rule.

This area also has long 66kV transmission lines marked by a steep voltage drop. So, substations at Kasama and Nakande along the 330kV transmission line are necessary to keep the voltage stability in that part of the Northeast area centered on these locations. Voltage problems have already surfaced, and installation at an early date (between 2010 and 2015) with a two-circuit line is proposed.

・ Interconnection with Malawi (Pensulo-Lusiwasi-Msoro-Chipata-Malawi)

The Malawi system is on a limited scale. In 2008, its peak load came to 268 MW, and its maximum transmission voltage was 132kV. For this reason, the interconnection with this system will be based on use of a 132kV transmission line.

The area is installed with 66kV transmission lines, but the 132kV lines must be constructed at an early date (2010 - 2015), considering the need for increase in the capacity of the Lusiwasi power station and stabilization of voltage.

(b) Power lines

There are two important power lines in this area: one leading from the Mambilima and Mumbotuta power stations, and the other, from the Kundabwika and Kabwelume power stations. The plans for these transmission lines are as follows.

・ Mambilima and Mumbotuta power lines

These two power stations have a combined output of 326 MW, which is extremely large for the load in the vicinity[20]. Almost all of this output is transmitted to other areas (mainly Copperbelt). As a result, it was decided to link these stations with Copperbelt, the major demand site, by means of transmission lines. There are two candidate routes, as indicated below.

- Mambilina, Mumbotuta - Pensulo - Kitwe
- Mambilina, Mumbotuta - (DRC) - Kitwe

Of these two, that through the DRC is about 300 km shorter, and therefore would offer advantages in aspects such as construction costs (203 million US$) and transmission loss (4MW reduction at peak time of 2030). However, this route would be through another country, and therefore entail a high uncertainty as regards construction and operation. For this reason, the route through Pensulo is recommended here.

The phase for development of this power line would be 2020 - 2025, in step with the power station construction.

・ Kalungwishi power line

In the Kalungwishi district, there are plans for construction of two power stations at Kundabwika Falls and Kabwelume Falls. The two would have a combined output of 218 MW[21]. This output, too, is high for the load in the vicinity, and will be transmitted to other areas through Kasama. The distance from Kalungwishi to the Kasama substation is about 250 km, and installation with a single-circuit 132kV transmission line would present problems in the aspects of thermal capacity and transmission loss. These problems could be addressed by installing a two-circuit line with wider conductor (2 x Bison) than usual or a single-circuit 330kV line.

Table 8.4 shows the relative merits of these options.

Although there remains the problem of separating power system in the Northeast area in the event of transmission line failure, these results suggest that it would be better to adopt the 330kV transmission line, which offers benefits in the aspects of construction costs and transmission loss.

The area to be served by this transmission line is one of those with very poor voltage stability. For this reason, the construction of a substation at Mporokoso along this line to improve the voltage stability in this area is recommended.

Properly speaking, the construction of this transmission line should be timed to coincide with the phase of construction of the Kundabwika and Kabwelume substations (2015 - 2020). To stabilize the voltage in this area, nevertheless, construction of part of the line (the Kasama-Mporokoso leg) in an earlier phase (preferably 2010 - 2015, when the Pensulo-Kasama 330kV transmission line is to be constructed) is recomended.

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[20] The forecast for combined peak load in 2030 at Mporokoso, Kawambwa Tea, Mbereshi, Nchelenge, Luwing, Mansa, and Kasama is 52.7 MW

[21] In the generation development plan, this value is 163MW. But, there is some possibility to install 218MW on this area, and transmission expansion plan considered more sevire condition.

Table 8.4 Comparison of the Kalungwishi-Kasama transmission lines

Types of transmission line	132kV, two-circuit, Bison conductor x 2	330kV, single-circuit, Bison conductor x 2
Transmission loss (in transmission of 218 MW)	14.6MW	4.6MW
Construction cost	97 million USD	82 million USD
Other matters	This type of line would enable stable operation of the power system, including the power station vicinity, even in an N-1 condition	The system in the power station vicinity would be taken off the grid in the event of failure of one circuit on the Kundabwika, Kabwelume-Kasama transmission line.

(c) Other transmission lines

In addition to international interconnections and power lines, this area has a need for development of other transmission lines to maintain voltage. The major such lines are as follows.

Table 8.5 132kV transmission development plan in north-east area

Name	Voltage	Year	Remarks
Kasama – Mbala	132kV	2010-2015	Installation at the time of construction of the Kasama-Pensulo 330kV transmission line
Kasama – Chinsali		2010-2015	
Lusiwasi – Mfue		2010-2015	Installation at the time of expanding capacity of Lusiwasi powerstation
Kalungwishi – Nchelenge		2015-2020	Installation at the time of construction of the Kalungwishi substation
Kalungwishi – Kawambwa Tea		2015-2020	

The major objective in the case of each of these transmission lines is stabilization of voltage in the area. Stable transmission over distances in excess of 100 km requires a 132kV system as opposed to the current 66kV system.

8.3.2 West area

Small-scale independent systems (diesel) are scattered in this area. Promotion of rural electrification requires interconnection of these systems. The characteristics of the transmission system in this area are as follows.

- Major planned power stations are Itezhi-tezhi (120 MW) and Kabompo Gorge (34 MW).
- Kaoma, Mongu, Senaga, Sesheke, and Kasempa are interconnected with 66kV transmission lines, but much of the area depends on independent systems.

- Most of the 66kV transmission lines are more than 100 km long.
- The demand density is low, and the load at each substation is light[22].
- The N-1 rule not met.

In this area, too, the biggest problem is voltage stability, particularly under the N-1 conditions. The plans for transmission development in this area are as follows.

A. Power lines

In this area, lines are needed from the Itezhi-tezhi and Kabompo Gorge power stations. The power line plans are as follows.

・ Itezhi-tezhi line

Over the distance from Itezhi-tezhi to Lusaka West, the plan is to install a 220kV transmission line from Itezhi-tezhi to Mumbwa and a 330kV transmission line from Mumbwa to Lusaka West. Each line has planned as a single circuit. Up until 2017, when the Kafue Gorge Lower power station is placed into operation, there will be a shortage of sources in Zambia as a whole, and the trip of this line will naturally be linked to load shedding. For this reason, the installation of a double-circuit line for the Itezhi-tezhi line is recommended.

This line should be installed in the same period as when the power station is constructed (2010 - 2015 phase).

・ Kabompo Gorge line

The Kabompo Gorge power station is to have an output of 34 MW, which is not so large. However, there are few power sources in the northwestern area, it will have an important role to improve voltage stability in this area. As such, the transmission line leading from it should ideally have a voltage of 132kV, the same as that of the system in the West area. It would be suitable for the line to be installed in the same phase as the power station input (2015 - 2020).

B. Western loop

Interconnection of the independent systems in the West area require the construction of a looped transmission line linking Itezhi-tezhi, Kaoma, Mougu, Lukulu, Kabompo, Mufumbe, and Kabompo Gorge. Due to the long transmission distance, it would be appropriate for this system to have a voltage of 132kV instead of the 66kV in use for some lines. In two legs (Itezhi-tezhi-Kaoma-Mongu and Kabompo Gorge-Mufumbe-Kabompo), it would be necessary to install double-circuit lines on later stage in order to assure the voltage stability needed to meet the N-1 rule.

As for the timing, it would be advisable to install the Itezhi-tezhi-Mongu leg in the same phase as construction of the Itezhi-tezhi power station (2010 - 2015), and to make extensions for the other legs, one after the other beginning with that linked to the power source, in the 2015 - 2020 phase.

[22] with the exception of Victoria Falls, the combined peak load at the ten other substations in the western area in 2030 is forecast at 59.6 MW

8.3.3 South Area

In this area, there are plans for construction of large-scale power stations at Batoka Gorge and Devil Gorge as well as for international interconnections with Namibia, Botswana, and Zimbabwe. The area is also the subject of plans for construction of a coal-fired power station at Maamba. It is consequently of crucial importance for power trade (import and export) and supply to all parts of Zambia. The transmission plans in this area are as follows.

A. Trunk transmission line

In light not only of the plans for construction of large-scale power stations at Batoka Gorge, Devil Gorge, and Maamba but also the need for international power interchange with Namibia, this area will have a very large power flow. Because the future transmission capacity would be short with only a single route, it would be indispensable to develop the trunk transmission line network. It may also be noted that transmission line failure on this route could very well trigger outage throughout Zambia. Therefore, it must be given a structure to enable stable transmission of power under the N-1 rule at the minimum. The plan for development of trunk transmission lines in this area was formulated with consideration of these factors. Table 8.6 shows the results.

Table 8.6 Plan for development of trunk transmission lines in the South area

Name	Voltage	Year	Remarks
Victoria Falls – Muzuma	330kV	2010-2015	Upgrade from 220kV to 330kV
Muzuma – Kafue Town			
Sesheke - Victoria Falls 2nd	220kV		Installation of 2nd Circuit
Victoria Falls – Maamba	330kV		New Circuit
Maamba – Muzuma			
Maamba- Kafue West 1st			New Circuit
Maamba- Kafue West 2nd			Double Circuit Tower
Devil Gorge Power Station		2015-2020	Installation in Victoria Falls – Maamba Line
Devil Gorge – Maamba 2nd			Installation of 2nd Circuit
Muzuma – Kafue Town 2nd		2020-2025	Installation of 2nd Circuit
Batoka Gorge Power Station		2025-2030	Installation in Victoria Falls – Devil Gorge Line
Batoka Gorge – Devil Gorge 2nd			Installation of 2nd Circuit

B. Others

Besides 330kV (and 220kV) transmission lines, this area contains 88kV systems at Muzuma and Mazabuka. In addition, it is installed with long-distance 33kV distribution lines. Substations such as Choma and Monze will not be able to cope with the future demand increase with their 33kV distribution lines.

The 88kV systems are in every case marked by a high degree of deterioration, and there are 66 and 132kV systems in the immediate vicinity in Zambia. Therefore, the plan on the premise of gradual abolition of the 88kV system along with facility expansion and of unification in the 132kV system is recommended. Table 8.7 shows the resulting plan.

Table 8.7 Plan for development of 132kV transmission lines in the South area

Name	Voltage	Year	Remarks
Muzuma – Maamba	88kV	2010-2015	Disuse
Kafue Town – Mazabuka			
Muzuma – Choma 1st	132kV		New Circuit
Muzuma – Choma 2nd			Double Circuit Tower
Choma - Monze			New Circuit
Monze - Mazabuka			New Circuit (Cut off Operation)
Kafue Town – Mazabuka 1st			New Circuit
Kafue Town – Mazabuka 2nd			Double Circuit Tower

Among the transmission lines shown in Table 8.7, abolition of the Muzuma-Maamba 88kV line is recommended when the 220kV line from Victoria Falls to Kafue Town is replaced with a 330kV line. This is because the 220/88kV transformers in Muzuma will become incapable of use when the voltage is raised to 330kV.

8.3.4 Lusaka area

The Lusaka area is one of the load centers in Zambia, and its load is supplied through 88- and 132kV systems from Leopards Hill, Lusaka West, and Kafue West. The power flow through this system is close to the thermal capacity of the transmission lines. Load shedding is required on the N-1 conditions. In 2030, the area's load is forecast to be more than triple its current level, and the power flow will undergo a corresponding increase. The plan for transmission development in this area is as follows.

A. Expansion of 330kV transmission lines

As the demand in the Lusaka area is forecast to exceed 1 GW in 2030, a new 330kV system must be introduced to supply power for the load in the city. So the construction of a substation (330/132kV) at Lusaka South and concomitant installation of 330kV transmission lines are recommended.

At present, there is a 330kV transmission line linking Kafue West, Leopards Hill, and Kabwe as the route for transmission of power from large-scale power stations such as Maamba, Devil Gorge, and Batoka Gorge in the direction of Copperbelt. In the future, however, this route alone will not be sufficient to assure transmission capacity up to the N-1 rule. The situation demands augmentation of the Kafue West-Lusaka West-Kabwe route to strengthen the connection between the South Area and the Copperbelt Area. Table 8.8 shows the plan for development of 330kV transmission lines in this area.

Table 8.8 Plan for development of 330kV transmission lines in the Lusaka Area

Name	Voltage	Year	Remarks
Kafue West – Lusaka West 2nd	330kV	2010-2015	
Lusaka West – Kabwe 1st			New Circuit
Lusaka West – Kabwe 2nd			
Lusaka South Substation			Installation in Kafue West – Leopards Hill Line
Kafue West – Lusaka West 3rd		2015-2020	
Kafue Gorge Lower – Lusaka South 1st			New Circuit Double Circuit Tower
Kafue Gorge Lower – Lusaka South 2nd			

B. Expansion of 132kV transmission lines

The transmission system in the city is currently a mixture of 88- and 132kV lines. The 88kV system will not have enough transmission capacity to cope with the future load increase, and its facilities are already in a deteriorated state. For these reasons, it is necessary to expand the 132kV system in Lusaka and phase out the 88kV system along with construction of the Lusaka South substation. Besides assuring the transmission capacity into the future, this will unify the voltage classes and enable more flexible operation of the system.

To this end, useage of a wider conductor (Zebra) is recommended than the conventional one (Wolf) for the 132kV transmission lines in this area. This is because most of the transmission lines here have a short distance (less than 30 km), and the available transmission capacity is determined by the thermal capacity of the line instead of voltage drop due to inductance. Under these circumstances, a switch to a wider line conductor is the most economical means of increasing capacity. Table 8.9 shows the plan for expansion of the 132kV transmission lines in this area.

Table 8.9 Plan for 132kV transmission line development in the Lusaka area

Name	Voltage	Year	Remarks
Leopards Hill – Waterworks 1st	88kV	2010-2015	Disuse
Leopards Hill – Waterworks 2nd			
Waterworks – Coventry			
Leopards Hill – Mapepe			
Mapepe – Kafue West			
Lusaka West – Roma 2nd	132kV	2010-2015	
Lusaka West – Coventry 2nd			
Leopards Hill – Coventry 2nd			
Lusaka South – Mapepe 1st			New Circuit
Lusaka South – Mapepe 2nd			Double Circuit Tower
Lusaka South – Coventry 1st			New Circuit
Lusaka South – Coventry 2nd			New Circuit
Lusaka South – Waterworks 1st			New Circuit
Lusaka South – Waterworks 2nd			Double Circuit Tower
Lusaka South – Woodland 1st			New Circuit
Lusaka South – Woodland 2nd			Double Circuit Tower
Leopards Hill – Avondale 1st			New Circuit
Leopards Hill – Avondale 2nd			Double Circuit Tower
Lusaka South – Chawama 1st		2015-2020	New Circuit
Lusaka South – Chawama 2nd			Double Circuit Tower
Avondale – Chelston 1st			New Circuit
Avondale – Chelston 2nd			Double Circuit Tower
Chelston – University 1st			New Circuit
Chelston – University 2nd			Double Circuit Tower
Lusaka West – Matero 1st		2020-2025	New Circuit
Lusaka West – Matero 2nd			Double Circuit Tower
Lusaka West – Makeni 1st			New Circuit
Lusaka West – Makeni 2nd			Double Circuit Tower
Lusaka South – Coventry 3rd		2025-2030	New Circuit

8.3.5 Copperbelt area

The Copperbelt area is another load center in Zambia. Most of the transmission lines in this area have a voltage of 220kV or 66kV. The main part of the load is that of mining companies. Most of the transmission lines in this area have a length of less than 40 km, and this facilitates application of 66kV transmission lines. The plan for transmission system development in this area centers around 66- and 220kV transmission lines supplying power to large-volume customers.

There are few power stations in this area, which receives almost all of its supply from the South area through 330kV transmission lines. As a result, the voltage stability is low, and there is a need for measures to cope with the future demand increase. There are two types of prospective measures, as follows.

- Installation of an intermediate switching station and SVC
- Installation of new transmission lines

Each of these measures is outlined below.

A. Installation of an intermediate switching station and SVC

An intermediate switching station will be constructed on the transmission line between Kabwe-Kitwe and Luano to improve the voltage stability in the event of transmission line failure. This switching station may also be expected to level the power flow on the transmission line between Kabwe and the station and act to reduce transmission loss.

In addition, installation of an SVC with a regulating capability of ±100 MVar in the Kitwe substation will improve voltage stability in normal operation and in the event of transmission line failure. In this area, there is a high mining load and great voltage fluctuation along with fluctuation of this load. The SVC therefore may also be expected to have effects for improving voltage.

B. Installation of new transmission lines

On the Zambian side, studies are currently under way for construction of a 330kV transmission line between Mumbwa and Lumuwana to increase the reliability of the power supply in the Copperbelt area. The construction of this line would not only enhance the voltage stability in the Copperbelt area but also bring a great reduction in transmission loss. The installation of two transmission line routes from power sources to the Copperbelt area would also improve the system reliability. However, the transmission distance on this line would be very long (350km) and consequently entail a high construction cost.

Table 8.10 compares these two prospective measures.

Table 8.10 Comparison of voltage stabilization measures in the Copperbelt area

	Intermediate switching station plus SVC	New transmission line
Description	・Construction of an intermediate switching station between Kabwe-Kitwe and Luano (8 cct initially, with eventual increase to 12 cct) ・Installation of SVC with ±100 MVar in the Kitwe substation	Construction of a 2-cct 330kV transmission line between Mumbwa and Lumuwana
Cost	28 million USD	210 million USD
Reduction of transmission loss (2030 peak)	5.3MW	29.9MW
Other matters	Ability to curtail voltage fluctuation in normal operation	Ability to send some power to Copperbelt even in the event of failure on the route between Leopards Hill-Kabwe-Kitwe and Luano Facilitation of response to load increase in the Lumuwana direction

Based on the results of comparison, installation of the intermediate switching station and SVC is recommended, which has less effect for reducing transmission loss but costs much less. If the load in this area increases beyond the level forecast in this study, it would be necessary to reconsider the other option of constructing an additional transmission line.

8.3.6 Summary of plans for transmission development in scenario 1-1

Tables 8.11 and 8.12 present specific figures for the amount of transmission facilities earmarked for development in the plan for transmission development in the scenario 1-1. Figures 8.3 – 8.12 present corresponding system diagrams for the years 2010, 2015, 2020, 2025, and 2030. It can be seen that the amount of transmission facilities to be developed would peak in a relatively early phase (2010 - 2015). This is because the problem of voltage stability, which is now very difficult to maintain, must be resolved early in order to cope with future power source development.

Table 8.11 Amount of transmission facility development (kms) in Scenario 1-1

Year	Voltage of Transmission Line (kV)			
	66	132	220	330
2010-2015	194	2,562	599	3,668
2015-2020	5	1,494	0	389
2020-2025	0	241	0	2,142
2025-2030	0	236	0	140

Table 8.12 Transmission development plan (Scenario 1-1)

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
3	Kariba North	Leopards Hill	2010-2015	123	330	2-Bison
2	Kabwe	Pensulo	2010-2015	298	330	2-Bison
1	Kabwe	Lusaka West	2010-2015	100	330	2-Bison
2	Luano	Kansanshi	2010-2015	197	330	2-Bison
1	Pensulo	Kasama	2010-2015	380	330	2-Bison
2	Pensulo	Kasama	2010-2015	380	330	2-Bison
1	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Lsaka West	2010-2015	34	330	2-Bison
1	Kafue Town	Muzuma(UP Grade)	2010-2015	189	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Kasama	Nakonde	2010-2015	210	330	2-Bison
2	Kasama	Nakonde	2010-2015	210	330	2-Bison
1	Kasama	Mporokoso	2010-2015	150	330	2-Bison
1	Victoria Falls	Muzuma(UP Grade)	2010-2015	159	330	2-Bison
1	Victoria Falls	Batoka Gorge	2010-2015	40	330	2-Bison
1	Victoria Falls	Muzuma	2010-2015	159	330	2-Bison
1	Batoka Gorge	Devil Gorge	2010-2015	70	330	2-Bison
1	Devil Gorge	Maamba	2010-2015	70	330	2-Bison
1	Maamba	Muzuma	2010-2015	55	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Luano	Michelo	2010-2015	31.9	220	2-HD153
1	Luano	Stadium	2010-2015	16.4	220	2-Lion
2	Luano	Stadium	2010-2015	16.4	220	2-Lion
1	Michelo	Bankroft	2010-2015	10	220	2-HD153
2	Michelo	Bankroft	2010-2015	10	220	2-HD153

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
2	Victoria Falls	Sesheke	2010-2015	224	220	Bison
1	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Coventry	Leopards Hill	2010-2015	28	132	Wolf
2	Coventry	Lusaka West	2010-2015	7	132	Wolf
2	Roma	Lusaka West	2010-2015	15	132	Wolf
1	Leopards Hill	Avondale	2010-2015	15	132	Zebra
2	Leopards Hill	Avondale	2010-2015	15	132	Zebra
1	Kasama	Mbala	2010-2015	161	132	Wolf
2	Kasama	Mbala	2010-2015	161	132	Wolf
1	Kasama	Chinsali	2010-2015	105	132	Wolf
1	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
2	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
1	Pensulo	Kanon	2010-2015	20	132	Wolf
2	Pensulo	Kanon	2010-2015	20	132	Wolf
1	Pensulo	Mutindo	2010-2015	110	132	Wolf
2	Pensulo	Mutindo	2010-2015	110	132	Wolf
1	Lusiwasi	Msoro	2010-2015	115	132	Wolf
2	Lusiwasi	Msoro	2010-2015	115	132	Wolf
1	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
2	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
1	Kabwe	Kapiri Mposhi	2010-2015	96	132	Wolf
1	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
2	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
1	Kaoma	Mongu	2010-2015	185	132	Wolf
1	Nampundwe	Lusaka West	2010-2015	60	132	Wolf
1	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
2	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
1	Mazabuka	Monze	2010-2015	60	132	Wolf
1	Mapepe	Lusaka South	2010-2015	20	132	Wolf
2	Mapepe	Lusaka South	2010-2015	20	132	Wolf
1	Lusaka South	Waterworks	2010-2015	14	132	Zebra
2	Lusaka South	Waterworks	2010-2015	14	132	Zebra
1	Lusaka South	Woodlands	2010-2015	13	132	Zebra
2	Lusaka South	Woodlands	2010-2015	13	132	Zebra
1	Lusaka South	Coventry A	2010-2015	21	132	Zebra

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
2	Lusaka South	Coventry A	2010-2015	21	132	Zebra
1	Coventry A	Coventry B	2010-2015	1	132	Zebra
2	Coventry A	Coventry B	2010-2015	1	132	Zebra
1	Muzuma	Choma	2010-2015	26	132	Wolf
2	Muzuma	Choma	2010-2015	26	132	Wolf
1	Choma	Monze	2010-2015	80	132	Wolf
1	Mutinond	Luchene	2010-2015	45	132	Wolf
2	Mutinond	Luchene	2010-2015	45	132	Wolf
2	Stadium	Avenue	2010-2015	1.27	66	2-HD124
3	Stadium	Avenue	2010-2015	1.27	66	2-HD124
2	Chisenga	Luano	2010-2015	11.4	66	Lynx
2	Mufulira	Kankoyo	2010-2015	0.4	66	2-HD124
2	Maposa	Dola Hill	2010-2015	21.3	66	Lynx
1	Maposa	Pamodzi	2010-2015	25	66	Lynx
2	Maposa	Pamodzi	2010-2015	25	66	Lynx
2	Ndola Refinery	Skyways	2010-2015	1.5	66	HD124
2	Pamodzi	Depot Road	2010-2015	6.3	66	Lynx
2	Kanon	Kaomb	2010-2015	21	66	Wolf
2	KZNGL	Victoria Falls	2010-2015	80	66	Wolf
	New SWS (Internal of Kabwe – Kitwe, LuanoLine)		2010-2015			
	Lusaka South SS (Internal of Leopards Hill – Kafue West Line)		2010-2015			
2	Kabwe	Lusaka West	2015-2020	100	330	2-Bison
3	Kafue West	Lsaka West	2015-2020	34	330	2-Bison
2	Devil Gorge	Maamba	2015-2020	70	330	2-Bison
1	Kundabwika	Mporokoso	2015-2020	95	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Mukushi	Lunsemfwa	2015-2020	10	132	Wolf
2	Mukushi	Lunsemfwa	2015-2020	10	132	Wolf
1	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
2	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
1	Kundabwika	Nchelenge	2015-2020	75	132	Wolf
1	Kabwelume	Kawambwa Tea	2015-2020	30	132	Wolf

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
1	Msoro	Chipata	2015-2020	80	132	Wolf
2	Msoro	Chipata	2015-2020	80	132	Wolf
1	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
2	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
1	Kabwe	BRKHL	2015-2020	3	132	Wolf
2	Kabwe	BRKHL	2015-2020	3	132	Wolf
1	Kapiri Mposhi	Mpongwe	2015-2020	60	132	Wolf
1	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
2	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
1	Kabompo Gorge	Mwinilunga	2015-2020	100	132	Wolf
1	Kabompo Gorge	Mufumbwe	2015-2020	110	132	Wolf
1	Mufumbwe	Kabompo	2015-2020	105	132	Wolf
1	Kabompo	Mumbeji	2015-2020	80	132	Wolf
1	Mongu	Lukulu	2015-2020	160	132	Wolf
1	Lukulu	Mumbeji	2015-2020	80	132	Wolf
1	Mumbeji	Zambezi	2015-2020	75	132	Wolf
1	Zambezi	Chavuma	2015-2020	80	132	Wolf
1	Lusaka South	Chawama	2015-2020	6	132	Wolf
2	Lusaka South	Chawama	2015-2020	6	132	Wolf
1	University	Chelston	2015-2020	5	132	Zebra
2	University	Chelston	2015-2020	5	132	Zebra
1	Avondale	Chelston	2015-2020	5.7	132	Zebra
2	Avondale	Chelston	2015-2020	5.7	132	Zebra
3	Ndola Refinery	Skyways	2015-2020	1.5	66	HD124
2	Dola Hill	Pamodzi	2015-2020	3.7	66	Lynx
3	Kitwe	New SWS	2020-2025	91	330	2-Bison
4	Kitwe	New SWS	2020-2025	91	330	2-Bison
1	Leopards Hill	Mpata Gorge	2020-2025	255	330	2-Bison
2	Leopards Hill	Mpata Gorge	2020-2025	255	330	2-Bison
1	Pensulo	Mumbotuta	2020-2025	190	330	2-Bison
2	Pensulo	Mumbotuta	2020-2025	190	330	2-Bison
1	Pensulo	New SWS	2020-2025	219	330	2-Bison
2	Pensulo	New SWS	2020-2025	219	330	2-Bison
2	Kafue West	Kafue Town	2020-2025	3	330	2-Bison
2	Kafue Town	Muzuma	2020-2025	189	330	2-Bison
1	Mumbotuta	Mambilima	2020-2025	210	330	2-Bison

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
1	Mumbotuta	Mansa	2020-2025	130	330	2-Bison
1	Mambilima	Mambilima Site2	2020-2025	10	330	2-Bison
2	Mambilima	Mambilima Site2	2020-2025	10	330	2-Bison
1	Mambilima	Mansa	2020-2025	80	330	2-Bison
2	Kaoma	Mongu	2020-2025	185	132	Wolf
1	Makeni	Lusaka West	2020-2025	13	132	Zebra
2	Makeni	Lusaka West	2020-2025	13	132	Zebra
1	Matero	Lusaka West	2020-2025	15	132	Zebra
2	Matero	Lusaka West	2020-2025	15	132	Zebra
2	Batoka Gorge	Devil Gorge	2025-2030	70	330	2-Bison
3	Devil Gorge	Maamba	2025-2030	70	330	2-Bison
2	Kabompo Gorge	Mufumbwe	2025-2030	110	132	Wolf
2	Mufumbwe	Kabompo	2025-2030	105	132	Wolf
3	Lusaka South	Coventry A	2025-2030	21	132	Zebra

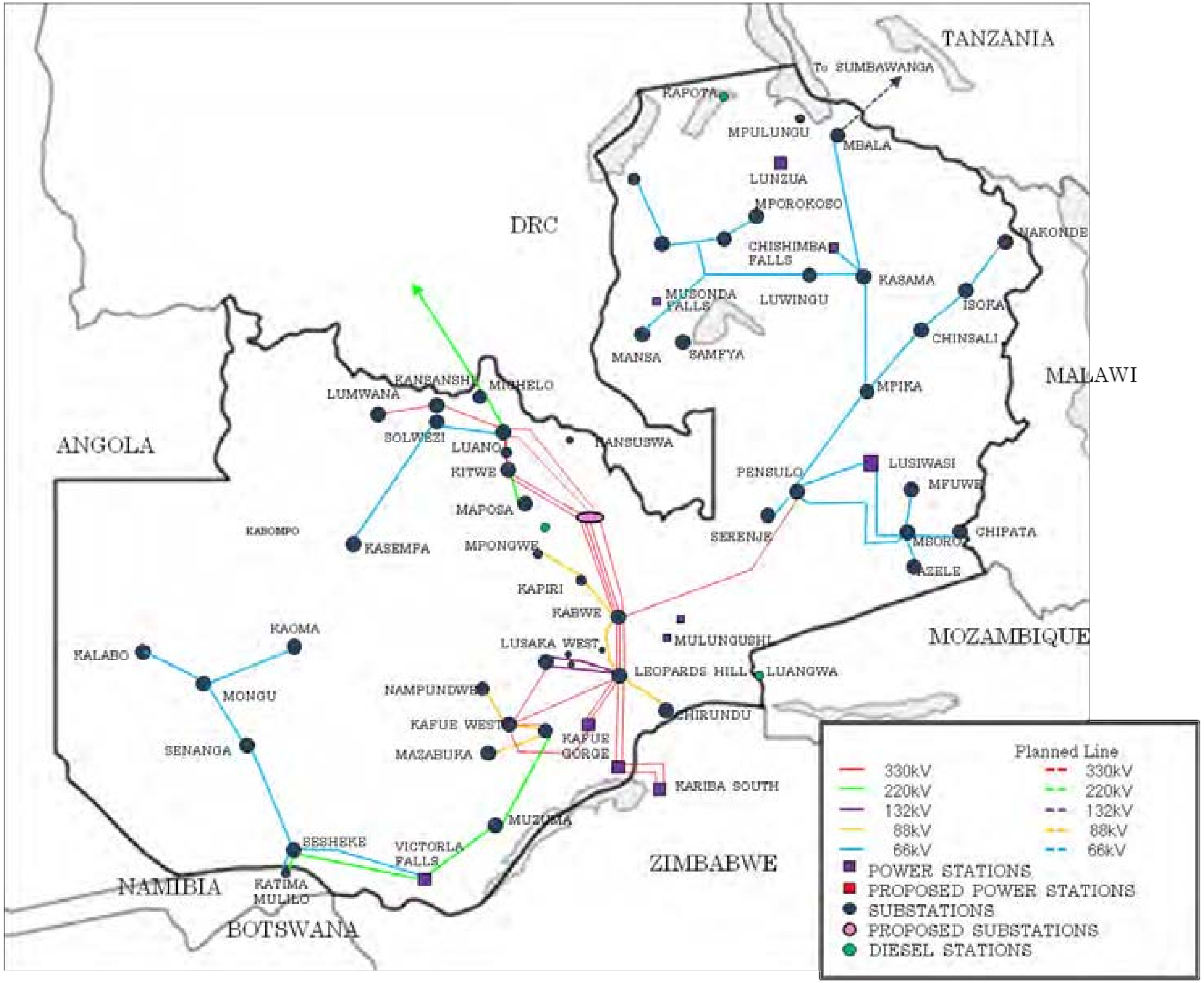

Figure 8.3 Zambian Power System on 2010

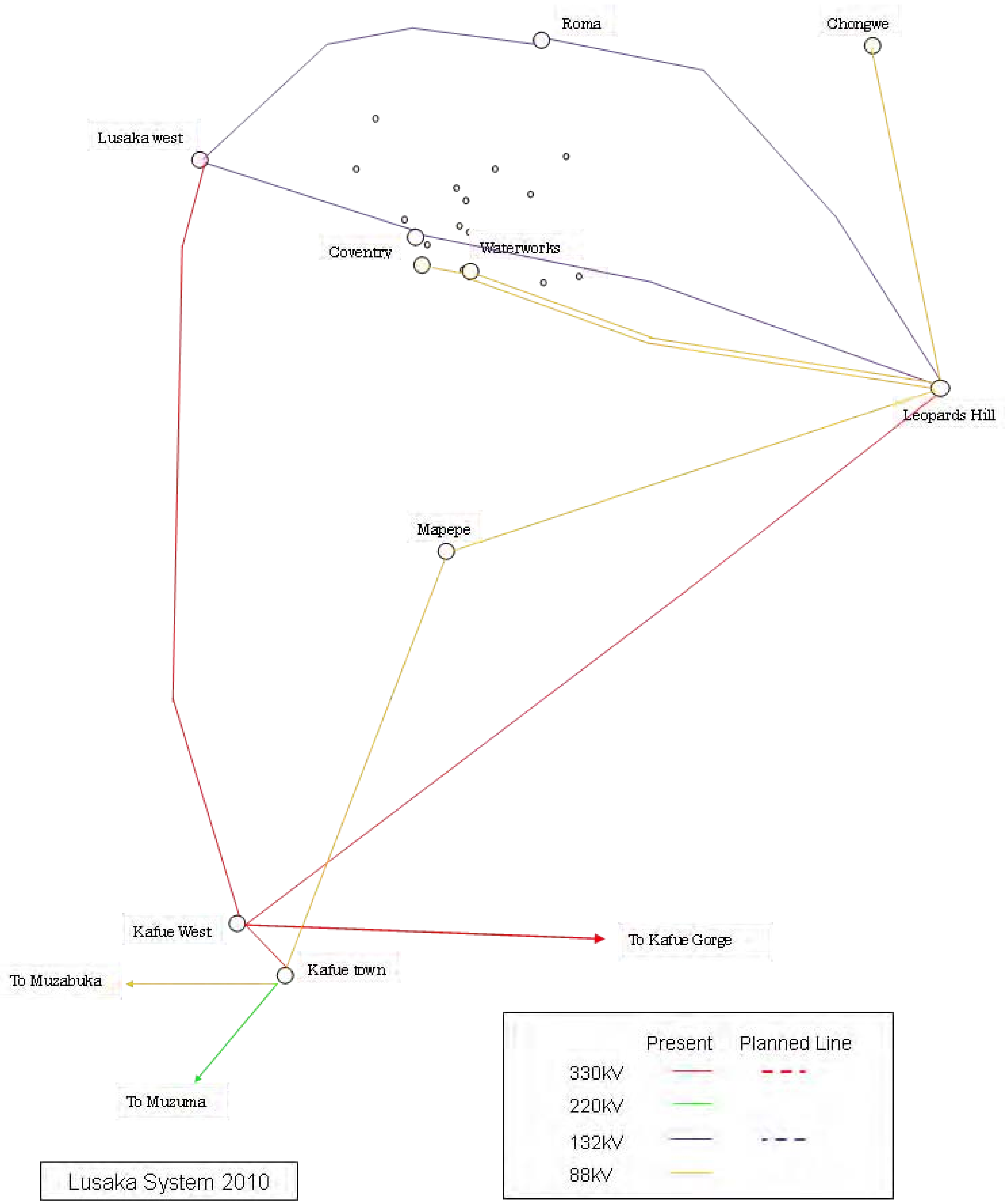

Figure 8.4 Lusaka Power System on 2010

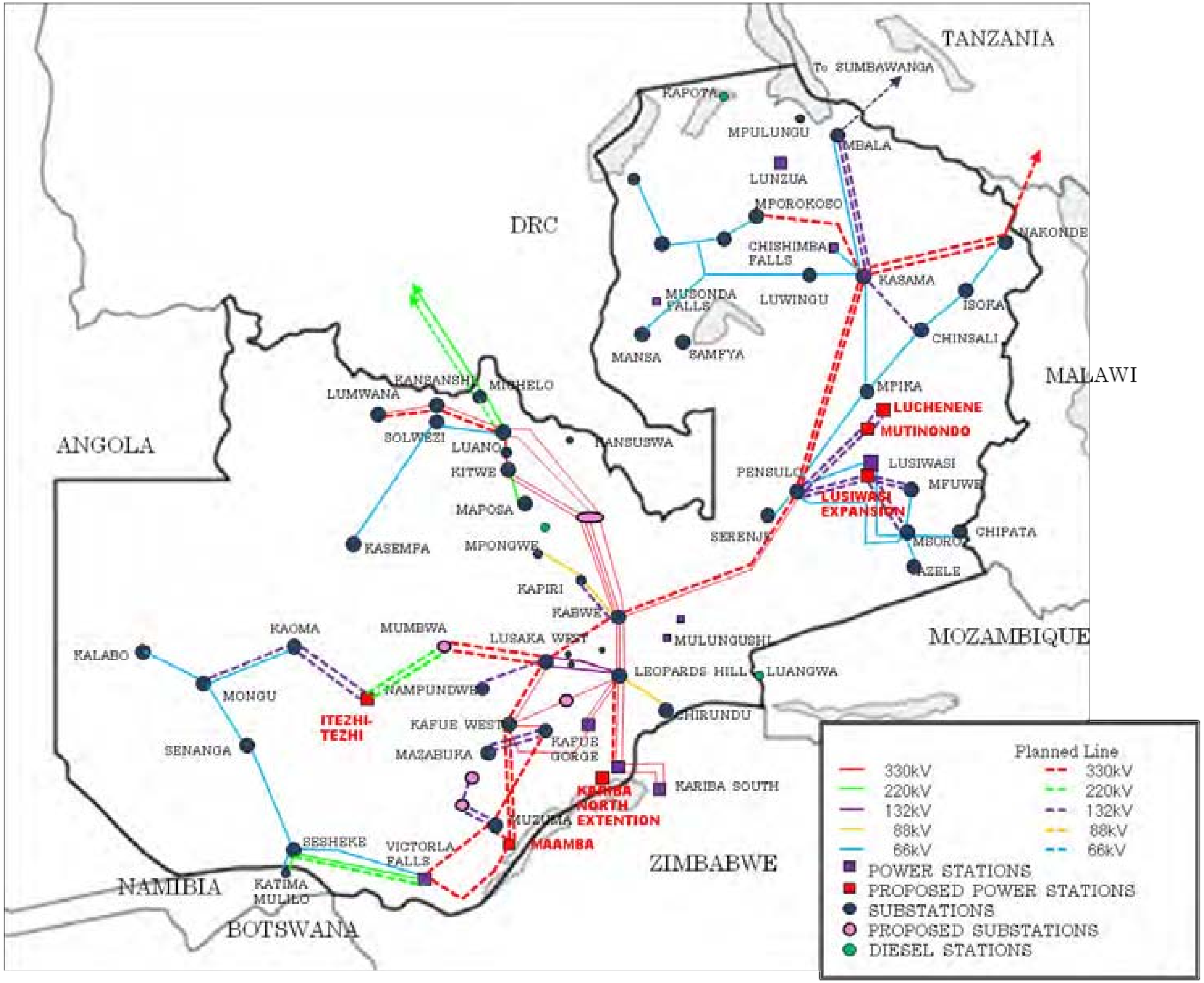

Figure 8.5 Zambian Power System on 2015 (Scenario1-1)

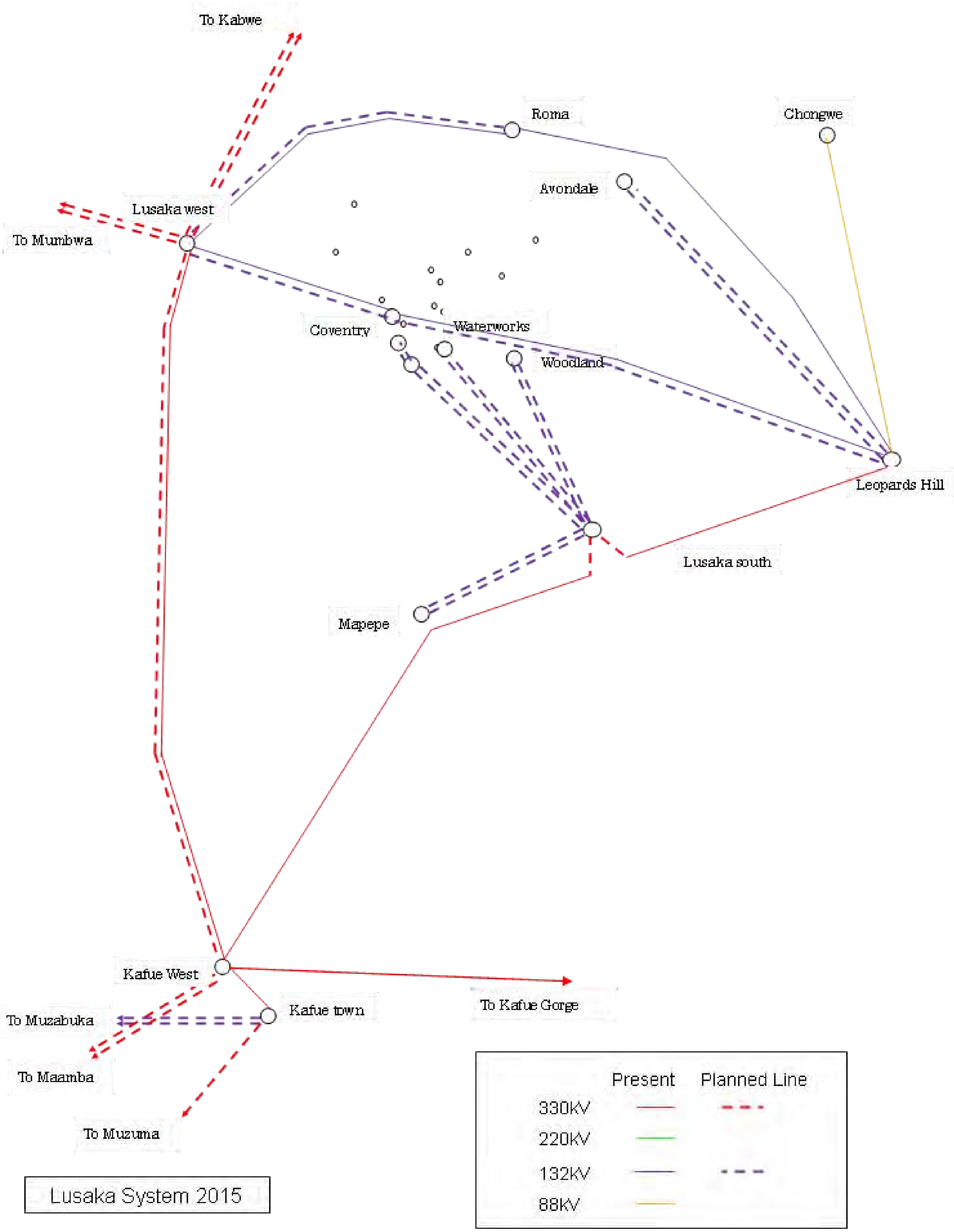

Figure 8.6 Lusaka Power System on 2015 (Scenario1-1)

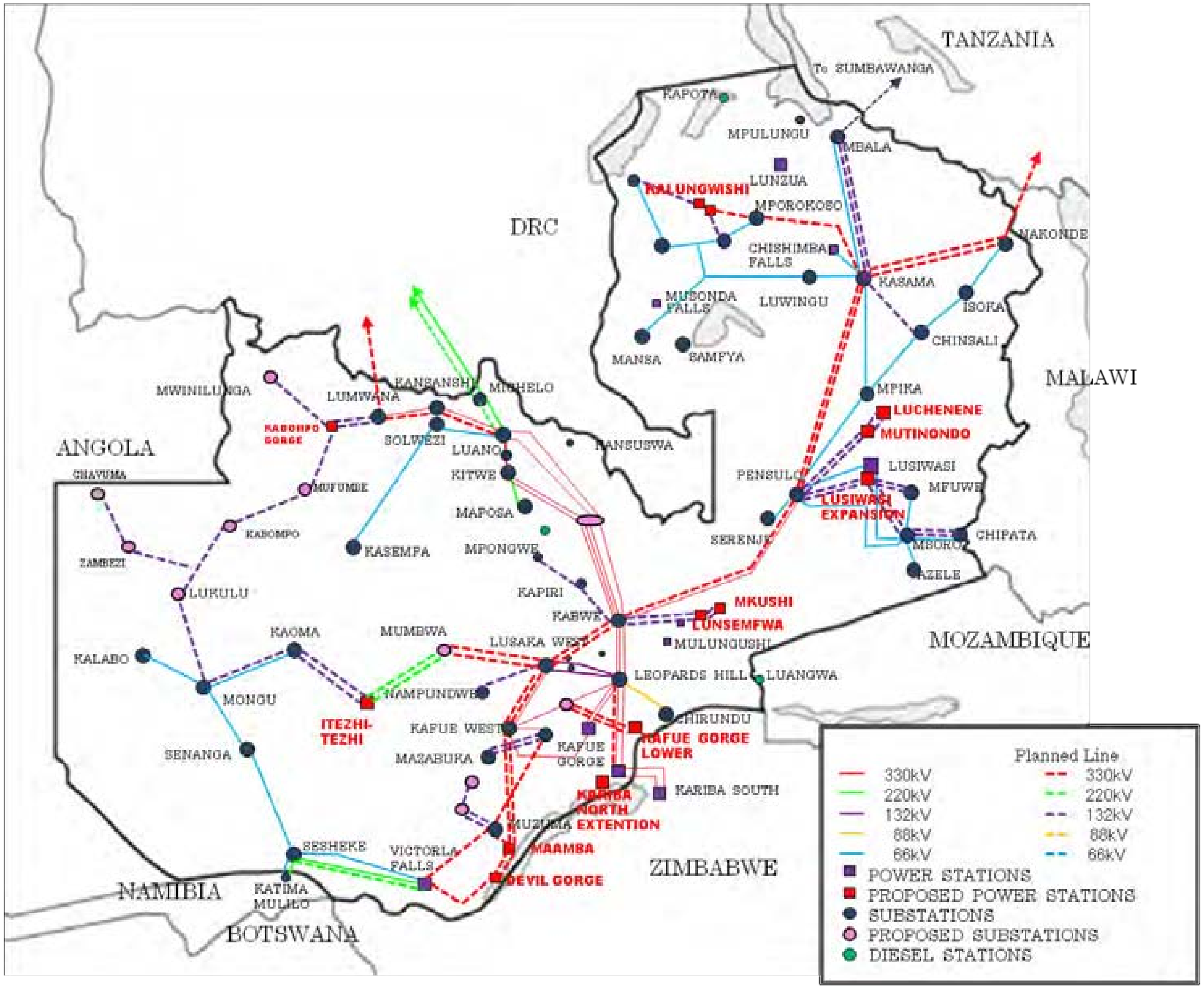

Figure 8.7 Zambian Power System on 2020 (Scenario1-1)

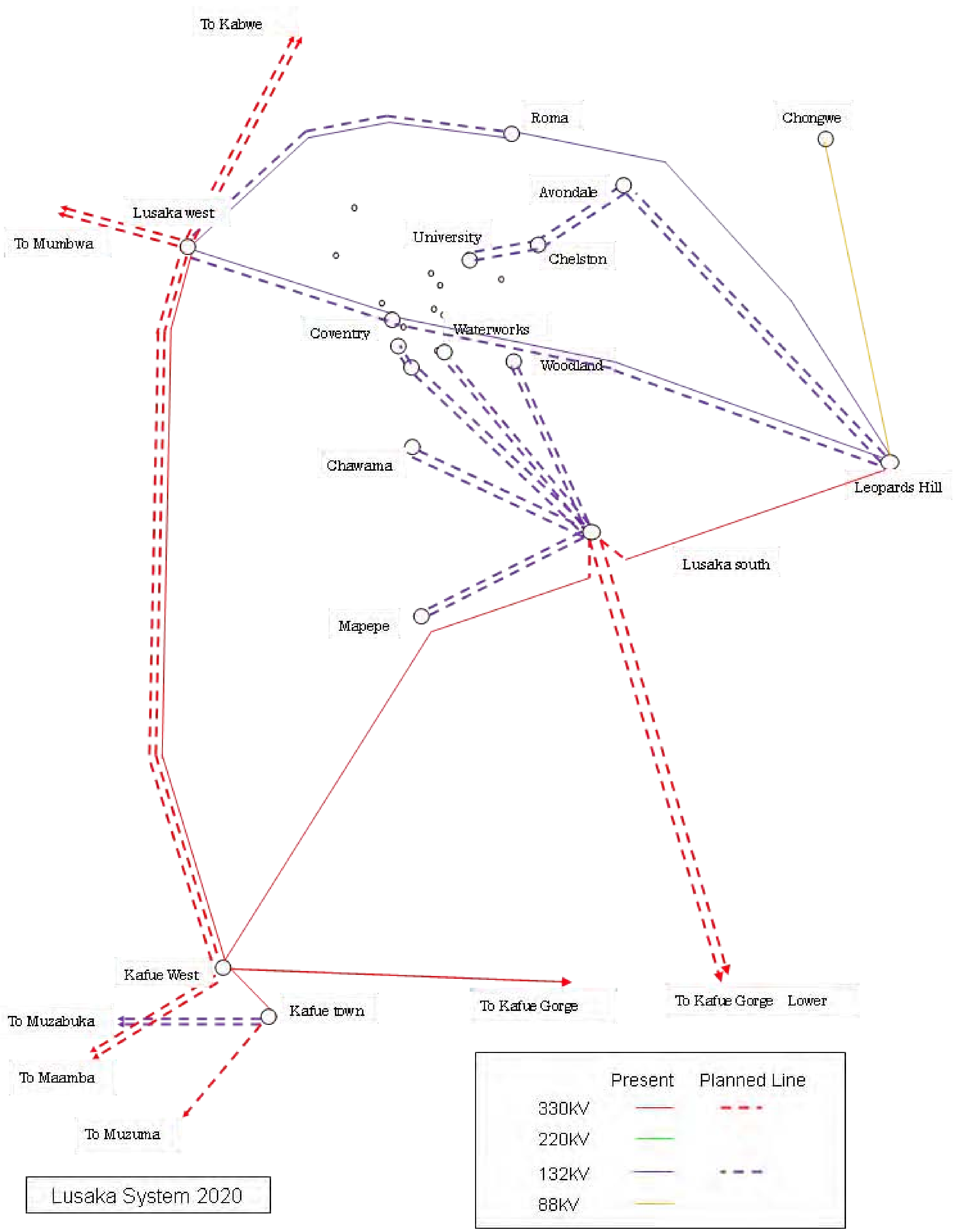

Figure 8.8 Lusaka Power System on 2020 (Scenario1-1)

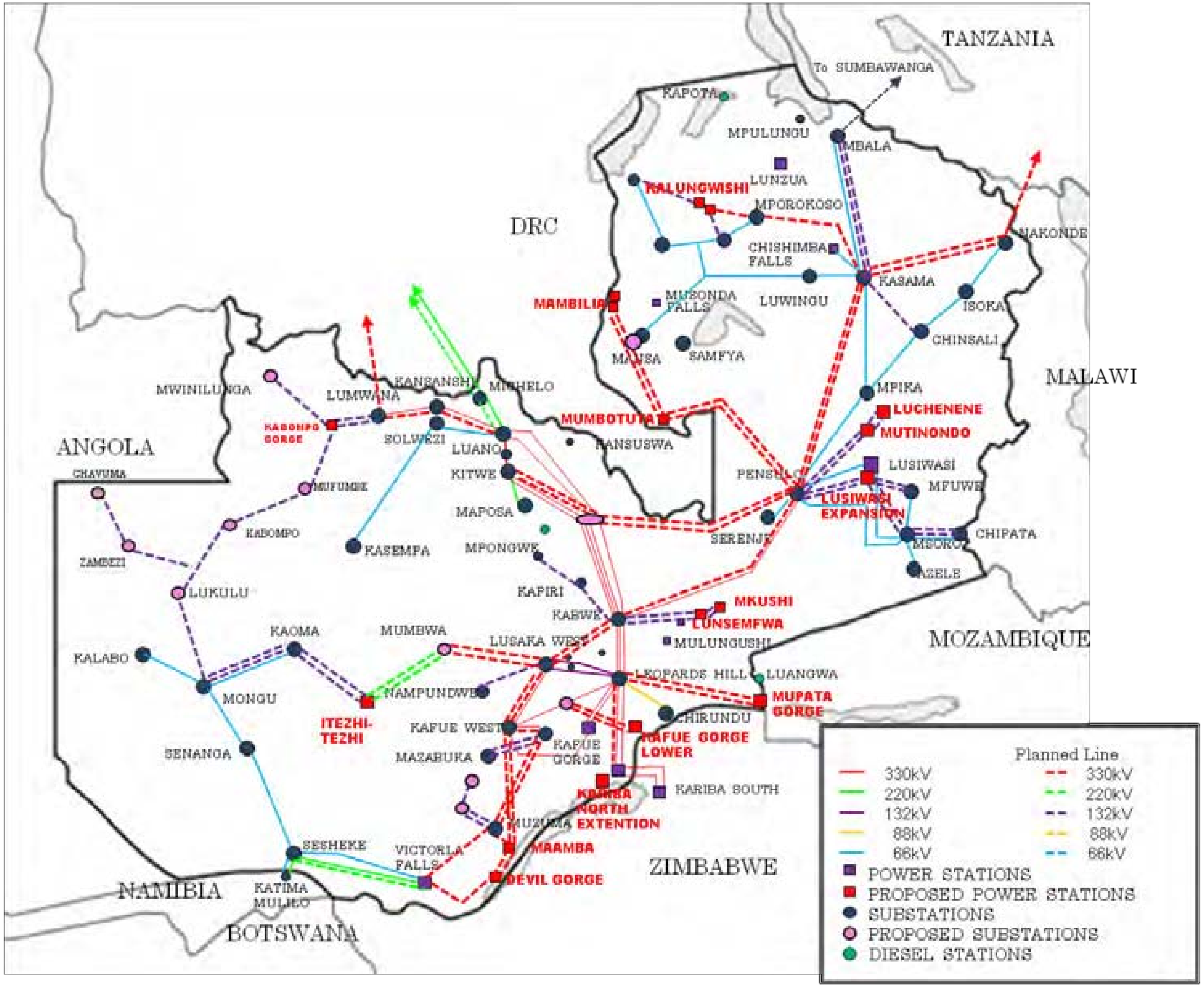

Figure 8.9 Zambian Power System on 2025 (Scenario1-1)

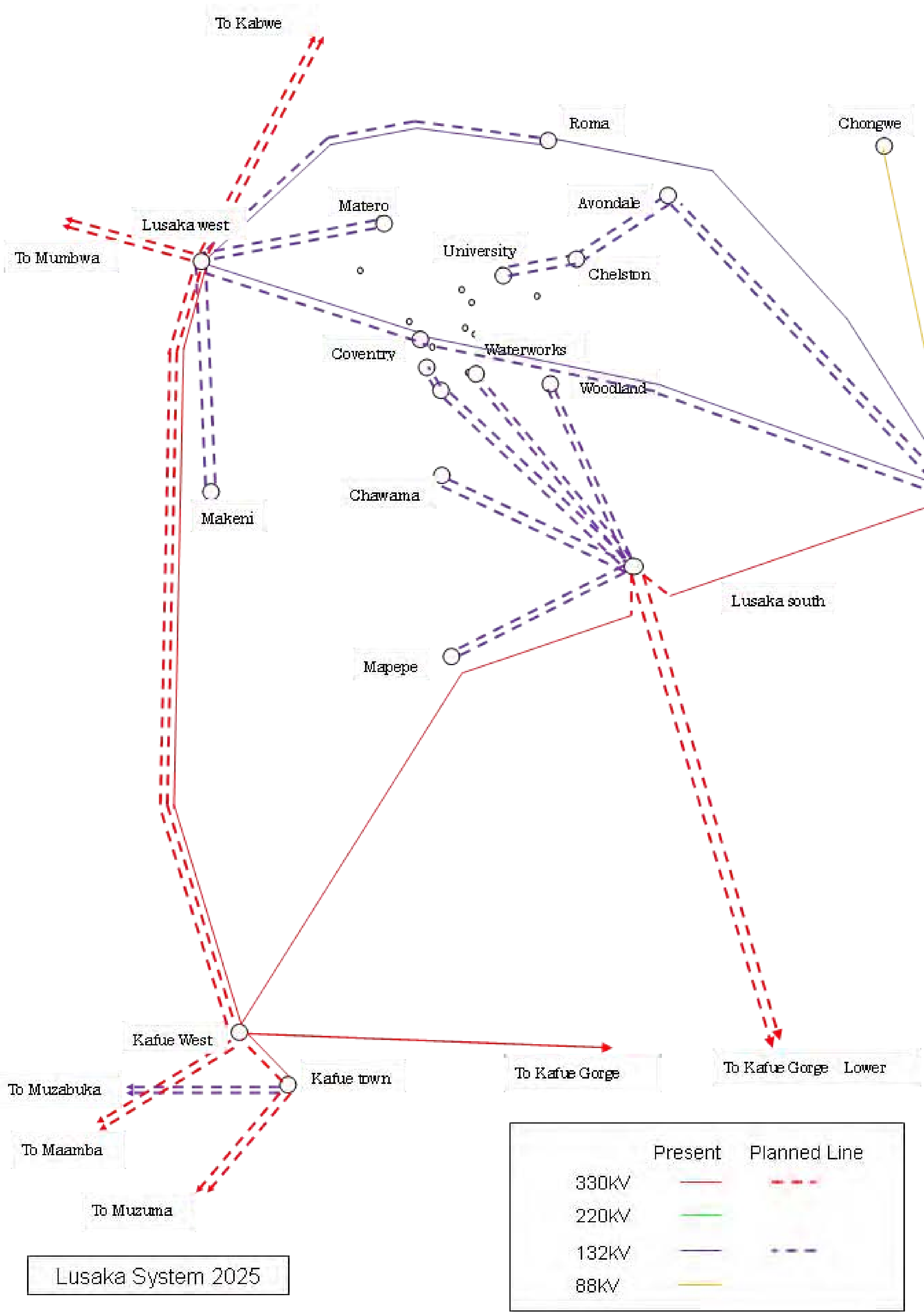

Figure 8.10 Lusaka Power System on 2025 (Scenario1-1)

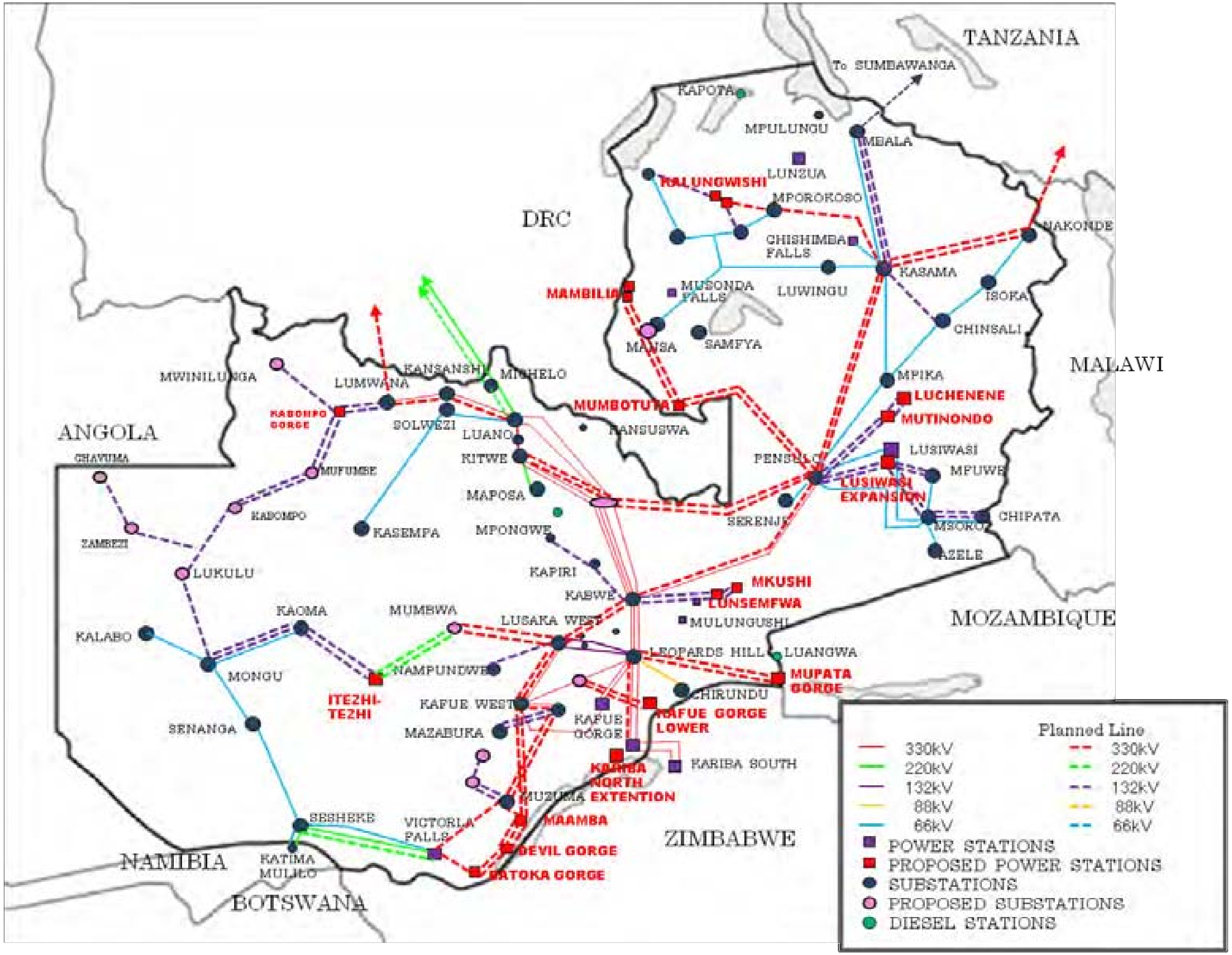

Figure 8.11 **Zambian Power System on 2030 (Scenario1-1)**

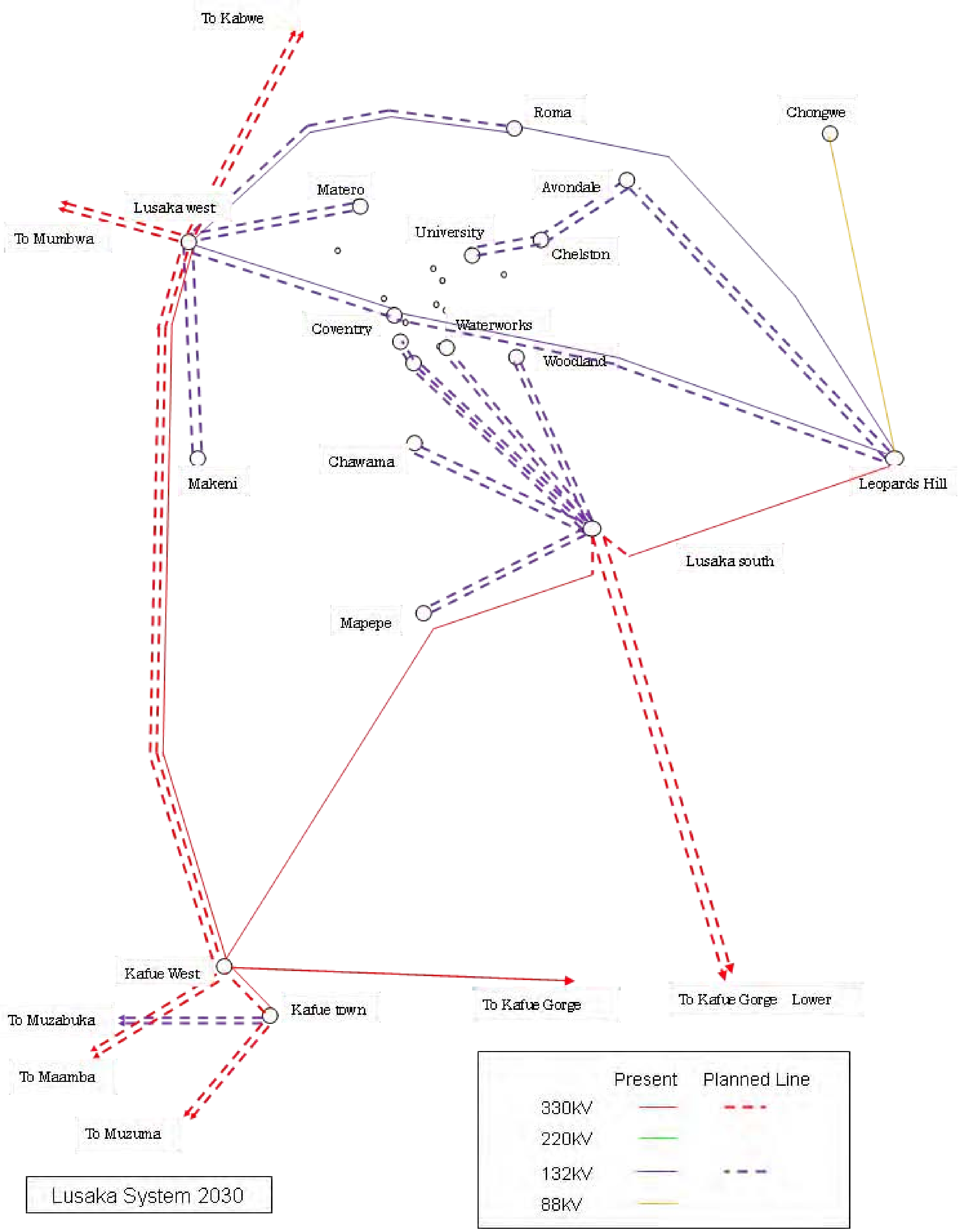

Figure 8.12 Lusaka Power System on 2030 (Scenario1-1)

8.4 Transmission development plan in the scenario 1-2

This transmission plan was formulated based on the results of the case of development of coal-fired thermal power sources (Scenario 1-2). The conditions as regards the demand forecast and international power interchange were the same as in Scenario 1-1. In this scenario, the siting of coal-fired power stations would have a great influence on transmission planning. The locations of the power station sites were taken as Table 8.13.

Table 8.13 Developing Plan of Coal Power Plant

Install year	Capacity (MW)	Location
2014	200	Maamba
2016	300	Maamba
2018	300	Kitwe
2021	300	Kitwe

Of these sites, plans are already moving ahead at that of Maamba, where a mine mouth coal power station is being constructed. The other candidate sites are another at Maamba, which is fairly close to Lusaka and equipped with a good transportation infrastructure, and Kitwe, which is located in the Copperbelt district (a load center) and equipped with a good railway infrastructure. Siting of all coal-fired power generation in Maamba would produce virtually the same transmission system composition as in Scenario 1-1, in which large-scale power sources are concentrated in the Zambezi basin. As such, examinations based on concentration of coal-fired sources in Kitwe was made, which constitutes a case different from that of Scenario 1-1.

The following sections present the transmission plan formulated in each regional area. The descriptions concern mainly the differences from Scenario 1-1.

8.4.1 Northeast area (Scenario 1-2)

In this area, the biggest difference from Scenario 1-1 would be the timing of the input of hydropower stations. In particular, the phase for development of the large-scale hydropower stations at Mambillima and Mumbotuta would be later than in Scenario 1-1, and this would push back the development of 330kV transmission lines to carry power from them. As a result, the development of the 330kV system in this area would also be later than in Scenario 1-1. Table 8.14 shows this difference.

Table 8.14 Plan for 330kV transmission development in the Northeast area

<table>
<tr><th rowspan="2">Name</th><th rowspan="2">Voltage</th><th colspan="2">Year</th><th rowspan="2">Remarks</th></tr>
<tr><th>Scenario1</th><th>Scenario2</th></tr>
<tr><td>Pensulo – Kasama 1st</td><td rowspan="14">330kV</td><td rowspan="6">2010-2015</td><td rowspan="6">2010-2015</td><td rowspan="2">New Circuit
Double Circuit Tower</td></tr>
<tr><td>Pensulo – Kasama 2nd</td></tr>
<tr><td>Pensulo – Kabwe 2nd</td><td>Installation of 2nd circuit</td></tr>
<tr><td>Kasama – Nakonde 1st</td><td rowspan="2">New Circuit
Double Circuit Tower</td></tr>
<tr><td>Kasama – Nakonde 2nd</td></tr>
<tr><td>Kasama – Mporokoso</td><td>New Circuit</td></tr>
<tr><td>Mporokoso - Kalungwishi</td><td>2015-2020</td><td>2015-2020</td><td>New Circuit</td></tr>
<tr><td>Pensulo – Mumbotuta 1st</td><td rowspan="7">2020-2025</td><td rowspan="3">2025-2030</td><td rowspan="2">New Circuit
Double Circuit Tower</td></tr>
<tr><td>Pensulo – Mumbotuta 2nd</td></tr>
<tr><td>Pensulo – New SWS 1st</td><td>New Circuit</td></tr>
<tr><td>Pensulo – New SWS 2nd</td><td rowspan="4">After
2030</td><td rowspan="4">New Circuit</td></tr>
<tr><td>Mumbotuta – Mambilima</td></tr>
<tr><td>Mumbotuta – Mansa</td></tr>
<tr><td>Mansa – Mambilima</td></tr>
</table>

It may be noted that there is no significant difference between scenarios 1-1 and 1-2 in respect of the plan for development of transmission lines with a voltage of no more than 132kV. The delayed installation of the 330kV transmission line between Mumbotuta and Mansa, however, would make the voltage stability situation in the Mansa district harsher than in Scenario 1-1. If the demand in this district increases more rapidly than in the forecast, it would be necessary to take steps such as installing a 132kV transmssion line between Kalungwishi and Mansa.

8.4.2 West area（Scenario1-2）

There is no major difference between scenarios 1-1 and 1-2 as regards the plan for transmission development in this area. Development of the Kabompo Gorge power station would be later than in Scenario 1-1, and electrification of the western districts would require installation of a transmission line between Kabompo Gorge and Lumwana, regardless of whether or not the power source is finished.

8.4.3 South area (Scenario1-2)

In this area, power source development would be later than in Scenario 1-1, and the transmission power flow would be smaller. As compared to Scenario 1-1, the plan would therefore delay construction of trunk transmission lines. Table 8.15 shows the plan for development of trunk transmission lines in this area. For other systems, there would be no difference from Scenario 1-1.

Table 8.15 Plan for trunk transmission line development in the South area

Name	Voltage	Year		Remarks
		Scenario1	Scenario2	
Victoria Falls – Muzuma	330kV	2010-2015	2010-2015	Upgrade from 220kV to 330kV
Muzuma – Kafue Town				
Sesheke - Victoria Falls 2nd	220kV			Installation of 2nd Circuit
Victoria Falls – Maamba	330kV			New Circuit
Maamba – Muzuma				
Maamba- Kafue West 1st				New Circuit Double Circuit Tower
Maamba- Kafue West 2nd				
Devil Gorge Power Station		2015-2020	2020-2025	Installation in Victoria Falls – Maamba Line
Devil Gorge – Maamba 2nd			2025	Installation of 2nd Circuit
Muzuma – Kafue Town 2nd		2020-2025	After 2030	Installation of 2nd Circuit
Batoka Gorge Power Station		2025-2030		Installation in Victoria Falls – Devil Gorge Line
Batoka Gorge – Devil Gorge 2nd				Installation of 2nd Circuit

8.4.4 Lusaka Area (Scenario1-2)

The plan for transmission development in this area in Scenario 1-2 would be almost the same as in Scenario 1-1, but the construction of the 330kV transmission line of Kafue West - Lusaka West - Kabwe would be later than in Scenario 1-1. This is because the input of coal-fired power in the north would reduce the flow of power from south to north by a commensurate amount. Table 8.16 shows the plan for development of 330kV transmission lines in this area.

Table 8.16 Plan for 330kV transmission line development in the Lusaka area

Name	Voltage	Year		Remarks
		Scenario1	Scenario2	
Kafue West – Lusaka West 2nd	330kV	2010-2015	2010-2015	
Lusaka West – Kabwe 1st				New Circuit
Lusaka West – Kabwe 2nd			After 2030	
Lusaka South Substation			2010-2015	Installation in Kafue West – Leopards Hill Line
Kafue West – Lusaka West 3rd		2015-2020	2020-2025	
Kafue Gorge Lower – Lusaka South 1st			2015-2020	New Circuit Double Circuit Tower
Kafue Gorge Lower – Lusaka South 2nd				

8.4.5 Copperbelt (Scenario1-2)

In Scenario 1-2, the construction of coal-fired power stations in this area would greatly improve items such as voltage stability and power flow. There would consequently be no need for measures required to stabilize voltage in Scenario 1-1 (i.e., installation of SVC or a new transmission line), but installation of the intermediate switching station is recommended even in the case of Scenario 1-2, for the following reasons.

- Until construction of the coal-fired power station in Kitwe, the voltage stability would remain poor. This would require installation of the intermediate switching station to curb voltage fluctuation when the transmission line is tripped.
- The switching station would level the current flowing through the Kabwe-Kitwe and Kabwe-Luano transmission lines, and thereby bring a reduction in transmission loss.

8.4.6 Summary of the plan for transmission development in the scenario 1-2

Table 8.17 shows the amount of transmission facilities to be developed in the plan based on coal-fired thermal power development scenario (scenario 1-2), and Table 8-18, the related details. Figures 8.13 – 8.16 present corresponding system diagrams for the years 2010, 2015, 2020, 2025, and 2030. It can be seen that the amount of transmission facilities to be developed would peak in a relatively early phase (2010 - 2015), but the degree of concentration would be lower than in Scenario 1-1. This is because the coal-fired power stations developed in the Kitwe district would reduce the flow of power through transmission lines to the north, and this reduction would relax conditions in respect of both thermal capacity and voltage stability relative to Scenario 1-1.

Table 8.17 Amount of transmission facility development (kms) in Scenario 1-2

Year	Voltage of Transmission Line (kV)			
	66	132	220	330
2010-2015	194	2,562	599	3,668
2015-2020	5	1,474	0	205
2020-2025	0	261	0	104
2025-2030	0	236	0	1,203

Table 8.18 **Transmission development plan (Scenario 1-2)**

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
3	Kariba North	Leopards Hill	2010-2015	123	330	2-Bison
2	Kabwe	Pensulo	2010-2015	298	330	2-Bison
1	Kabwe	Lusaka West	2010-2015	100	330	2-Bison
2	Luano	Kansanshi	2010-2015	197	330	2-Bison
1	Pensulo	Kasama	2010-2015	380	330	2-Bison
2	Pensulo	Kasama	2010-2015	380	330	2-Bison
1	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Lsaka West	2010-2015	34	330	2-Bison
1	Kafue Town	Muzuma(UP Grade)	2010-2015	189	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Kasama	Nakonde	2010-2015	210	330	2-Bison
2	Kasama	Nakonde	2010-2015	210	330	2-Bison
1	Kasama	Mporokoso	2010-2015	150	330	2-Bison
1	Victoria Falls	Muzuma(UP Grade)	2010-2015	159	330	2-Bison
1	Victoria Falls	Batoka Gorge	2010-2015	40	330	2-Bison
1	Victoria Falls	Muzuma	2010-2015	159	330	2-Bison
1	Batoka Gorge	Devil Gorge	2010-2015	70	330	2-Bison
1	Devil Gorge	Maamba	2010-2015	70	330	2-Bison
1	Maamba	Muzuma	2010-2015	55	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Luano	Michelo	2010-2015	31.9	220	2-HD153
1	Luano	Stadium	2010-2015	16.4	220	2-Lion
2	Luano	Stadium	2010-2015	16.4	220	2-Lion
1	Michelo	Bankroft	2010-2015	10	220	2-HD153
2	Michelo	Bankroft	2010-2015	10	220	2-HD153
2	Victoria Falls	Sesheke	2010-2015	224	220	Bison
1	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Coventry	Leopards Hill	2010-2015	28	132	Wolf
2	Coventry	Lusaka West	2010-2015	7	132	Wolf
2	Roma	Lusaka West	2010-2015	15	132	Wolf
1	Leopards Hill	Avondale	2010-2015	15	132	Zebra

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
2	Leopards Hill	Avondale	2010-2015	15	132	Zebra
1	Kasama	Mbala	2010-2015	161	132	Wolf
2	Kasama	Mbala	2010-2015	161	132	Wolf
1	Kasama	Chinsali	2010-2015	105	132	Wolf
1	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
2	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
1	Pensulo	Kanon	2010-2015	20	132	Wolf
2	Pensulo	Kanon	2010-2015	20	132	Wolf
1	Pensulo	Mutindo	2010-2015	110	132	Wolf
2	Pensulo	Mutindo	2010-2015	110	132	Wolf
1	Lusiwasi	Msoro	2010-2015	115	132	Wolf
2	Lusiwasi	Msoro	2010-2015	115	132	Wolf
1	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
2	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
1	Kabwe	Kapiri Mposhi	2010-2015	96	132	Wolf
1	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
2	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
1	Kaoma	Mongu	2010-2015	185	132	Wolf
1	Nampundwe	Lusaka West	2010-2015	60	132	Wolf
1	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
2	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
1	Mazabuka	Monze	2010-2015	60	132	Wolf
1	Mapepe	Lusaka South	2010-2015	20	132	Wolf
2	Mapepe	Lusaka South	2010-2015	20	132	Wolf
1	Lusaka South	Waterworks	2010-2015	14	132	Zebra
2	Lusaka South	Waterworks	2010-2015	14	132	Zebra
1	Lusaka South	Woodlands	2010-2015	13	132	Zebra
2	Lusaka South	Woodlands	2010-2015	13	132	Zebra
1	Lusaka South	Coventry A	2010-2015	21	132	Zebra
2	Lusaka South	Coventry A	2010-2015	21	132	Zebra
1	Coventry A	Coventry B	2010-2015	1	132	Zebra
2	Coventry A	Coventry B	2010-2015	1	132	Zebra
1	Muzuma	Choma	2010-2015	26	132	Wolf
2	Muzuma	Choma	2010-2015	26	132	Wolf
1	Choma	Monze	2010-2015	80	132	Wolf
1	Mutinond	Luchene	2010-2015	45	132	Wolf

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
2	Mutinond	Luchene	2010-2015	45	132	Wolf
2	Stadium	Avenue	2010-2015	1.27	66	2-HD124
3	Stadium	Avenue	2010-2015	1.27	66	2-HD124
2	Chisenga	Luano	2010-2015	11.4	66	Lynx
2	Mufulira	Kankoyo	2010-2015	0.4	66	2-HD124
2	Maposa	Dola Hill	2010-2015	21.3	66	Lynx
1	Maposa	Pamodzi	2010-2015	25	66	Lynx
2	Maposa	Pamodzi	2010-2015	25	66	Lynx
2	Ndola Refinery	Skyways	2010-2015	1.5	66	HD124
2	Pamodzi	Depot Road	2010-2015	6.3	66	Lynx
2	Kanon	Kaomb	2010-2015	21	66	Wolf
2	KZNGL	Victoria Falls	2010-2015	80	66	Wolf
	New SWS (Internal of Kabwe – Kitwe, LuanoLine)		2010-2015			
	Lusaka South SS (Internal of Leopards Hill – Kafue West Line)		2010-2015			
1	Kundabwika	Mporokoso	2015-2020	95	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Kitwe	Kitwe Coal	2015-2020	10	330	2-Bison
2	Kitwe	Kitwe Coal	2015-2020	10	330	2-Bison
1	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
2	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
1	Kundabwika	Nchelenge	2015-2020	75	132	Wolf
1	Kabwelume	Kawambwa Tea	2015-2020	30	132	Wolf
1	Msoro	Chipata	2015-2020	80	132	Wolf
2	Msoro	Chipata	2015-2020	80	132	Wolf
1	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
2	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
1	Kabwe	BRKHL	2015-2020	3	132	Wolf
2	Kabwe	BRKHL	2015-2020	3	132	Wolf
1	Kapiri Mposhi	Mpongwe	2015-2020	60	132	Wolf
1	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
2	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
1	Kabompo Gorge	Mwinilunga	2015-2020	100	132	Wolf

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
1	Kabompo Gorge	Mufumbwe	2015-2020	110	132	Wolf
1	Mufumbwe	Kabompo	2015-2020	105	132	Wolf
1	Kabompo	Mumbeji	2015-2020	80	132	Wolf
1	Mongu	Lukulu	2015-2020	160	132	Wolf
1	Lukulu	Mumbeji	2015-2020	80	132	Wolf
1	Mumbeji	Zambezi	2015-2020	75	132	Wolf
1	Zambezi	Chavuma	2015-2020	80	132	Wolf
1	Lusaka South	Chawama	2015-2020	6	132	Wolf
2	Lusaka South	Chawama	2015-2020	6	132	Wolf
1	University	Chelston	2015-2020	5	132	Zebra
2	University	Chelston	2015-2020	5	132	Zebra
1	Avondale	Chelston	2015-2020	5.7	132	Zebra
2	Avondale	Chelston	2015-2020	5.7	132	Zebra
3	Ndola Refinery	Skyways	2015-2020	1.5	66	HD124
2	Dola Hill	Pamodzi	2015-2020	3.7	66	Lynx
3	Kafue West	Lsaka West	2020-2025	34	330	2-Bison
2	Devil Gorge	Maamba	2020-2025	70	330	2-Bison
1	Mukushi	Lunsemfwa	2020-2025	10	132	Wolf
2	Mukushi	Lunsemfwa	2020-2025	10	132	Wolf
2	Kaoma	Mongu	2020-2025	185	132	Wolf
1	Makeni	Lusaka West	2020-2025	13	132	Zebra
2	Makeni	Lusaka West	2020-2025	13	132	Zebra
1	Matero	Lusaka West	2020-2025	15	132	Zebra
2	Matero	Lusaka West	2020-2025	15	132	Zebra
3	Kitwe	New SWS	2025-2030	91	330	2-Bison
1	Leopards Hill	Mpata Gorge	2025-2030	255	330	2-Bison
2	Leopards Hill	Mpata Gorge	2025-2030	255	330	2-Bison
1	Pensulo	Mumbotuta	2025-2030	190	330	2-Bison
2	Pensulo	Mumbotuta	2025-2030	190	330	2-Bison
1	Pensulo	New SWS	2025-2030	219	330	2-Bison
2	Kafue West	Kafue Town	2025-2030	3	330	2-Bison
2	Kabompo Gorge	Mufumbwe	2025-2030	110	132	Wolf
2	Mufumbwe	Kabompo	2025-2030	105	132	Wolf
3	Lusaka South	Coventry A	2025-2030	21	132	Zebra

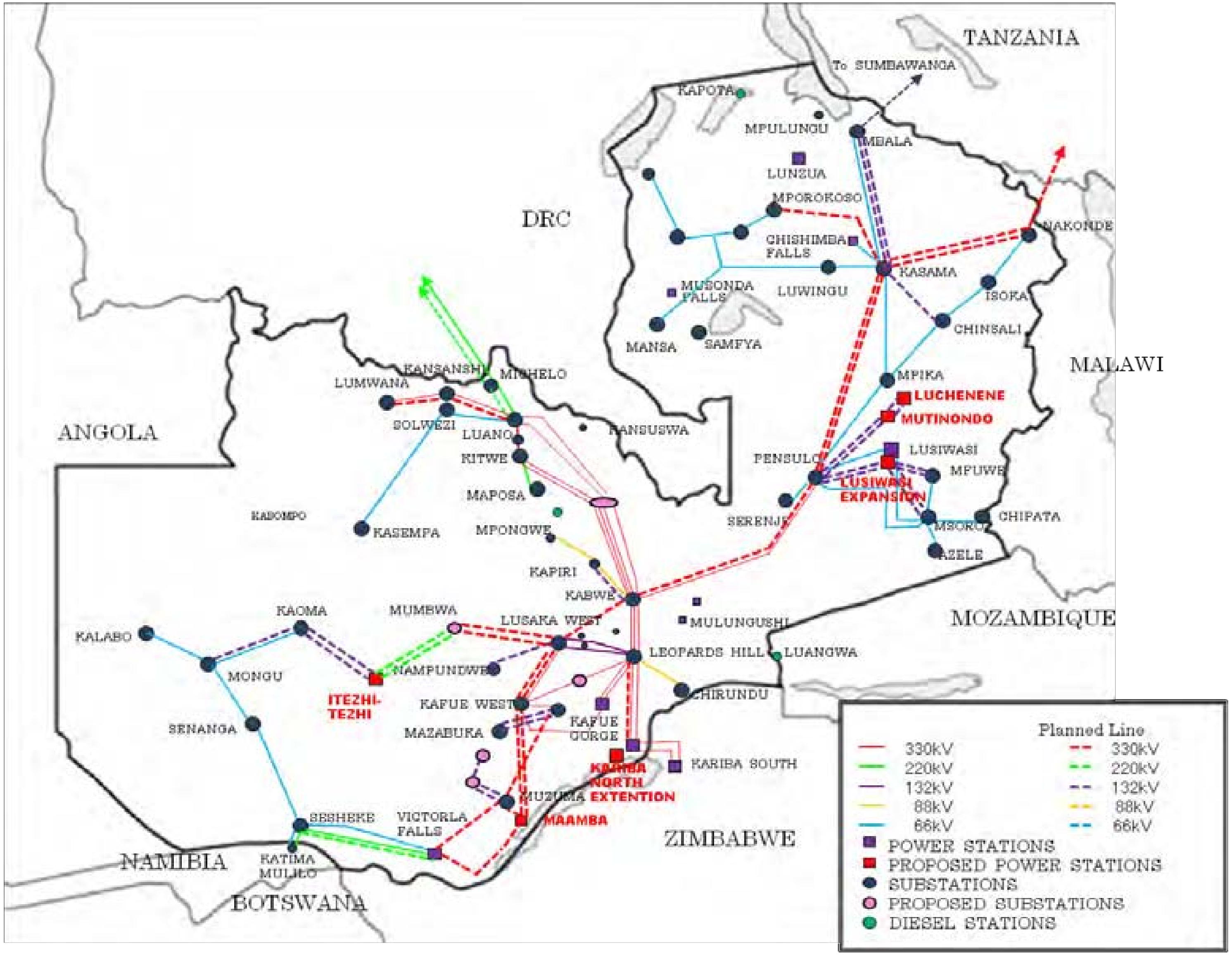

Figure 8.13 Zambian Power System on 2015 (Scenario 1-2)

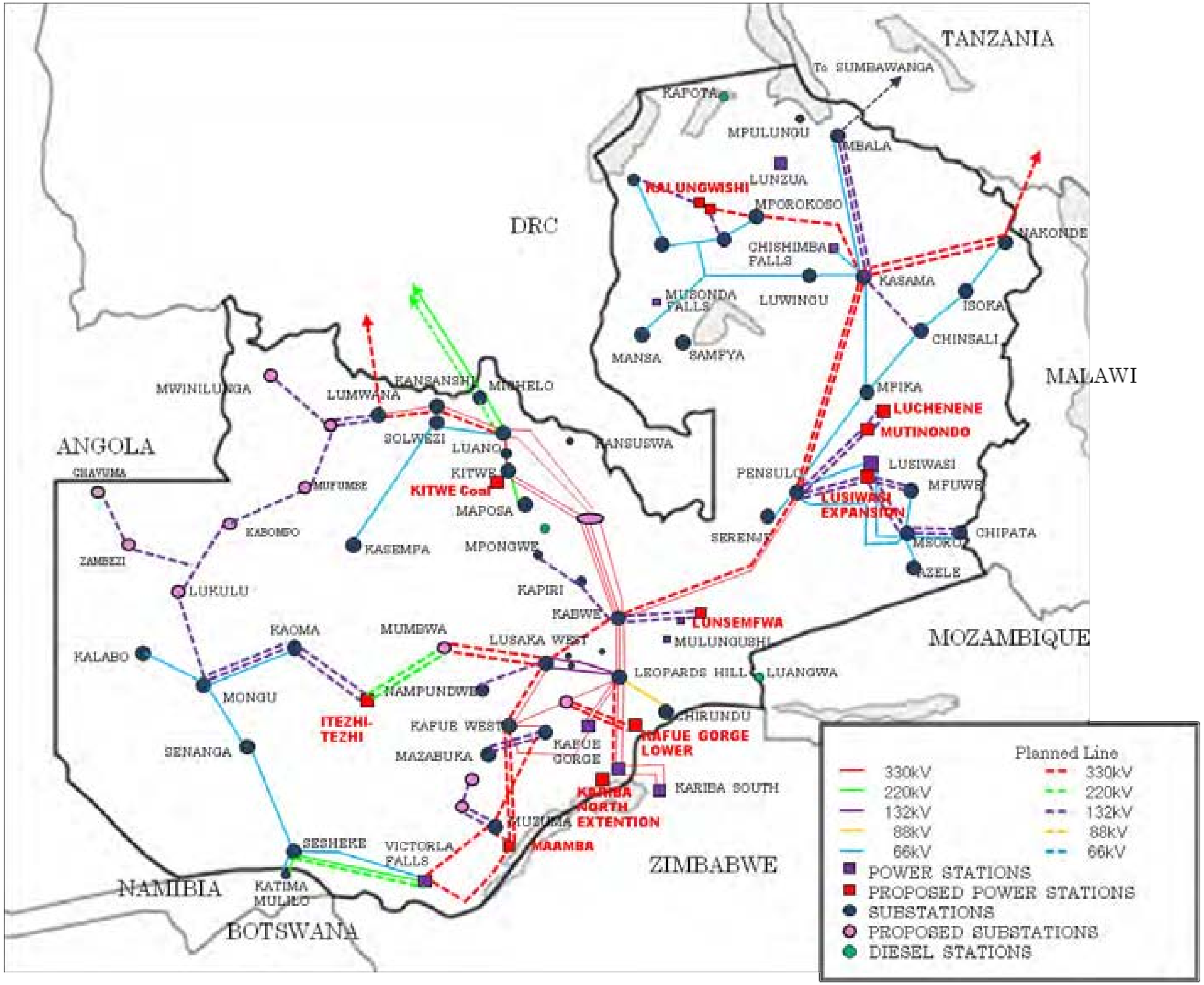

Figure 8.14 Zambian Power System on 2020 (Scenario 1-2)

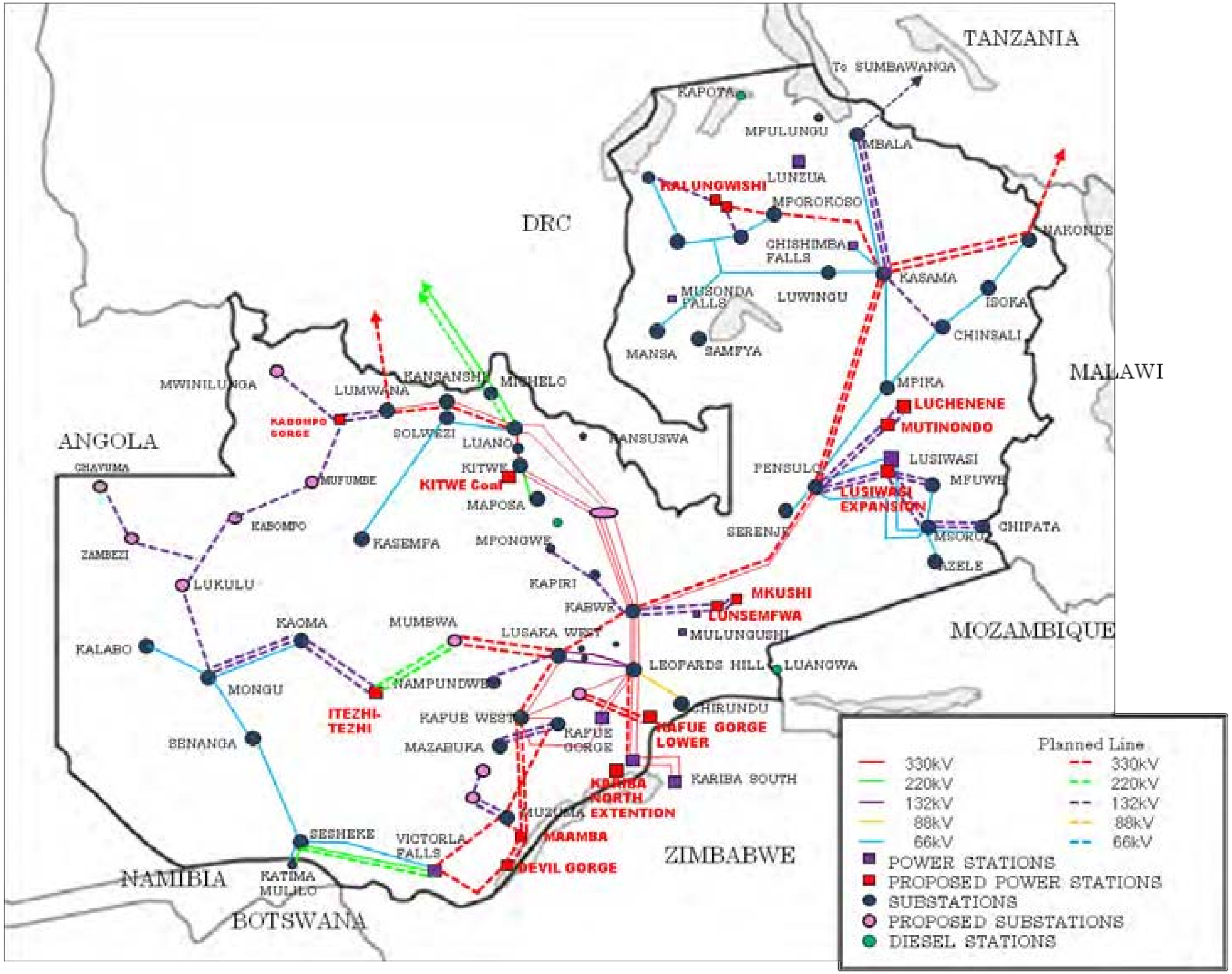

Figure 8.15 Zambian Power System on 2025 (Scenario 1-2)

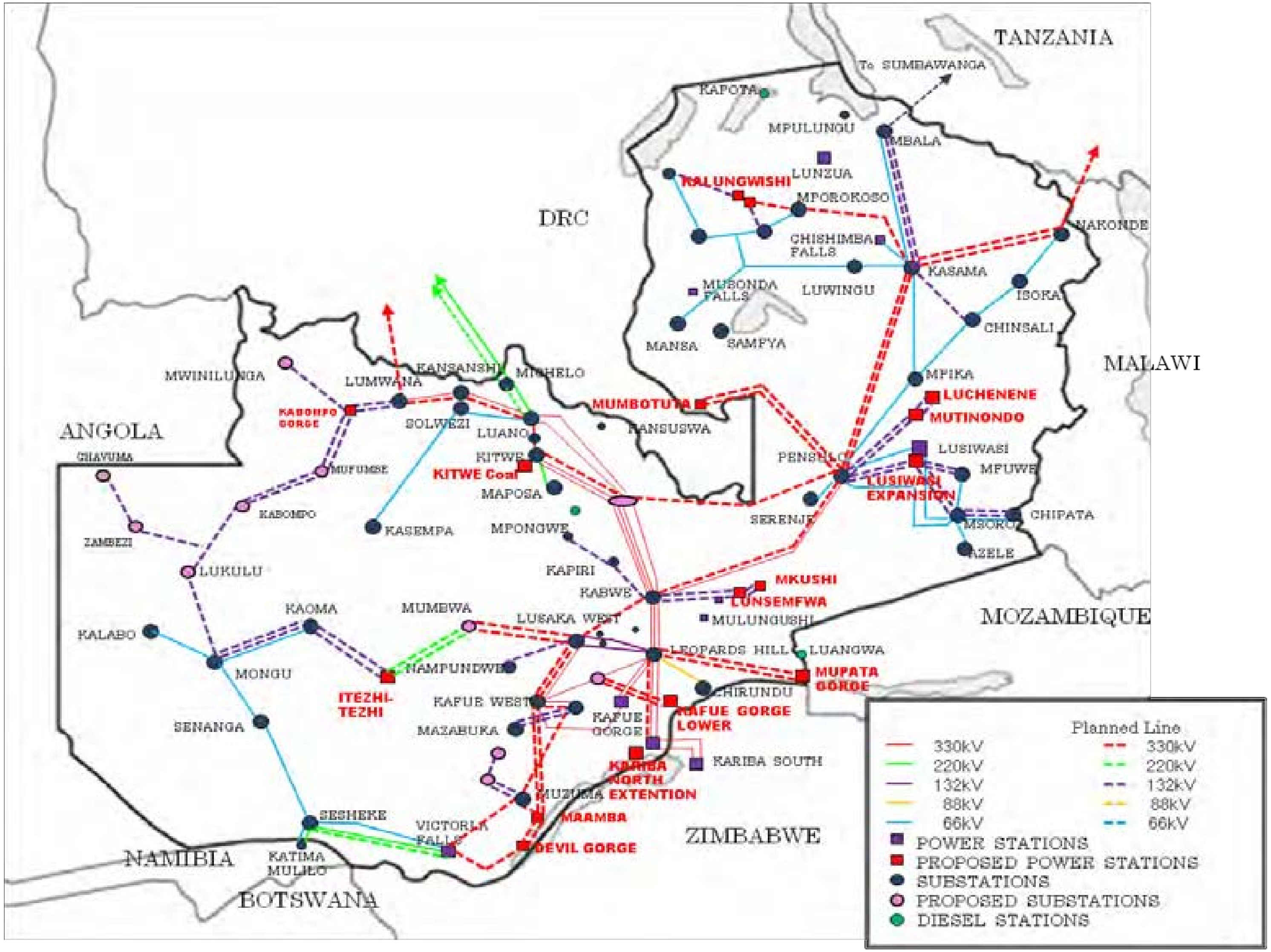

Figure 8.16 Zambian Power System on 2030 (Scenario 1-2)

8.5 Summary of transmission development plans

This section presents the cost of transmission development and transmission loss to summarize the plans prepared for transmission development. Table 8.19 shows the transmission development costs in Scenario 1-1, and Table 8.20, those in Scenario 1-2. These cost figures were calculated on the basis of equipment costs in 2008, and do not reflect factors such as future inflation rates.

Table 8.19 Transmission development cost in Scenario 1-1 (million USD)

Year	Transmisson Line	Switchgear	Transformer	Total
2010-2015	1,324	133	126	1,583
2015-2020	295	33	42	371
2020-2025	597	52	27	675
2020-2030	74	8	16	98
Total	2,290	226	211	2,728

Table 8.20 Transmission development cost in Scenario 1-2 (million USD)

Year	Transmisson Line	Switchgear	Transformer	Total
2010-2015	1,324	133	126	1,583
2015-2020	259	29	35	324
2020-2025	41	9	35	86
2020-2030	310	25	13	348
Total	1,934	197	210	2,341

From these tables, it can be seen that the cost of transmission development in Zambia would be very high and in 2030 reach a cumulative USD2.7 billion in Scenario 1-1 and USD2.3 billion in Scenario 1-2. The amounts required in the 2010 - 2015 phase would be particularly high, accounting for more than 50 percent of the total to 2030. The reason is that the transmission system in Zambia at present is operating under extremely tough conditions, and to meet any further demand increase will require a substantial increase in the trunk system and other component systems.

It also can be seen that Scenario 1-2 has generally lower development costs than Scenario 1-1 and would shift the development to a later phase (2025 - 2030). This is because the construction of coal-fired power stations at Kitwe would reduce the flow of power from south to north, and the development at Mambilima and Mumbotuta would be delayed.

Table 8.21 shows the transmission loss at peak time periods in 2010, 2015, 2020, 2025, and 2030.

Table 8.21 Transmission system loss at peak load in Zambia

Year	Peak Load (MW)	Scenario1-1				Scenario1-2			
		With IC*1		Without IC*2		With IC*1		Without IC*2	
		(MW)	(%)	(MW)	(%)	(MW)	(%)	(MW)	(%)
2010	1689.6	-	-	110.8	6.6	-	-	-	-
2015	2366.6	158.9	6.7	129.9	5.5	159.3	6.7	129.8	5.5
2020	2771.7	208.4	7.5	145.1	5.2	183.2	6.6	120.0	4.3
2025	3245.78	203.2	6.3	145.4	4.5	195.1	6.0	123.1	3.8
2030	3877.86	278.1	7.2	203.5	5.2	219.1	5.7	148.8	3.8

***1:** In the case of power import and export through international interconnections, under the conditions shown in Table 8-3.

***2:** In the case of no transmission or reception of power through international interconnections.

From this table, it can be seen that, with the transmission development, the loss rate would become somewhat lower relative to 2010 beginning in 2015. Due to the influence of the coal-fired power development in Kitwe, Scenario 1-2 would have less transmission loss than Scenario 1-1.

International interchange applying additional load on the Zambian system would entail higher loss. In certain cases, it would result in loss of more than 70 MW more than in the case of no international interchange in 2030. As this indicates, regular performance of power interchange requires consideration of transmission loss.