Chapter 4 Regional Cooperation in Power Sector

Kenya’s power grid is linked with that of neighboring Uganda on the west side with a 132kV transmission line through which power is mutually shared. Kenya and Uganda thus have their electric power grids integrated into a single system. Moreover, there is a plan in which large amount of power will be brought from neighboring Ethiopia on the north with a Direct Current transmission line. Under these circumstances, the study team visited both Uganda and Ethiopia to conducted site survey on their electric power sectors.

3.1 Activities of East Africa Power Pool

3.1.1 East Africa Power Pool (EAPP)

In working out a national electric power development plan, it is understood that not only power generation and power system (transmission lines and substation systems) of own country are very important but also taking wide range view such as "Regional Power Sharing” where power is shared with neighboring countries. It would enable Kenya to import inexpensive power from neighboring countries where primary energy such as hydro-power is abundant. This concept of sharing electric power among a group of countries has come to be recognized as very important policy in African continent, where economic growth and increase of population are quite remarkable, and a number of such power pooling systems can be found.

Among them, South African Power Pool (SAPP), having its base in South Africa, is boasting the largest scale with as many as 12 member countries. On the other hand, East African Power Pool (EAPP) in which Kenya is a member country was founded in May, 2005, 10 years behind SAPP, upon signing of collective notes by the 9 member countries of Common Market for Eastern & Southern Africa (COMESA) and Nile Basin Initiative (NBI). Its headquarters is located in Addis Ababa where, it still is in infancy, preparatory activities are being performed such as organizing staff, laying down rules of operation etc.

Member countries are Burundi, Ethiopia, Kenya, Rwanda, Sudan, Uganda, Tanzania, Congo, and Egypt [1]. However, only Kenya and Uganda and part of Tanzania have attained certain degree of integration of their electric power grids that could qualify as “power pool” in real sense of the word.

With a view to strengthen function of EAPP, ministers of energy of Eastern Africa Community (EAC) decided to prepare East African Power Master Plan (EAPMP). The contract between EAC and BKS Acres (Canadian consultant) was made for carrying out the Master Plan study in March 2003. Phase-I for EAPMP was completed in September 2004, and Phase-II for EAPMP

---

[1] Study on the Interconnection of the Electricity Networks of the Nile Equatorial Lakes Countries, Feasibility Report, Volume 1, pp.2 of ANNEX A.

was completed in March 2005. In the Master Plan, concrete action programs are presented concerning interconnection of electric power systems among Kenya, Uganda and Tanzania. In addition, the national newspaper BUSINESS DAILY dated July 6, 2009 announced that EAC will update Phase-II of EAPMP by taking another 15 months.

At present, it is noteworthy that at present Uganda and Tanzania are suffering from shortage of power that was caused by drop of water table in water reservoirs for power stations under prolonged drought. This situation furthered expectation for a scheme to distribute cheap power from Ethiopia who has huge hydro-power potential within the region on medium to long term basis.

3.1.2 East Africa Power Master Plan (EAPMP)

The final Phase-II report of EAPMP submitted by BKS Acres in March 2005 recommends to formulate cross-border interconnection lines between Kenya, Uganda, and Tanzania, rather than construct independent power system in each country, because of the profits of efficient utilization of generating facilities or cheaper generation cost, etc. This report is still effective.

(1) Demand Forecast

Demand forecast from EAPMP Phase-II is shown in Table 4-1.1. Comparing with the demand forecast in EAPMP, the corresponding forecast from KPLC's LCPDP is drastically increased. For example, EAPMP forecasts average rate of demand growth in Kenya from 2010 - 2025 as 5.45%, while LCPDP forecasts as 10.43%.

Table 4-1.1 Demand Forecast (EAPMP and LCPDP)

Year	Energy (GWh)				Peak demand (MW)				
	Kenya	Uganda	Tanzania	Combined	Kenya	Uganda	Tanzania	Combined	KPLC's LCPDP in 2008
2001	4,476	1,437	2,654	8,381	712	270	465	1,465	
2002	4,623	1,506	2,708	8,837	793	283	475	1,511	
2005	5,303	1,684	3,334	10,322	877	317	589	1,738	
2010	7,092	2,280	4,434	13,806	1,173	418	792	2,322	1,267
2015	9,254	3,383	5,526	18,163	1,531	616	986	3,053	2,112
2020	12,067	5,007	6,868	23,942	1,996	902	1,223	4,017	3,474
2025	15,728	7,453	8,518	31,699	2,602	1,334	1,515	5,314	5,611
2002-10	5.49%	5.32%	6.36%	5.74%	5.02%	5.00%	6.60%	5.52%	
2010-25	5.45%	8.21%	4.44%	5.70%	5.45%	8.04%	4.42%	5.67%	10.43%

Source : The East African Power Master Plan Study Final Phase II Report

(2) Method of Establishing System Planning

For establishing future power system, the following 3 cases are compared in EAPMP.

i) Case-1: Independent System
To establish independent power system in each country

ii) Case-2: Interconnection
To construct cross-border transmission line between Kenya, Uganda, Tanzania, and also Zambia.

iii) Case-3: One integrated system
To construct one complete system integrating Kenya, Uganda, and Tanzania, as if those three are a single country.

In the comparison of the planning, the following conditions are considered.

- LOLE : Loss of load expectation : 10 days / year
- Discount rate : 12% (9% case and 15% case are also considered)
- Price of imported oil : US$ 25 / barrel
- Price of imported coal : US$ 27 / ton (Price at Mombasa port)
- Tax for emission of exhaust from thermal plants : US$ 10 / ton
- Loss for blackout : US$ 0.71 / kWh

Economical comparison of the 3 cases is made between capital investment in 20 years duration from 2004 to 2023, and operation cost (fuel cost and maintenance charge) in 35 years duration from 2004 to 2038. All the costs in future were converted to the value of the year 2004. However, in the period from 2024 to 2038, additional investment and additional increase of demand, change of fuel price, are not considered.

(3) Candidates of Power Development

Candidates of hydro and thermal power plants considered in EAPMP study were listed in Table 4-1.2 and Table 4-1.3.

Table 4-1.2 Candidates of Hydro Power Plants

Project	Total capacity (MW)	Unit cost of energy ($/kWh)
Bujagali 5th unit	50	0.017
Mpanga	144	0.030
Ruhudji	358	0.034
Kalagala	450	0.034
Masigira	118	0.038
Ayago North	304	0.038
Karuma	200	0.039
Ayago South	234	0.041
Mandera	21	0.043
Rumakali	222	0.056

Source : The East African Power Master Plan Study Final Phase II Report

Table 4-1.3　Candidates of Thermal Power Plants

Country	Thermal Plants
Uganda	30 MW, 60 MW Combustion Turbines and associated Combined Cycle
Kenya	60 MW, 90 MW Combustion Turbines and associated Combined Cycle, 150 MW Coal, 70 MW Geothermal
Tanzania	60 MW Combustion Turbines and associated Combined Cycle (both gas and IDO), Mchuchuma, 150 MW Coal

Source :The East African Power Master Plan Study Final Phase II Report

(4) Power Development and Its Cost

i) Case-1 : Independent System

In this case, each country will develop generating plants considering its own available energy sources (water or oil etc.) in their own countries. Each country will maintain appropriate Reserve Margin, and will construct transmission lines from generating plants to demand centers.

Amounts of necessary generating facilities from 2004 to 2023 are ; 1,645MW in Kenya, 995MW in Uganda, 798MW in Tanzania. The total is 3,438MW.

Necessary power sources until 2023 in Kenya are shown in Table 4-1.4, and Table 4-1.5. Mombasa coal fired thermal or new Geo-thermal facilities are also considered in KPLC's LCPDP.

For the transmission lines, 220kV Olkaria－Lessos, 2 circuits lines are also proposed. In this plan, one circuit of this line directly connect Olkaria and Lessos while another goes via. Nakuru (Lanet) S/S by constructing new 220kV Nakuru S/S. Lessos－Kisumu line is planned to be 220kV because the plan considered 360MW gas combustion turbine/combined cycle plant in Kisumu and thus, such new line becomes necessary.

Table 4-1.4 Development Plan for Generating Plants in Kenya (Case-1 ; 2005~2023)

Type	Capacity (MW)	Location
Coal fired thermal	750	Mombasa
Geo-thermal	455	Specific site
Combustion turbine/combined cycle	360	Kisumu (assumed for study purpose)
Others	80	
Total	1,645	

Source : The East African Power Master Plan Study Final Phase II Report

Table 4-1.5 Development Plan for Transmission Facilities in Kenya (Case-1; 2005 - 2023)

Lines	No. of circuits	Voltage (kV)	Length (km)
Olkaria－Lessos	1	220	170
Olkaria－Nakuru－Lessos	1	220	170
Lessos－Kisumu	1	220	80
Lessos－Muhoroni	1	132	57
Muhoroni－Chemost	1	132	31
Kisumu－Muhoroni	1	132	49
Rabai－Embakasi	2	330	440

Source : The East African Power Master Plan Study Final Phase II Report

The costs required in this case are shown in Table 4-1.6 below.　The costs are calculated by converting investigation and operating costs for 35 years into the present values (year 2004).

Table 4-1.6　Cost for Case-1 (Independent System)

Country	Cost (Million US$)		
	Generation	Transmission	Total
Uganda	314	98	412
Kenya	2,409	142	2,551
Tanzania	823	115	930
Total	3,546	355	3,901

Source : The East African Power Master Plan Study Final Phase II Report

ii)　Case-3 : One Integrated System

By integrating systems of three countries into one system, power source can be effectively utilized. This means the reserve margin can be shared by the member countries so that it can be minimized.　Total capacity of the necessary generating system can also be minimized. Developed capacity of new generating facilities will be 1,015MW in Kenya, 1,073MW in Uganda, 942MW in Tanzania, and 3,030MW in total. This is 408MW less than the total capacity of Case-1, 3,438MW. Development of generating capacities in Kenya in the period of 2005 - 2023 is shown in Table 4-1.7.　In comparison with Table 4-1.4 for Case-1, the differences of capacity decrease of coal fired thermal and combustion turbine/combined cycle are conspicuous.

Table 4-1.7 Development Plan for Generating Plants in Kenya (Case-3 ; 2005~2023)

Type	Capacity (MW)	Location
Coal fired thermal	300	Mombasa
Geo-thermal	455	Specific site
Combustion turbine/combined cycle	180	Kisumu (assumed for study purpose)
Others	80	
Total	1,015	

Source : The East African Power Master Plan Study Final Phase II Report

The development plan for transmission lines in Kenya (Case-3) is shown in Table 4-1.8. Interconnection of minimum power sources for their effective operation becomes necessary so that cross-border interconnection lines, such as 220kV Tororo－Lessos line between Uganda and Kenya, and 330kV Arusha－Embakasi line between Tanzania and Kenya are recommended. Meanwhile, increase of power import will affect internal power flow in Kenya. Rabai－Embakasi line is 330kV in Case-1, however, it becomes 220kV in Case-3 and it decreases investment. 220kV Lessos－Kisumu line which was recommended in Case-1 became unnecessary because the combustion turbine/combined cycle plant in Kisumu became much smaller.[2]

Under such circumstances, differences of costs in transmission line augmentation between Case-1 and Case-3 are not large. Economical advantage of Case-3 is mainly due to reduction of development costs for generating facilities.

Table 4-1.8 Development Plan for Transmission Facilities in Kenya (Case-3 ; 2005 - 2023)

Lines	No. of circuits	Voltage (kV)	Length (km)
Arusha－Embakasi	1	330	150(Kenya),110(Tanzania)
Tororo－Lessos	2	220	120(Kenya),35(Uganda)
Olkaria－Lessos	1	220	170
Olkaria－Nakuru	1	220	70
Lessos－Muhoroni	1	132	57
Muhoroni－Chemost	1	132	31
Kisumu－Muhoroni	1	132	49
Rabai－Embakasi	1	220	440

Source : The East African Power Master Plan Study Final Phase II Report

The costs required in this case are shown in Table 4-1.9 below. The costs are calculated

---

[2] In this study of EAPMP, 220kV Lessos - Kisumu line became unnecessary. However, as described in 4.1.2 of this Chapter, the present demand forecasted in LCPDP is much larger than the demand of EAPMP, and the line becomes again necessary for transmitting power from Lessos to Kisumu.

by converting investigation and operating costs for 35 years into the present values (year 2004).

Table 4-1.9 Cost for Case-3 (One Integrated System)

Cost (Million US$)		
Generation	Transmission	Total
2,955	489	3,445

Source : The East African Power Master Plan Study Final Phase II Report

(5) Economical Analysis

Cost comparison of Case-1 (Independent system) and Case-3 (One integrated system) is shown in Table 4-1.10. In this table, rate of loan is set as 12%. And the cases of 9% and 15% are also shown.

Efficient use of generating facilities and decrease of reserve margin will decrease the investment cost for Case-3. Case-3 has advantages.

Table 4-1.10 Cost Comparison of "Independent System" and "One Integrated System"

Scenario	9%	12%	15%
(i) Independent System	5,094 MUS$	3,901 MUS$	3,099 MUS$
(ii) One Integrated System	4,401 MUS$	3,445 MUS$	2,784 MUS$
Benefit (a-b)	693 MUS$	456 MUS$	315 MUS$
B/C Ratio (a/b)	1.16	1.13	1.11

Source : The East African Power Master Plan Study Final Phase II Report

(6) System Recommended under EAPMP

The power system recommended in EAPMP is shown in Figure 4-1.1. 220kV Olkaria - Nairobi North line, augmentation of Olkaria-Lessos line inside of Kenya, and 330kV Arusha - Embakashi line as an interconnection line with Tanzania, augmentation of 220kV Tororo - Lessos line as an interconnection line with Uganda, are shown. 220kV Olkaria - Nairobi North line had been already constructed.

Source : The East African Power Master Plan Study Final Phase II Report

Fig. 4-1.1 Power System of East African Power Master Plan

4.2 Power Sector in Uganda and Export to Kenya

4.2.1 Power Sector

In Uganda, electric power had been generated and distributed solely by Uganda Electricity Board (UEB). In 1999, restructuring the power sector was executed according to revision of the electric power law, where pyramid-type management of UEB was converted to function-oriented management creating Uganda Electricity Generation Co. Ltd (UEGCL), Uganda Electricity Transmission Co. Ltd (UETCL), Uganda Electricity Distribution Co. Ltd (UEDCL), and Rural Electrification Agency (REA).

In power generation section, while existing generation facilities were all transferred to UEGCL, renovation and new installation of facility are going to be entrusted to private sector on long term agreement. In power transmission section, UETCL operates and maintains those lines in higher voltage than 33kV as its own property. In distribution section, UEDCL is responsible for lines in voltage of 33kV or less who in practice is contracting out to UMEME (joint venture of UK and South African investors) for operation and maintenance.

4.2.2 Power Demand

(1) Peak Demand and Energy Demand

Table 4-2.1 and 4-2.2 show trend of peak demand and energy demand in Uganda. In 2007, water intake to Owen Falls power station was restricted to counter drop in water level of Victoria Lake under prolonged drought allowing only 80% of full output capacity. This in turn worked as an oppressive force on the power demand resulting in a negative growth in 2007 . This trend since has turned around to upward trend.

Demand forecast was carried out on three scenarios, with a result of growths high 9.7%, moderate 7.7% and low 5.0%.

Table 4-2.1 Past and Forecast of Peak Demand in Uganda (Moderate scenario: 7.7% growth)

Year	2007	2008	2009	2010	2011	2012	2013		2018		2023
Peak demand (MW)	368	387	425	456	485	519	552		804		1227
Growth rate (%)	-0.5	5.2	9.8	7.3	6.4	7.0	6.4		7.8		8.8

Source：UETCL Grid development plan 2008-2023

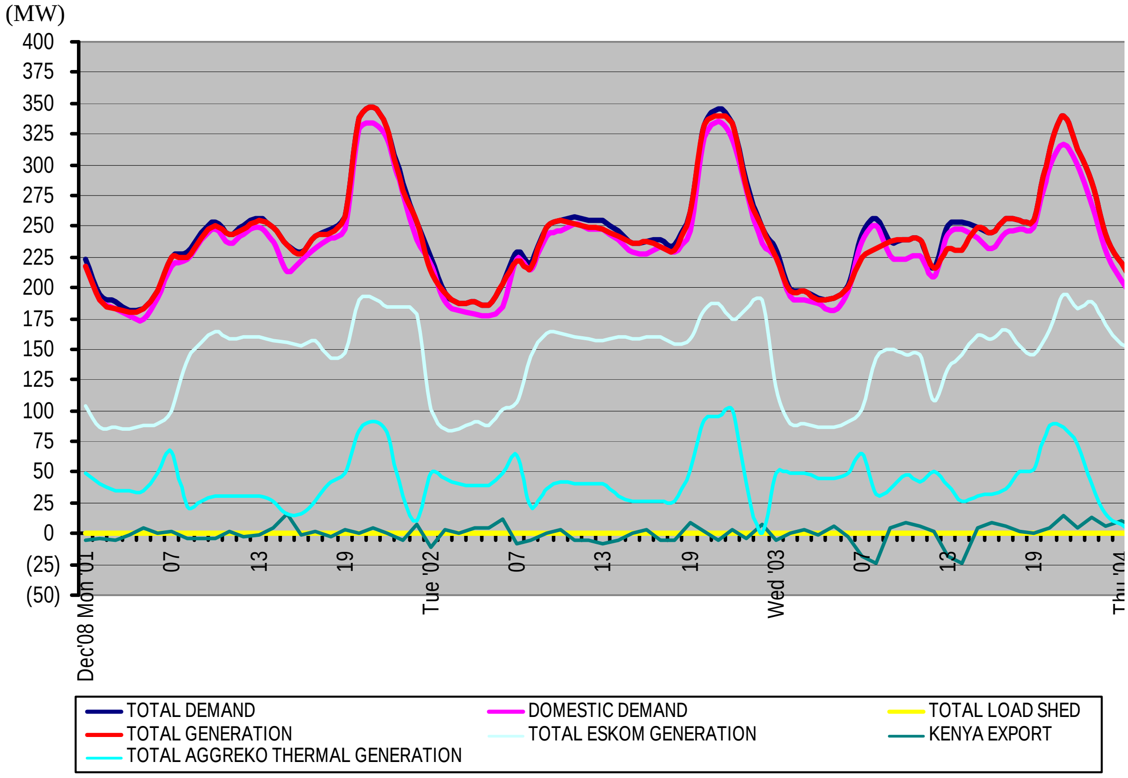
Table 4-2.2 Past and Demand Forecast of Energy Demand

Year	2007	2008	2009	2010	2011	2012	2013		2018		2023
Energy demand (GWh)	1,929	1,999	2,209	2,362	2,489	2,635	2,770		3,903		5,864
Growth rate (%)	-10.9	3.6	10.5	6.9	5.4	5.9	5.1		8.6		8.5

Source：UETCL Grid development plan 2008-2023

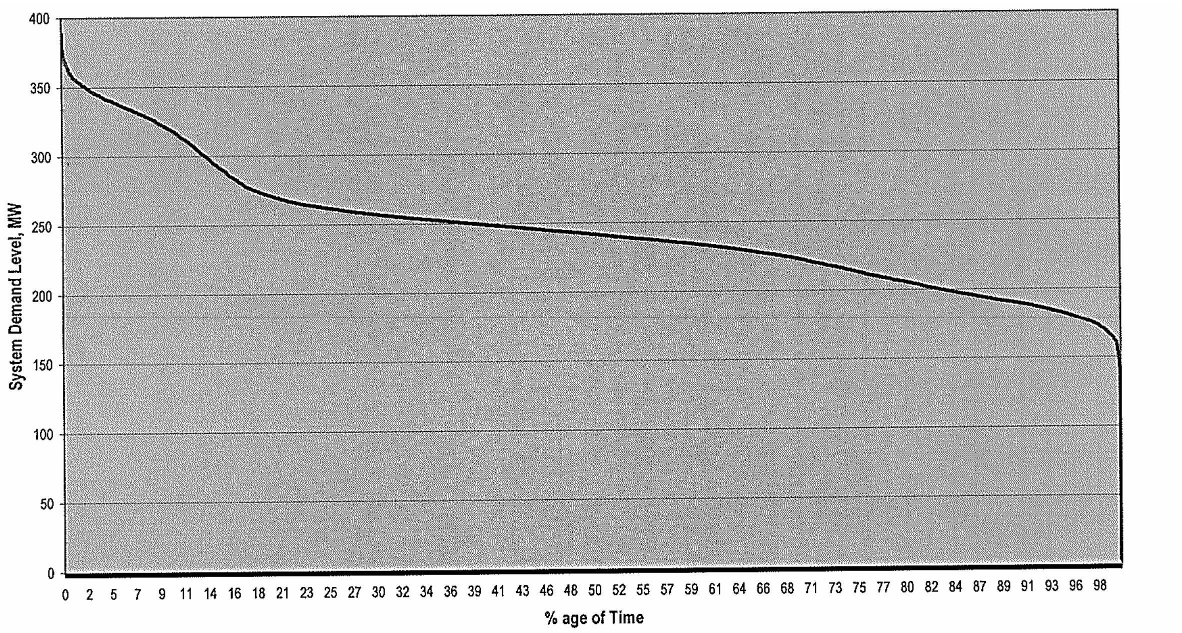
(2) Load Curve

Figure 4-2.1 illustrates daily load curve on Dec. 1 (Monday) thru 3 (Wednesday) in 2008. Peak normally appears at the time of switching-on of lighting in the evening. Figure 4-2.2 illustrates duration-of-load curve in 2008. Yearly load factor is reported to be about 60%.



Source：UETCL

Fig. 4-2.1　Daily Load Curve (Dec. 1(Monday) ～Dec.3 (Wednesday), 2008)



Source：UETCL

Fig. 4-2.2 Duration-of-Load Curve in Uganda (2008)

4.2.3 Power Development Plan

Table 4-2.3 indicates existing electric power sources. Hydro-power is predominant accounting for 71% of all sources. Owen Falls power station comprising Kiira and Nalubaale stations with Victoria Lake as water source is the most outstanding power source. Heavy reliance on hydro-power makes the country's power system vulnerable to climate. Drought in 2007 induced drop of power generation at this station and the shortage of power had to be countered by introduction of scheduled load shedding and installation of two sets of diesel engine power plants manufactured by Aggreko, UK at Lugogo and Kiira cities.

Table 4-2.3 Existing Generating Facilities in Uganda (August 2008)

	Power Station	Installed Capacity (MW)	Share (%)
Hydro	Owen Falls Complex (Kiira and Nalubaale)	380	68.2
	Mobuku 1 (KLM)	5	0.9
	Mobuku 3(KCCL)	9.5	1.7
	Subtotal:	394.5	70.9
Thermal	Aggreko 1, Lugogo	50	9.0
	Aggreko 2, Kiira	50	9.0
	Mutundwe	50	9.0
	Subtotal:	150	26.9
Cogeneration	Kakira Sugar Works	12	2.2
	Subtotal:	12	2.2
Total		556.5	100.0

Source：UETCL Grid development plan 2008-2023

Table 4-2.4 shows electric power development plan from 2009 to 2023 classified in source of energy. During coming 14 years, total 1710.5MW is expected to be generated, hydro-power 1460.5MW, thermal power 200MW (including solar energy) and co-generation 50MW. Among others, Bujagali power station is slated to play primary role in the immediate future generating 50MW in 2010 plus 200MW in 2011.

Table 4-2.4 Power Development Plan in Uganda

	Power Station	Installed Capacity (MW)	Completion Year
Hydro	Bujagali	250	2010, 2011
	Karuma	250	2014
	Ishima	100	2013
	Ayago	550	2017
	Karuma B	250	2021
	Maziba	1	2010
	Ishasha	6.5	2009
	Paidha	3	2009
	Kikagati	10	2010
	Bugoye	13	2009
	Mpanga	18	2010
	Buseruka	9	2009
	Subtotal	1460.5	
Thermal	Namanve	50	2009
	Invespro, Nalubaale	50	2009
	Mputa	50	2010
	Namugoga Solar	50	2012
	Subtotal	200	
Cogeneration	Kanyara Sugar Works	50	2009
	Subtotal	50	
		1710.5	

Source：UETCL Grid development plan 2008-2023

4.2.4 Power Export

Uganda is exporting surplus electric power to neighboring countries based on bilateral agreements. It is noted though that power output from Owen Falls power station, primary power producer source of the country, has been declining recently due to drop of water level in Victoria Lake under prolonged drought and the same trend is also found in export of power. Uganda’s future plan of demand and supply expects that Bujagali, Ishima, and Ayago power stations are completed in due course allowing export of surplus power. Table 4-2.5 shows expected export of electric power and energy from Uganda to the neighboring countries.

Table 4-2.5 Export of Electric Power and Energy from Uganda

		2007	2008	2009	2010	2011	2012	2013		2018		2023
Power (MW)	Kenya	1	1	1	1	10	10	70		80		110
	Tanzania	8	8	8	9	9	9	20		150		150
	Rwanda	1	1	1	1	1	1	30		30		50
	DR Congo							50		50		50
	Total	10	10	10	11	20	20	170		310		360
Energy (GWh)	Kenya	10	10	10	10	88	88	92		701		771
	Tanzania	70	70	70	79	79	79	175		1314		1314
	Rwanda	9	9	9	9	9	9	79		89		175
	DR Congo							438		438		438
	Total	89	89	89	98	175	175	784		2542		2698

Source：UETCL Grid development plan 2008-2023

4.2.5 Energy Exchange Agreement

Since 1950's, there used to be the Energy Exchange Agreement between Uganda and Kenya. This agreement has been updated periodically. Status of power flow changes at every moment, while the results of the power flow analysis shown in this Final Report give the values when the demands in each substations reach maximum. This means, except for the moment of maximum demand, the flow of the power of some of the transmission line in the diagrams of the power system analysis may go in opposite direction from the results. However, the unit price of energy given in this agreement is the same even if the direction changes. And the unit price is so determined that it reflects the fluctuation of fuel price. The Survey Team obtained the draft Energy Exchange Agreement between KPLC and UETCL which is to be updated and signed soon. The unit price of energy set in this draft Agreement is given by the following formula.

Unit price of energy：	US$ 0.06728/kWh plus a Fuel Charge rate
Fuel Charge rate：	Average fuel cost in US$ per kWh for all thermal plants within the KPLC interconnected system, for the month of billing.

This agreement has been applied for the past decades.

The energy sold to Uganda from Kenya is 46GWh in 2007/08, amounting 0.7% of total generation in Kenya. On the other hand, the energy purchased from Uganda by Kenya is 26GWh at the same period. Even Uganda, which is said to have heavy power deficiency, can export the power for a short time. This is the advantage of cross-border interconnection.

4.2.6 Power Grid

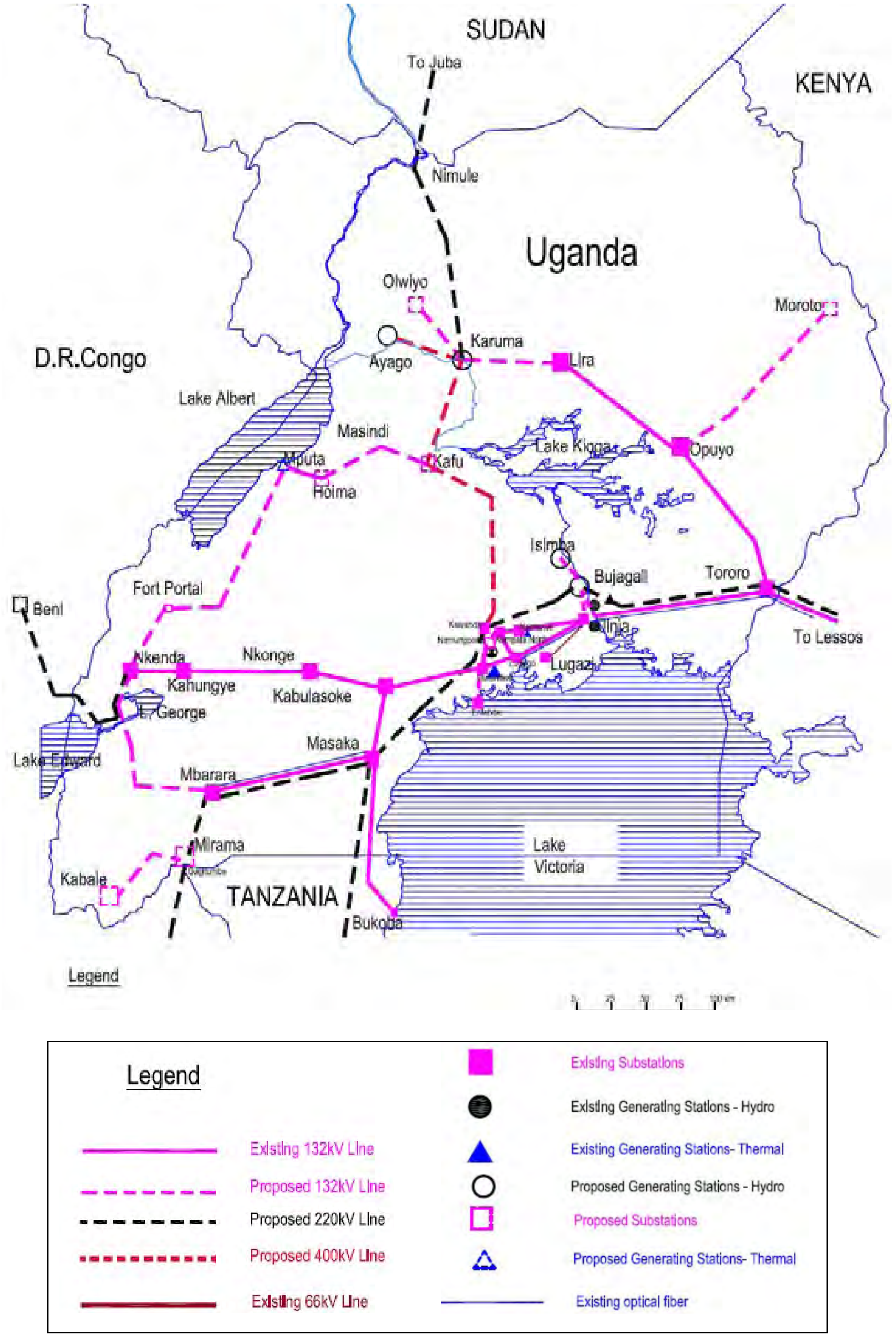
Electric power grid in Uganda is constituted mainly of 132kV lines including some 66kV lines which, however, are going to be phased out. At present in 2008, there are 132kV transmission lines in 1366.5km in total plus 66kV lines of 38km long and 13 primary substations. 132kV power is dropped to 33kV at substations and placed on 33kV distribution lines. This is further dropped to 11kV at 33/11kV substations near consumers.

It is reported that there is a plan to introduce a 220kV transmission line in future as trunk line running east-west to meet growing scale of domestic electric power demand, which is also expected to be integrated into the cross-border regional grid.　Moreover introduction of 400kV line is reported being considered.　Expansion plans of power grid are shown in the following Table 4-2.6 and Figure 4-2.3.

Table 4-2.6 Expansion Plan of Grid around Uganda

Section	Distance(km)	Voltage(kV)	Start of operation
Opuyo－Moroto	200	132	2010
Mputa－Nkenda	273	132	2011
Mputa－Hoima	54	132	2011
Karuma－ Lira	80	132	2012
Karuma－Olwiyo	60	132	2012
Tororo－Opuyo－Lira	260	132	2012
Mutundwe－Entebbe	50	132	2012
Mputa－FortPortal－Nkanda	180	132	2012
Mbarara－Nkenda	160	132	2012
Kawanda－Masaka	142	220	2012
Mbarara－Mirama(Uganda Part)	66	220	2012
Mirama－Kabaale	76	132	2013
Nkenda－Mpondwe	70	220	2013
Ishima－Bujagali	40	132	2014
Bujagali－Tororo－Lessos(Uganda Part)	127	220	2014
Masaka－Mutukula－Mwanza(Uganda Part)	85	220	2014
Karuma－ kawanda	264	400	2015
Nalubaale－Lugazi	38	132	2016
Ayago－Karuma	60	400	2017

Source：UETCL Grid development plan 2008-2023



Source: UETCL Grid development plan 2008-2023

Fig. 4-2.3 Expansion Plan of Power Grid of Uganda

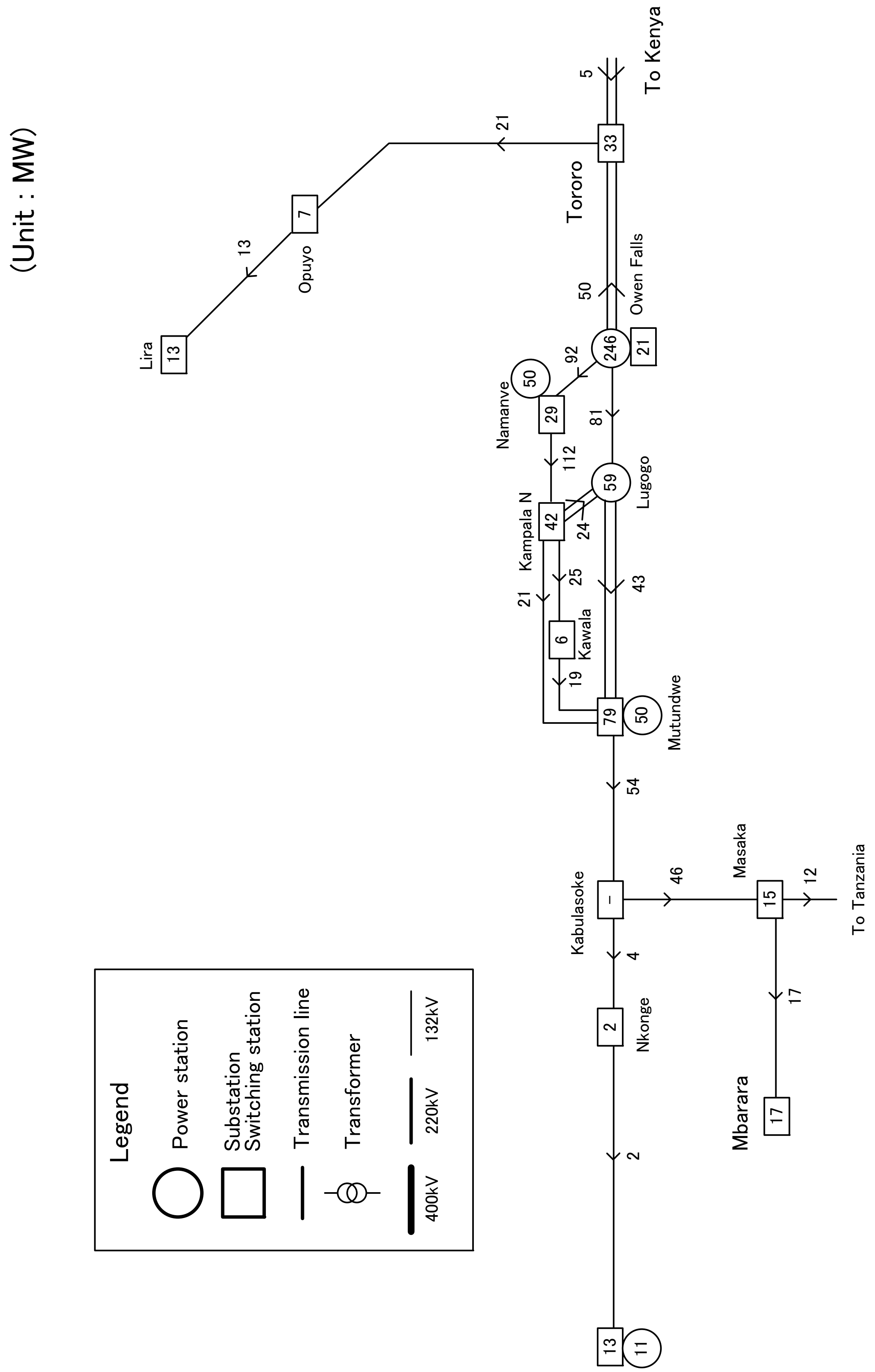
4.2.7 Power Flow

Expected power output varies tremendously between wet and dry seasons in Uganda because hydro-power is the mainstay. It is thus a normal practice to figure out circulation of electric power based on the average power output between the two seasons.

Figure 4-2.4 illustrates present power flow in Uganda in 2008. Output of Owen Falls power station rules the total flow of the country so that the flows exist from the station as the center to the west, Kampala, and the other flow to east, Tororo.

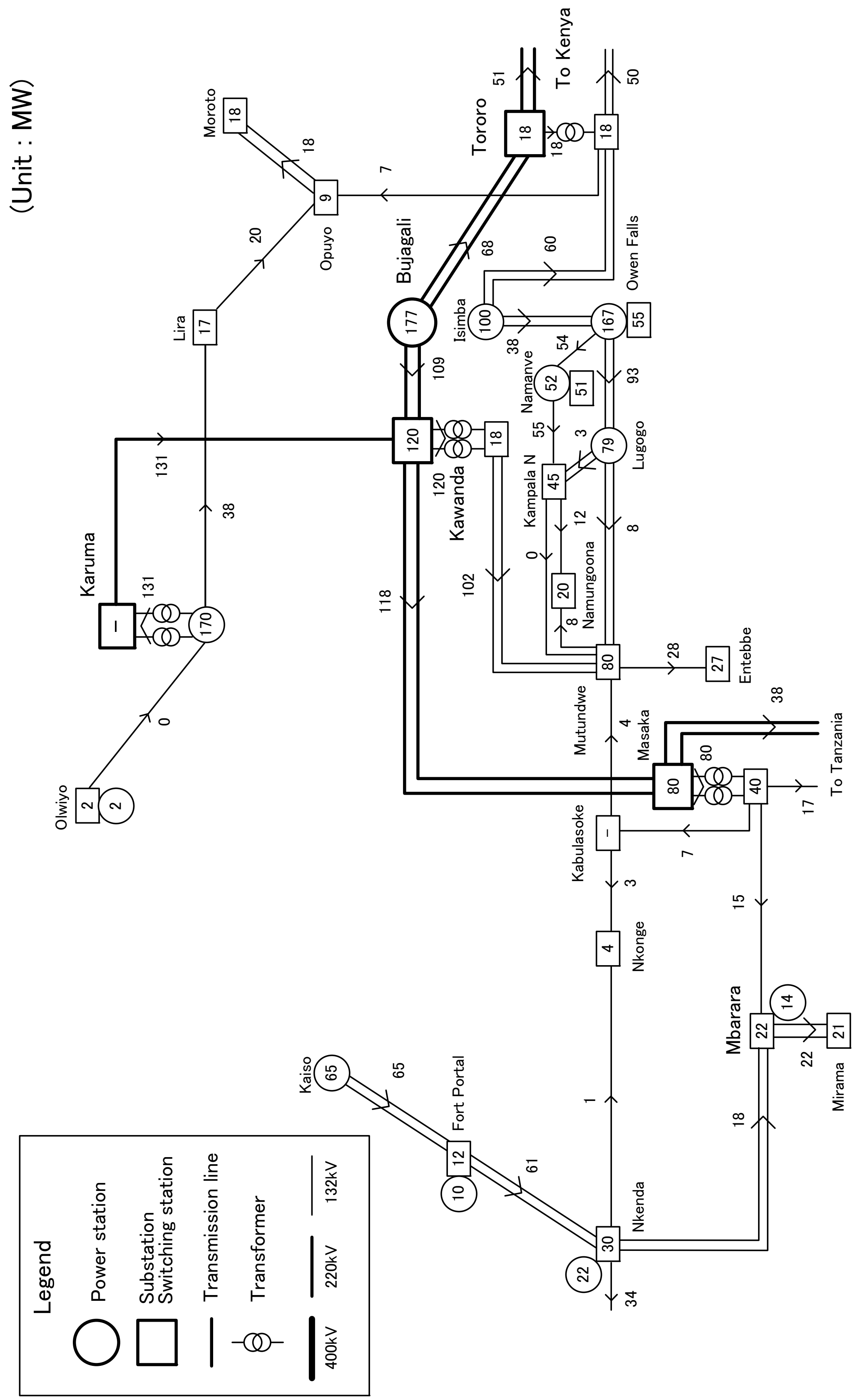
Figure 4-2.5 illustrates expected power flow in Uganda in 2013. By this time both Bujagali and Karuma power stations will have started operation relieving the load on Owen Falls power station and the 220kV transmission line running east-west will be functioning as a trunk line to incorporate the two power stations into main system. There will be lines 220kV transmission line carrying 51MW and 132kV transmission line carrying 50MW for export of 101MW power to Kenya. This total figure differs from that indicated in Table 4-2.5 (70MW). The former is understood to be the case where the balance of demand and supply is entirely directed toward export to Kenya.

Figure 4-2.6 illustrates electric power circulation in 2017 when Ayago power station will have been completed and 400kV line partially put into operation. Export to Kenya indicates a high value of 288MW assuming the same case as that of 2013.



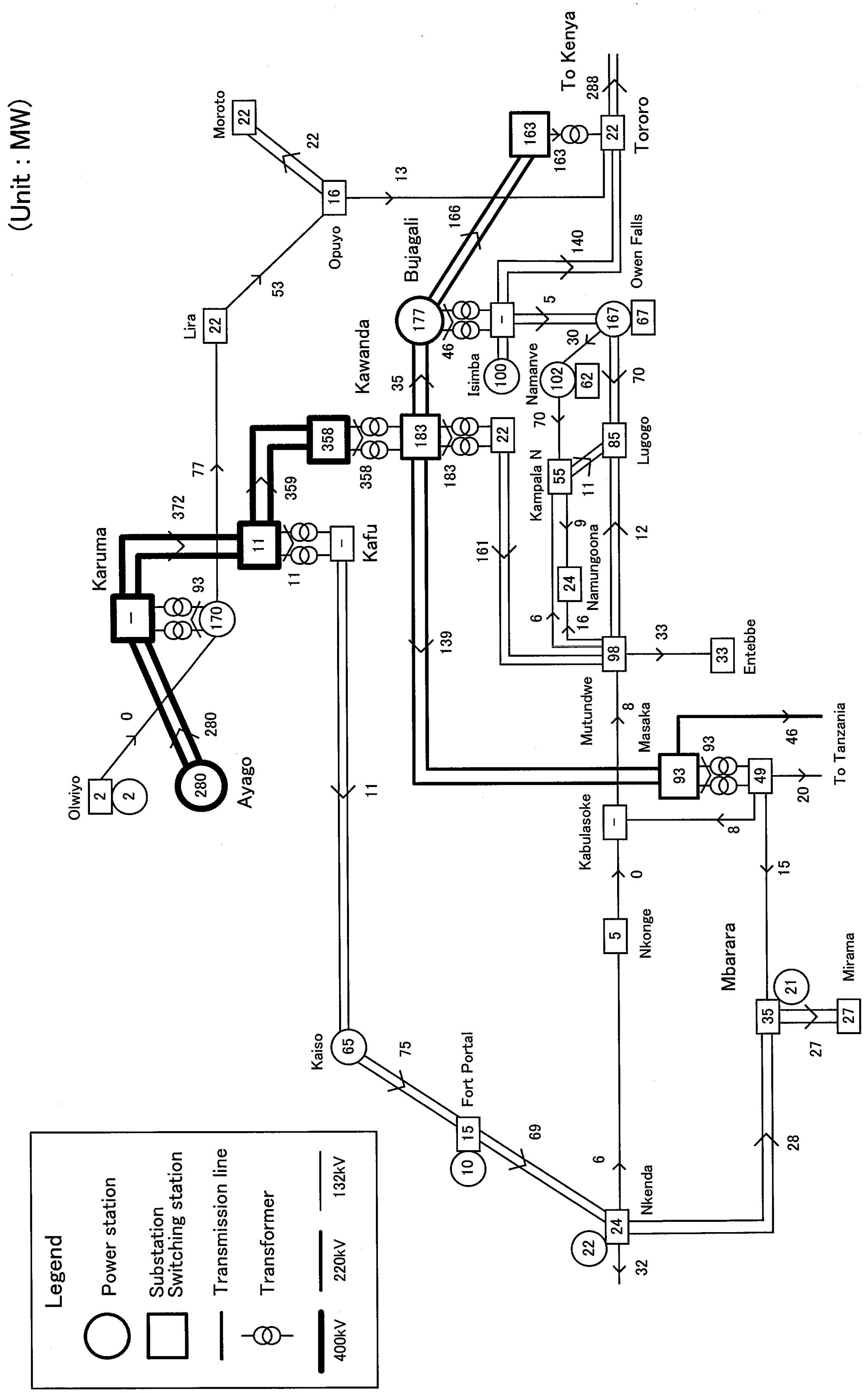
Source:　UETCL, illustration by the Study Team

Fig. 4-2.4　Power Flow in Uganda (2008)



Source:　　　UETCL, illustration by the Study Team

Fig. 4-2.5　Power Flow in Uganda (2013)



Source : UETCL, illustration by the Study Team

Fig. 4-2.6 Power Flow in Uganda (2017)

4.2.8 Foreign Donors' Activities in Uganda

Major activities of foreign donors in Uganda in the power sector are shown in Tables 4-2.7 and 4-2.8. Due to the political unrest in the past and uncertain repayment capacity, there are not so much activities by foreign donors in construction of generating facilities and transmission facilities.

Table 4-2.7 Foreign Donors' Activities for Generating Facilities in Uganda

Type	Power station	Installed Capacity (MW)	Estimated cost (M US$)	Fund	Contractor
Hydro	Bujagali	250	419.2 (EAPMP 2004 より)	Bujagali Energy Limited (IPP) (Fund from WB, IDA, IFC, MIGA, etc.)	Consortium of Veidekke, and Skanska International Civil Engineering, Alstom Power Ltd.
	Karuma	250	428.9 (EAPMP 2004)	To be determined	To be determined
	Ayago	550	994.8 (EAPMP 2004)	To be determined	To be determined

Source : JICA Survey Team, and data from Appraisal Report 2008, Interconnection of Electric Grids of Nile Equatorial Lakes Countries, AfDB

Table 4-2.8 Foreign Donors' Activities for Transmission Facilities in Uganda

Section	Length (km)	Voltage (kV)	Estimated Cost	Fund
Karuma－ Lira	80	132	110,000 $/km (EAPMP 2004)	To be determined
Mbarara－Nkenda	160	132	110,000 $/km (EAPMP 2004)	To be determined
Kawanda－Masaka	142	220		DANIDA
Bujagali － Tororo － Lessos (Uganda Part)	127	220	190,000 $/km (EAPMP 2004)	To be determined
Karuma－ Kawanda	264	400	190,000 $/km (EAPMP 2004)	To be determined
Ayago－Karuma	60	400	190,000 $/km (EAPMP 2004)	To be determined

Source : JICA Survey Team, and data from Appraisal Report 2008, Interconnection of Electric Grids of Nile Equatorial Lakes Countries, AfDB

Transmission lines over 66kV are owned and operated by UETCL. Hence, when the projects are implemented, UETCL will be the partner of the donors.

4.3 Electric Power Sector in Ethiopia and Export Potential

4.3.1 Overall Economic Situation

Since the per capita GNI of Ethiopia is $170, it is classified in as one of the least less-developed countries (LLDC).

Such being the case, it is a long term target for Ethiopia to become a “middle-income country” after 20-30 years growing out of the "low-income country" category.

Though the country achieved 2-digit economic growth during the past 5 years, future is not necessarily bright. Drought due to meager precipitation during wet season in 2008, skyrocketing oil price coupled with domestic inflation reaching 40% per annum are beginning to cast a pall over the country's future economy.

Electrification rate per capita is assumed to be 20% in 2007 based on number of population in electrified areas. However, actual number of people would be smaller than this figure, probably around 6%, for expense of leading service wire to household is to be borne by the user. In order to achieve the aforementioned economic growth target, it is understood to be imperative to enhance electrification rate.

Looking at electric energy source, the country heavily depends on hydro-power, as much as 85%, the fact that is making it inevitable to exercise scheduled power interruption during dry season, which is a serious problem for the industry as well. Wet season here is from June thru September, but residual effect of previous dry season still pervades in its beginning. The Study Team witnessed scheduled load shedding during the stay in capital city Addis Ababa in spite of rainfall every day, there was normally no power during daytime and there was no power every other evening.

Thus, the government plans to tap the huge hydro-potential of upper reach of River Nile for generation of cheap hydro-electric power. This will serve dual purpose, namely, i) elimination of domestic power shortage and ii) gaining foreign hard currency by exporting electricity . Two gigantic hydro-power projects are in fact in progress, Gibe II power station (420MW) and Gibe III power station (1800MW) are expected to be put into operation in September, 2009 and in 2012/2013 respectively.

4.3.2 Power Sector in Ethiopia

Power transmission, distribution and selling in Ethiopia are being undertaken only by the Ethiopian Electric Power Corporation (EEPCo), which is the sole public corporation in electric power sector. It comes under the jurisdiction of the Ministry of Mine and Energy (MoME). EEPCo was founded in 1997 by restructuring its predecessor Ethiopian Electric Light and Power Agency (EELPA), which had been founded in 1956 succeeding the business of an Italian enterprise then doing electric business in the country.

4.3.3 Power Demand

(1) Peak Demand and Energy Demand

Table 4-3.1 shows record of peak demand and energy demand from 1998 thru 2008.

During this period, demands demonstrated high growth rates, average 7.8% and 8.5% in peak demand and energy demand respectively, thanks to the 2-digit economic growth. Particularly in 2005, the growth rates jumped high to maximum 20.6% and 14.5% for peak demand and energy demand respectively.

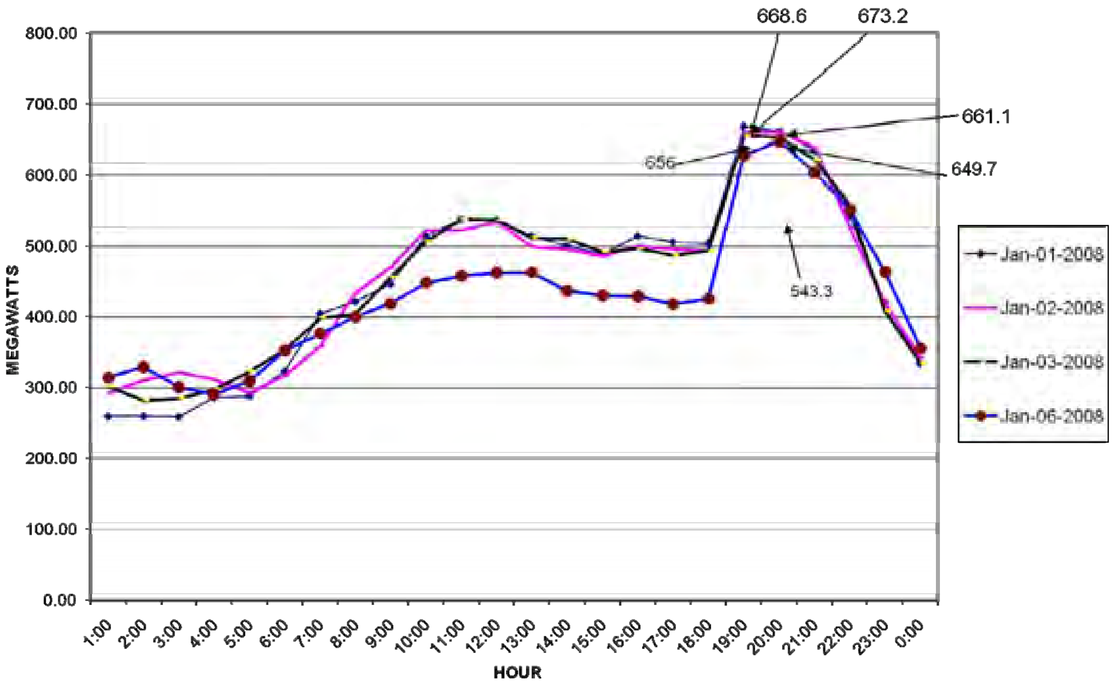
Table 4-3.1 Record of Peak Demand and Energy Demand

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Peak Demand (MW)	318	318	328	352	391	405	432	521	587	623
Growth Rate (%)	7.7	0.2	3.0	7.3	11.1	3.6	6.7	20.6	12.6	6.1
Energy Demand (GWh)	1565	1619	1655	1782	1976	2028	2261	2589	2897	3301
Growth Rate (%)	0.8	3.4	2.2	7.7	10.9	2.6	11.5	14.5	11.9	14.0

Sourse：EEPCo

(2) Daily Load Curve

Figure 4-3.1 indicates daily load curve on a day in January, 2008 in Ethiopia. As seen, peak demand appears between 19-20 p.m. when lighting starts in the evening. Average yearly load factor is reported to be around 58%.



Source：EEPCo

Fig. 4-3.1 Daily Load Curve in Ethiopia (January, 2008)

(3) Demand Forecast

Tables 4-3.2 and 4-3.3 indicate forecasted peak demand, and energy demand respectively. And Figure 4-3.2 indicate domestic peak demand excluding export.

The peak demand in 2008 should be taken as a suppressed demand caused by deficiency of supply, namely it was believed to be obscured latent demand. The forecast for the succeeding years assumes that there will be sufficient supply. As a consequence, average growth rates from 2008 thru 2011 turned out to be rather high 29% and 21% in target scenario and moderate scenario respectively. Afterwards, demand levels off from 2011 thru 2018, 13% and 11% in target scenario and moderate scenario respectively. It is expected that from 2011 onwards, power as much as 1,250MW could be exported to Kenya, Sudan and Djibouti considering the completion of large scale hydro-power stations by that time.

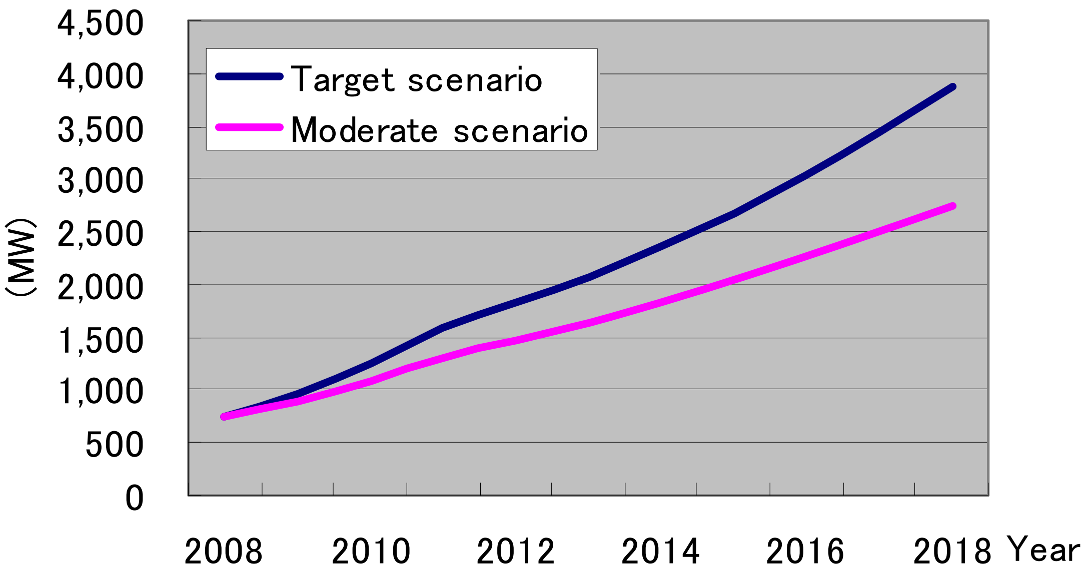
Table 4-3.2 Peak Demand Forecast (Peak MW)

(MW)

	Year	2008		2011		2013		2015		2017	2018
Domestic demand	Target scenario	747	-	1600	-	-	-	2672	-	3433	3883
	Moderate scenario	747	-	1311	-	-	-	2036	-	2495	2733
Plus export to Kenya & Sudan	Target scenario	747	-	2850	-	3297	-	3922	-	-	5133
	Moderate scenario	747	-	2561	-	2887	-	3286	-	-	3983

Source：Power System Development Program EEPCo July 2008

Note. Data not available in column marked " - ".



Source：Power System Development Program EEPCo July 2008

Fig. 4-3.2 Peak Demand Forecast Curve in Ethiopia (Domestic)

Table 4-3.3 Energy Demand Forecast in Ethiopia

(GWh)

	Year	2008		2011		2013		2015		2017	2018
Domestic demand	Target scenario	3765	-	7856	-	-	-	13456	-	17299	19435
	Moderate scenario	3765	-	6603	-	-	-	10256	-	12569	13763
Plus export to Kenya & Sudan	Target scenario	3765	-	13240	-	16491	-	19903	-	-	27536
	Moderate scenario	3765	-	11987	-	14427	-	15413	-	-	21864

Source：Power System Development Program EEPCo July 2008

Note. Data not available in column marked " - ".

4.3.4 Power Development Plan

(1) Existing Power Plants

Table 4-3.4 shows existing power plants with locations and capacities, and Figure 4-3.3 illustrates the proportion of power sources. Obviously, the power sources in Ethiopia are predominantly hydro-power, 86%. Remaining is from diesel (13%) and very small geo-thermal (1%). As hydro-power generation is dependent on climate (precipitation), the country tends to suffer from severe power shortage under prolonged drought.

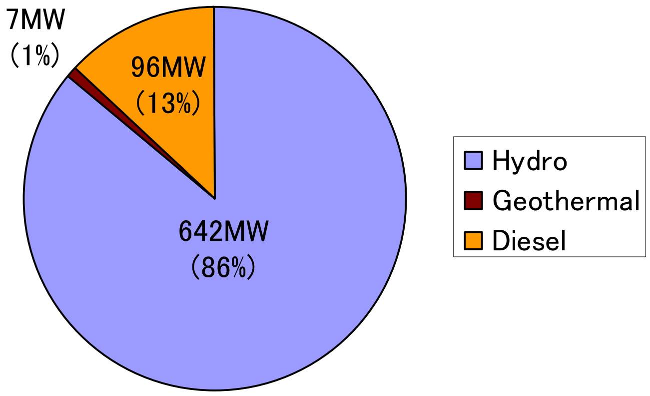
In fact, the Study Team witnessed scheduled load shedding being exercised in Addis Ababa during the stay in the beginning of July, when it was just the beginning of wet season but residual effect of dry season was still pervading.

Table 4-3.4 Existing Power Plants in Ethiopia

(MW)

Power station		Installed capacity	Dependable capacity
Hydro	Koka	43.2	38.4
	T.Abay-I	11.4	11.4
	Awash II	32	32
	Awash III	32	32
	Finchaa	100	100
	Melka Wakena	153	148
	T.Abay II	73	68
	Fincha IVth Unit	34	28
	Gilgel Gibe-I	192	184
	Sub-total	670.6	641.8
Geo-thermal	Aluto Langano	7.3	7.3
	Sub-total	7.3	7.3
Diesel	Stand by Diesel (Synchronizable)	22.2	19.3
	Awash 7 Killo Diesel (Containerized)	28	28
	Kaliti I Diesel (Containerized)	11.2	11.2
	Dire Dawa Diesel	40	38
	Sub-total	101.4	96.5
Grand total		779.3	745.6

Source：EEPCo



Source：EEPCo

4-3.3 Existing Power Plants in Ethiopia （Effective Capacity）

(2) Power Development Plan

Table 4-3.5 summarizes power development plan that has been included in a long term development plan in 2008. It intends to develop 7,984MW of power in total in ten years from 2009 thru 2018, mainly from hydro power generation, to meet domestic demand as well as for export. Gibel Gibe II power station (output 420MW) was substantially completed and impounding water into reservoir is in progress at present in July, 2009. It will start power generation in September of the same year. In addition, Tekeze and Beles power stations will also start operation, increasing the total output to 1,798MW, almost two times that of the previous year. Shortage of power could be eliminated at a stroke and even export of power materialized.

Gibe III power station will be located at lower reach of Gibe II power station on Gibe river, accompanied with the highest dam in the world (240m). It will generate whopping 1800MW of power with 10 units of 180MW generators. Progress of the project in July, 2009 was around 30%. Power output will be in two steps, 900MW in 2011 and another 900MW in 2012. Although it was planned in the initial stage to start transmitting power to Kenya through a direct current 400kV transmission line in 2012, delay of this line will push back the start to 2013. Electric power delivery will step-wisely be increased from 200MW in 2013 to 1000MW in 2020.

Table 4-3.5 Power Development Plan（Demand of Target Scenario＋Export）

Year	Plant Addition	Type	Unit No. × MW Capacity	Total (MW)	System dependable capacity (MW)
2008	Tekeze (One Unit)	Hydro	1 × 75	75	808
2009	Gilgel Gibe Ⅱ Tekeze(Three Unit) Beles	Hydro Hydro Hydro	4 ×105 3 × 75 4 × 115	1145	1798
2010	Neshe	Hydro	2 × 47.5	95	1973
2011	Gibe Ⅲ(Phase I) Wind	Hydro Wind	5 × 180 36	936	2909
2012	Gibe Ⅲ(PhaseⅡ) Chemoga Yeda I ChemogaYeda Ⅱ Aluto Langano	Hydro Hydro Hydro Geothermal	5 × 180 2 × 81 2 × 59 30	1210	4119
2013	Halele Werabesa Geba I + Tendaho	Hydro Hydro Hydro	2 × 48 4 × 81.5 3 × 71.5	636.5	4740
2014	Genale Dawa Ⅲ Geba Ⅱ	Hydro Hydro	3 × 86 2 × 78.5	415	5239
2015	Gibe Ⅳ	Hydro	8 × 184	1472	6711
2018	Mendaya	Hydro	8 × 250	2000	8711
Total			-	7984.5	

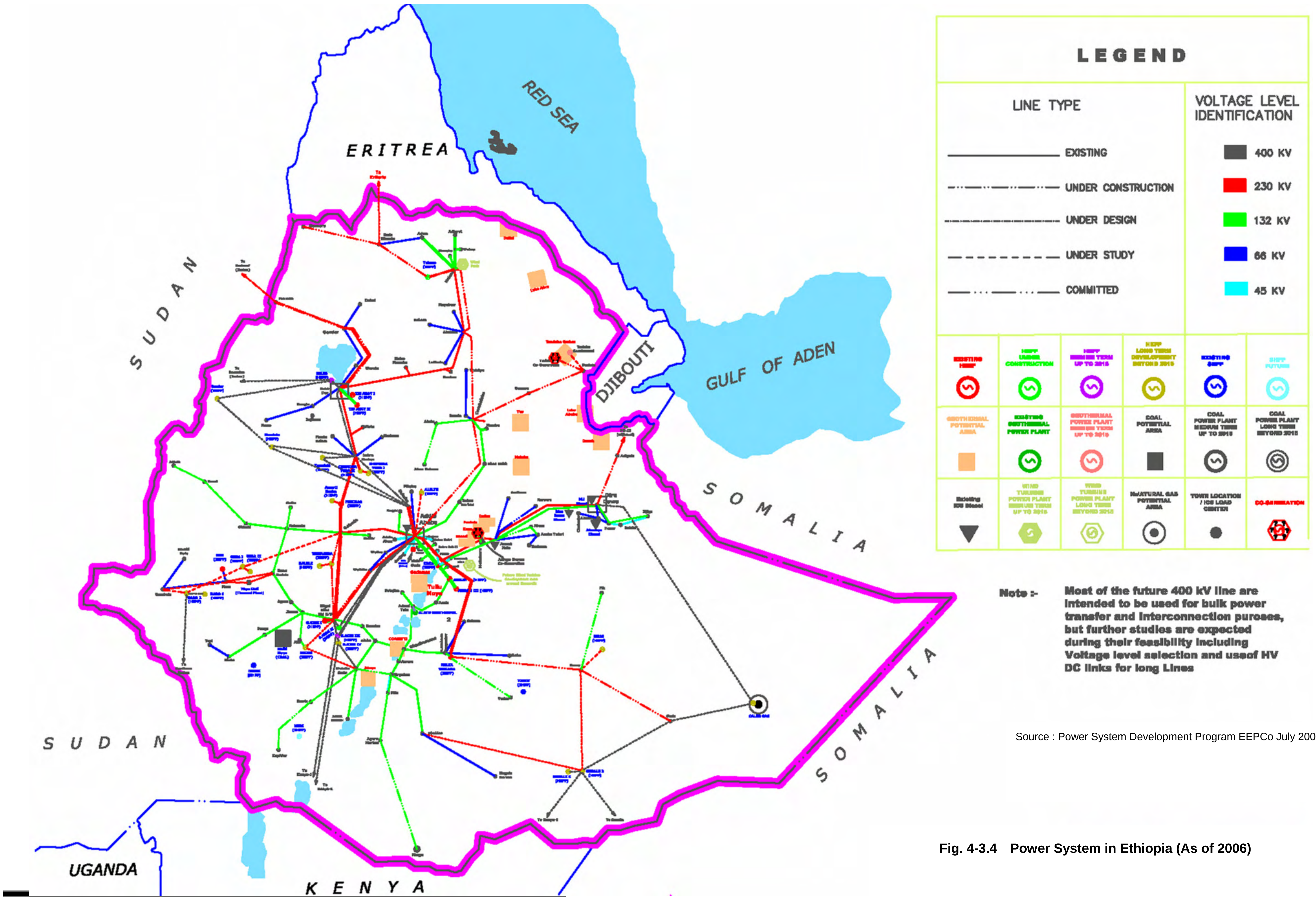
Source：Power System Development Program EEPCo, July 2008.

4.3.5 Expansion of Transmission Lines

(1) Existing Transmission Lines

Power system in Ethiopia as of 2006 is as illustrated in Figure 4-3.5. Voltage is classified into 230kV, 132kV, 66kV and 45kV and lengths of them are 2,194km、2,743km、1,782km, and 399km respectively. Details of segmental length of 230kV lines are tabulated in Table 4-3.6.

As for progress of Ethiopia－Kenya interconnection line, even though the project office of EEPCo for the line exists at Addis Ababa, the donor for the line construction is not yet fixed according to the officials in the office.



Note :- Most of the future 400 kV line are intended to be used for bulk power transfer and interconnection purposes, but further studies are expected during their feasibility including Voltage level selection and useof HV DC links for long Lines

Source : Power System Development Program EEPCo July 2008

Fig. 4-3.4 Power System in Ethiopia (As of 2006)

Table 4-3.6 230kV Transmission Line

From	To	length (km)
Finchaa	Debre Markos	95.00
Finchaa	Ghedo	93.60
Ghedo	Gefersa	133.85
Debre Markos	Bahir Dar-2	195.00
Bahir Dar-2	Gondar-2	143.00
Alamata	Mekele	141.00
Bahir Dar-2	Alamata	347.00
Alamata	Mekele	141.00
Gefersa	Sebeta	10.70
Sebeta	Kaliti-1	13.80
Kaliti-1	Koka	65.67
Koka	M.Wakena	164.07
Koka	Dire Dawa-3	337.00
Gilgel Gebi-1	Ghedo	130.00
Gilgel Gebi-1	Wolkite	68.90
Wolkite	Sebeta	114.50
Total		2,194.09

Source：EEPCo

(2) Expansion Plan of Transmission Lines

Table 4-3.7 indicates the expansion plan of transmission lines. For the first time, ultra-high voltage 400kV transmission lines are going to be put into operation in 2009 to accommodate power generation at Gibe II power station. Power demand scale in 2018 is estimated at approx. 5 times larger than that of 2008. Expansion of transmission lines will be carried out accordingly, expansion total being 6,460.9km comprised of 2,556km of 400kV, 2,941.6km of 230kV, and 963.3km of 132kV.

4.3.6 Power Purchase Agreement

At this stage, the Power Purchase Agreement between KPLC and EEPCo does not exist. However, KPLC recently dispatches engineers to Ethiopia frequently. They say those engineers are discussing the agreement with EEPCo. Actually, some counterpart engineers of JICA Survey Team had visited Ethiopia during the field survey period. The JICA Survey Team had obtained the copy of the draft Power Purchase Agreement between EEPCo and the power company of Djibouti (EDD).

Table 4-3.7 Expansion Plan of Transmission Line

Connection From-To	Voltage (kV)	No. of circuits	Length (km)	In-service Year
Gibe II-Gilgel Gibe I	400	1	30	2009
Gibe II-Sebeta II	400	1	185	2009
Beles-Bahr Dar II	132	1	133.3	2009
Bahir Dar II-Debre Markos	400	2	200	2009
Debre Markos-Sululta	400	1	230	2009
Sululta-Gefersa	230	2	17	2009
Komolcha-Aksta	132	1	100	2008
Finchaa-Ghedo	230	1	82	2008
Ghedo-Gefersa	230	1	93.6	2008
Tekeze-E.Silase-Humera	230	2	532	2009
Tekeze-Mekele	230	1	90	2009
Alaba-Hossana	230	1	40	2009
Hosana-Ggibe old	230	1	72	2009
Jimma-Agaro	230	1	35	2009
Agaro-Bedele	230	1	82	2009
Ggibe old-Jimma	230	1	71	2009
Melka Wakena-Ramo-Gode	230	1	612	2009
Melka Wakena-Yadot	132	1	100	2009
Harar-Fik	132	1	170	2009
Sawla-KeyAfer	132	1	100	2009
Hagere Mariam-B.Laguma	132	1	225	2009
Gondar-Metema	132	1	135	2009
Alamata-Mekele	230	1	111	2009
Kombolcha- Samara-Dichato	230	1	243	2009
Alamata-Kombolcha-Cotobe-kaliti	230	1	415	2009
Metu-Gambela	230	1	150	2010
Bedele-Metu	230	1	90	2010
Gibe III-Wolita sodo	400	2	65	2011
W.Sodo-AkakiII	400	1	260	2011
W.Sodo -GibeII	400	1	109	2011
Sebeta II-Sululta	400	1	50	2011
AkakiII- SebetaII	400	1	32	2011
W.Sodo -Yirgalem	230	1	101	2011
Geba 2-Metu	400	1	30	2013
Geba1-Geba2	400	1	30	2013
Halele-Werabesa	230	1	30	2013
Werabesa-Werabesa Tap	230	1	5	2013
Werabesa-Ghedo	230	2	70	2013
GenaleIII-Wolita Sodo	400	1	300	2014
Genale3-WolitaSodo	400	1	300	2014
Gibe IV-Gibe III	400	3	60	2015
GibeIII-Wolita Sodo	400	2	65	2015
Mendaya-Ghimbi	400	3	120	2018
Ghedo-Sebeta	400	1	133	2018
Ghimbi-Ghedo	400	2	200	2018
Ghedo-D.Markos	400	1	157	2018
Total	-	-	6460.9	-

Source: Power System Development Program EEPCo, July 2008.

4.3.7 Foreign Donors' Activities in Ethiopia

Major activities of foreign donors in Ethiopia are shown in Table 4-3.8. Similar to Uganda, donors do not easily offer their loan for the planned generating and transmission facilities. Especially the donors for most of the planned transmission lines are not yet determined.

Table 4-3.8 Foreign Donors' Activity for Generating Facilities in Ethiopia

Type	Power Station	Installed Capacity (MW)	Estimated Cost (€ mil.)	Fund		Contractor	Completion Year
				Govern-ment （€ mil.）	Others （€ mil.）		
Hydro	Gibe II	420	56	22	50 (Italian Gov., EIB)	Salini (Italy)	2009
Hydro	Tekeze	300	73	No data	EEPCO	Wambo Engineering Corporation CWGC (China)	2009
Hydro	Beles	460	199	No data	EEPCO	Salini (Italy)	2009
Hydro	Gibe Ⅲ	1,800	1,445	No data	ADB, JP Morgan, Italian Gov.	Salini (Italy)	2013
Hydro	Neshe	95	130	EEPCO	To be determined	GEZHOUBA Water & Power Group of China	2010

Source : Data from Japanese Embassy in Ethiopia

Chapter 5 Power System Analysis

Based on LCPDP (December 2008), power system analysis was conducted in this chapter for the following purposes :

- To confirm the needs for the construction of 220kV transmission lines between Olkaria and Lessos, and 132kV (original proposal) transmission line between Lessos and Kisumu,
- To determine the scale/size of these transmission lines, and
- To verify the advantage of the construction of these transmission lines

There were 2 target years for the analysis, namely, 2013, which LCPDP defined as the commencement year for the operation of the transmission line between Olkaria and Lessos, and 2020, in order to verify the long term function after the construction of the line. In addition, both scenarios for wet and dry seasons were analyzed to obtain the different load flow patterns since there are many hydropower stations in the whole country.

5.1 Conditions for the Power System Analysis

5.1.1 Demand Forecast, and Augmentation Plan of Generating Plant & Grid

The power demand, power sources and reinforcement plan of the grid for the analysis came from LCPDP (December 2008). This latest edition was obtained from KPLC during the first site survey. LCPDP had been internally restructured by KPLC in September 2008.

The power demand forecast was already discussed in 3.1 of Chapter 3, and the forecast for the maximum power demand is again mentioned in Table 5-1.1. The augmentation plans of the generating plant and grid, which were discussed in 3.2 and 3.3, are used for the analysis.

Table 5-1.1 Power Demand Forecast used for Analysis

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Peak load (MW)	1,086	1,173	1,267	1,368	1,477	1,715	1,905	2,112	2,339	2,586	2,856	3,151	3,474

Source: LCPDP, December 2008

5.1.2 Software for Analysis and Modeling

The software PSS/E (Version 31) was used for the power system analysis. KPLC provided the Survey Team with necessary input data in PSS/E format which the Survey Team could utilize for this analysis.

For the analysis this time, the data from LCPDP (September 2008 and December 2008) were updated for the year 2013 by Survey Team.

The loads of each substation in 2020 were calculated based on 2013 data and were made commensurate to the total demand rate between 2013 and 2020. Power generating plan and the system augmentation were fitted to the data in LCPDP (December 2008).

The model of grid for analysis as of 2013 reflects all generating facilities and 400kV, 220kV, 132kV and 66kV transmission line networks in detail, as shown in Table 5-1.2 below.

Table 5-1.2 Scale of Model for Analysis

Item	Demand	No. of busses				No. of lines				No. of generators
		400kV	220kV	132kV	66kV	400kV	220kV	132kV	66kV	
Quantity	1711MW	4	19	47	59	6	25	58	63	50

Source: JICA Survey Team

Hydropower plants generally decrease their output during the dry seasons. Based on records in the past seven (7) years, the hydropower generation during the dry seasons was generally considered at about 70% rating in the analysis, and also at 50% rating in the extremely dry case.

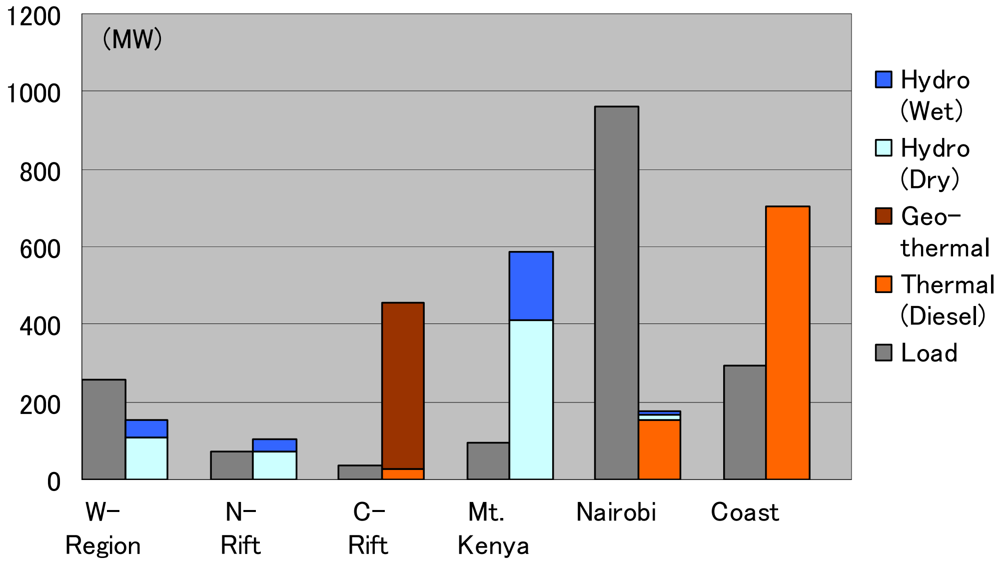
5.2 Result of Power Flow Analysis for 2013

5.2.1 Geographical Distribution of Power Sources and Loads

The load flow is influenced by the balance of electrical supply and load, regionally. In case that the electrical supply and load regionally balances, the load flow is to be small, while in case unbalanced, the load flow is to be large.

The actual status of electrical supply and load in Kenya are shown in Figure 5-2.1. Nairobi area has 56% of the entire electricity demand in Kenya but the power sources do not exist in the area so as to import the power from other regions such as Coast area, Mt. Kenya area, and Central Rift Valley area. In connection to the variety of power generation, there are thermal power plants less subject to the amount of precipitation in wet and dry seasons, such as Olkaria geo-thermal power plant in the Central Rift Valley area and large scale thermal power plants in the Coastal area. On the other hand, there are a lot of hydropower plants in the areas of Mr. Kenya, North Rift Valley and West Region, so that the output varies in the wet and dry seasons.

The 132kV transmission line Naivasha-Lanet-Lessos will be loaded by the balance between demands and generation outputs both in the West Region (including Lanet substation) and North Rift Valley Region. The West Region has a large power demand for supply to Kisumu-city and Nakuru-city being the third and fourth-most populous cities respectively. Meanwhile, the power sources around these regions are not sufficient even including the power import from Bujagali P/S in Uganda. Although the deficit power must be supplied through the 132kV transmission line of Naivasha－Lanet－Lessos from eastern side, those lines were constructed more than 50 years ago and tend to be overloaded. The current carrying capacity of the 132kV transmission lines is only 77 MW (under power factor of 95%) per one circuit.



Source: KPLC

Fig. 5-2.1 Power Sources and Load Distribution in Kenya

5.2.2 Result of Load Flow

Figures through 5-2.2 to 5-2.6 indicate the results of load flow analysis for scenarios of (i) Wet season, (ii) Dry season with 70% rating of hydropower, and (iii) Extremely dry season with 50% rating of hydropower, BEFORE and AFTER the upgrading of planned transmission lines 220kV Olkaria－Lessos line and 132kV Lessos－Kisumu line, in 2013. Power flows of the major transmission lines are shown in Table 5-2.1.

Table 5-2.1 Load Flow of Major Transmission Lines, per One Circuit

(Unit：MW)

Line		132kV Olkaria-Naivasha	132kV Naivasha-Lanet	132kV Lanet-Lessos	132kV Lessos-Muhoroni	**220kV Olkaria-Lessos**	**132kV Lessos-Kisumu**	132kV Juja-Ruaraka	Fig. No.
Transmitting cap. per cct.		143	77	77	77			77	
Before augmen-tation of lines	Wet	134	60 [119]	6 [11]	49 [129]	-	-	82 [163]	5-2.2
	Dry 70%	168	94 [187]	36 [71]	71 [127]	-	-	100 [199]	5-2.3
	Dry 50%	201	130 [260]	65 [129]	89 [129]	-	-	100 [200]	5-2.4
After augmen-tation of lines	Wet	112	38 [75]	16 [31]	43 [84]	41	5	70 [140]	5-2.5
	Dry 50%	124	53 [105]	1.4 [44]	62 [84]	62	25	66 [121]	5-2.6

[ ]:Under N-1 condition

Red:Overload under normal condition, Orange:Overload under N-1 condition

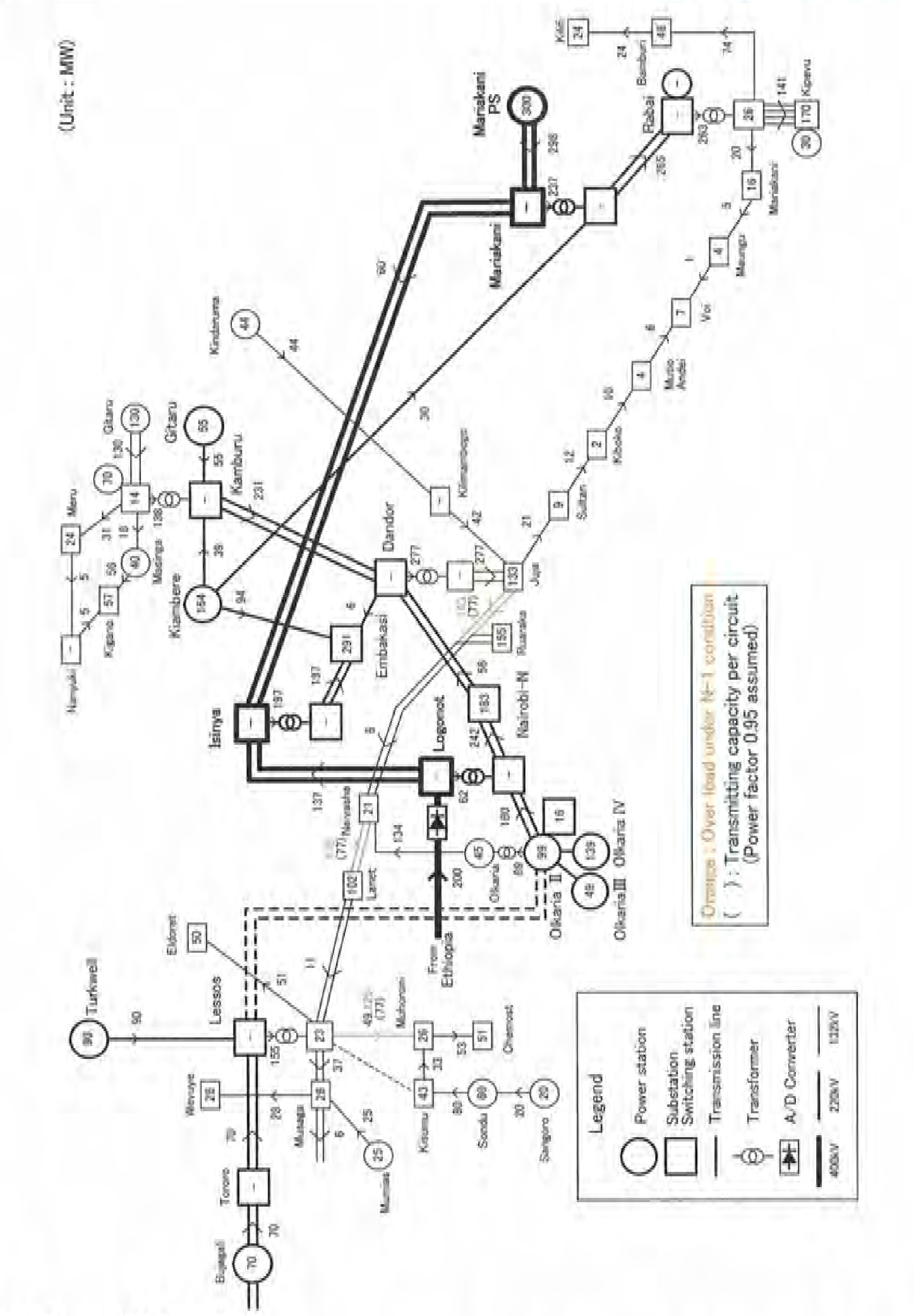
Source: JICA Survey Team

Before planned upgrading of the transmission lines during the rainy season, there is not any overload on transmission lines under the normal operating condition, whereas there is overload on 132kV transmission lines of Naivasha－Lanet line, Lessos－Muhoroni line, and Juja－Ruaraka line under N-1 conditions. According to the regulation of electricity supply reliability in KPLC, it is ruled that the any fault under N-1 conditions should not cause blackout. Therefore, some countermeasures must be needed for major facilities against the operation under N-1 conditions.

Before completing of planned upgrading of the transmission lines during the dry seasons, there are a lot of overloading on the lines. Especially, the overload may occur on 132kV lines of Olkaria－Naivasha, Naivasha－Lanet, and Juja－Ruaraka, even under the normal operating condition.

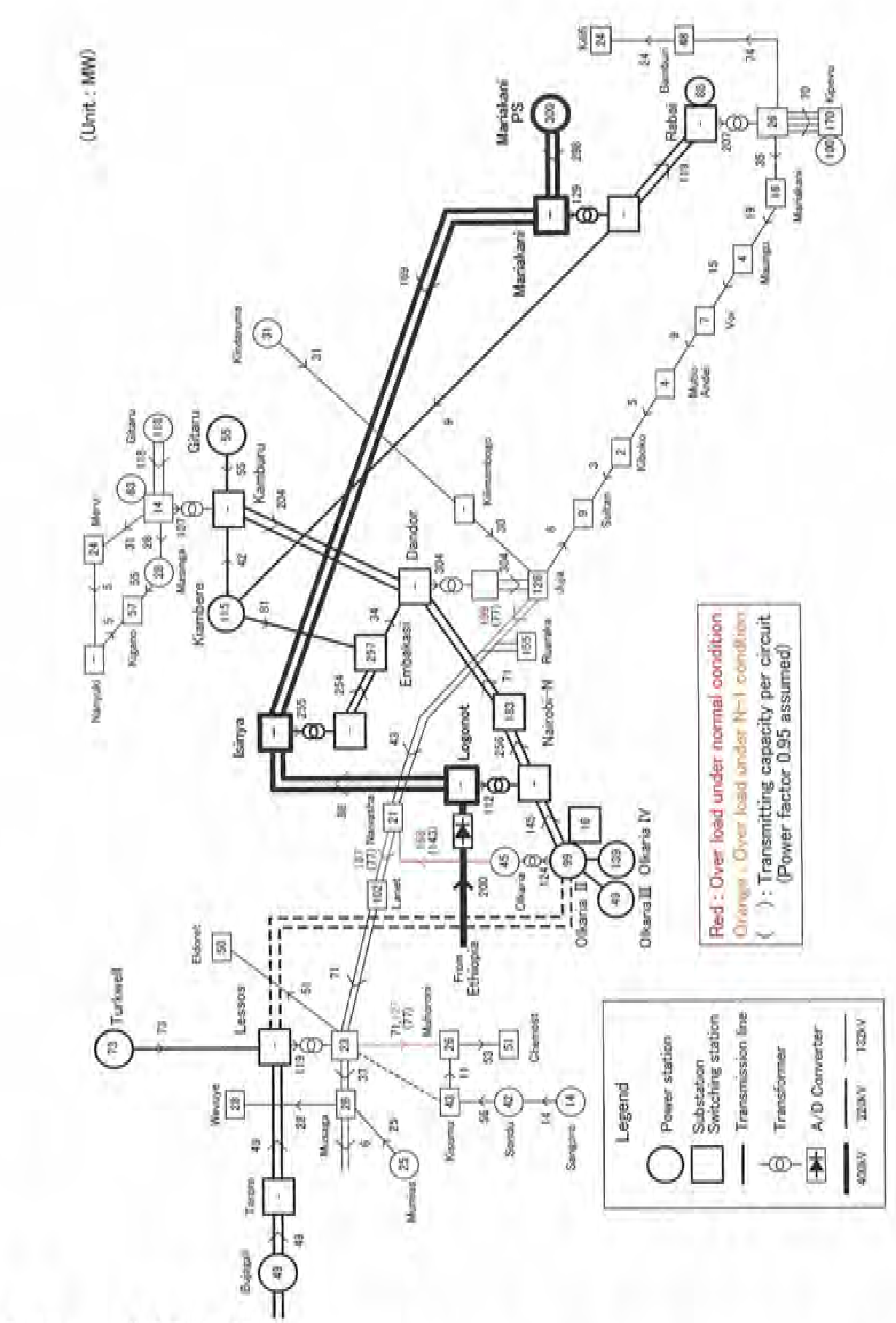
Among those transmission lines, the overload on the 132kV line Juja－Ruaraka will not be settled even after completion of planned upgrading of the transmission lines because this transmission line is used for the purpose of feeding a large power (155MW) to Ruaraka substation. Therefore, this problem should be resolved separately, and would not be considered in this scope of this survey.

Most of the problems of overload on many transmission lines will be settled after implementation of planned upgrading of the transmission lines. However, overload of two lines, 132kV Lessos－Muhoroni and 132kV Naivasha－Lanet will remain under N-1 conditions. This matter will be discussed in Chapter 5, 5.2.3 and 5.2.4.



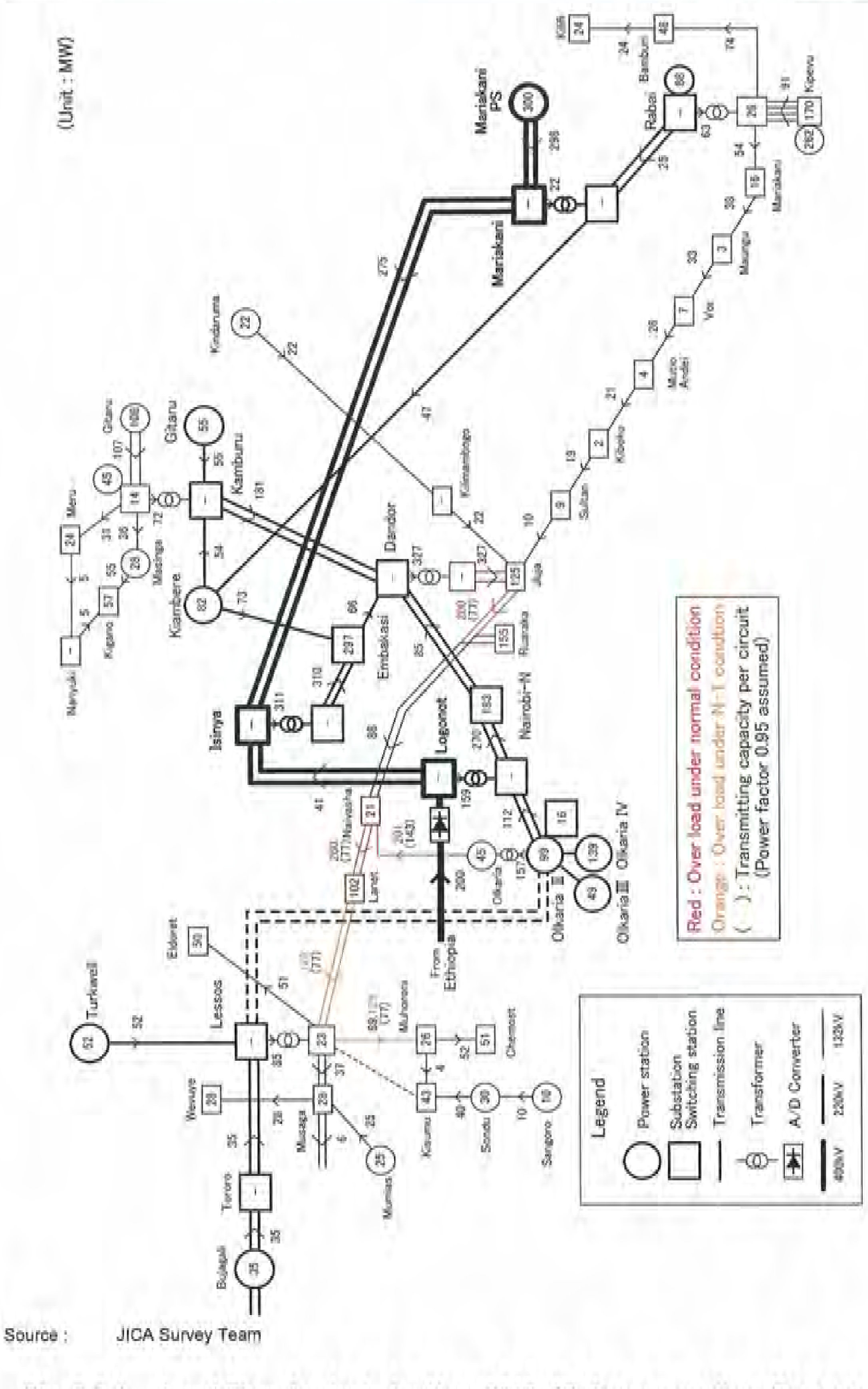
Source : JICA Survey Team

Fig. 5-2.2 Load Flow Analysis for Year 2013（Before reinforcement of T/L, Wet season）



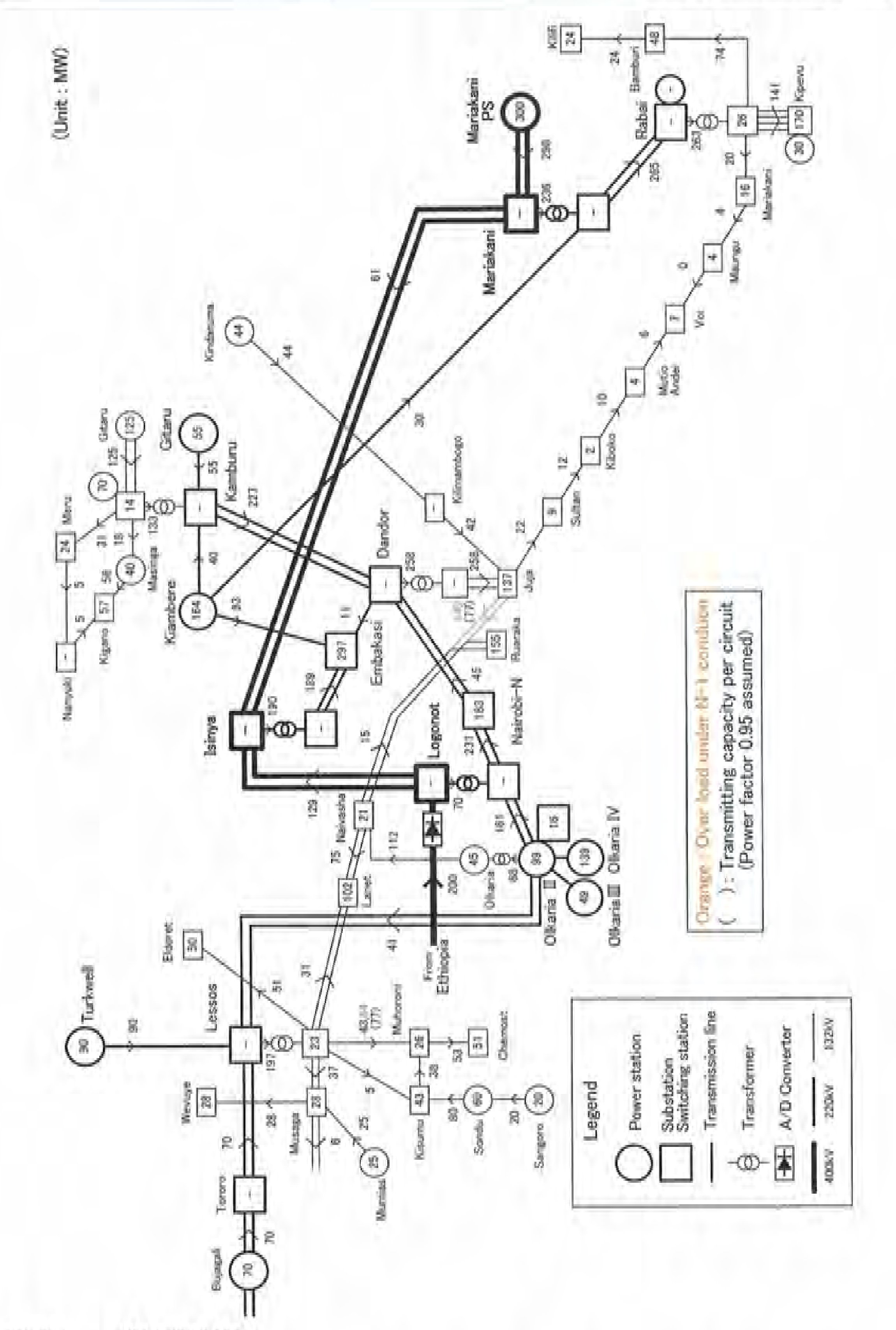
Source : JICA Survey Team

Fig. 5-2.3 Load Flow Analysis for Year 2013 (Before upgrading, Dry season with 70% hydropower output)



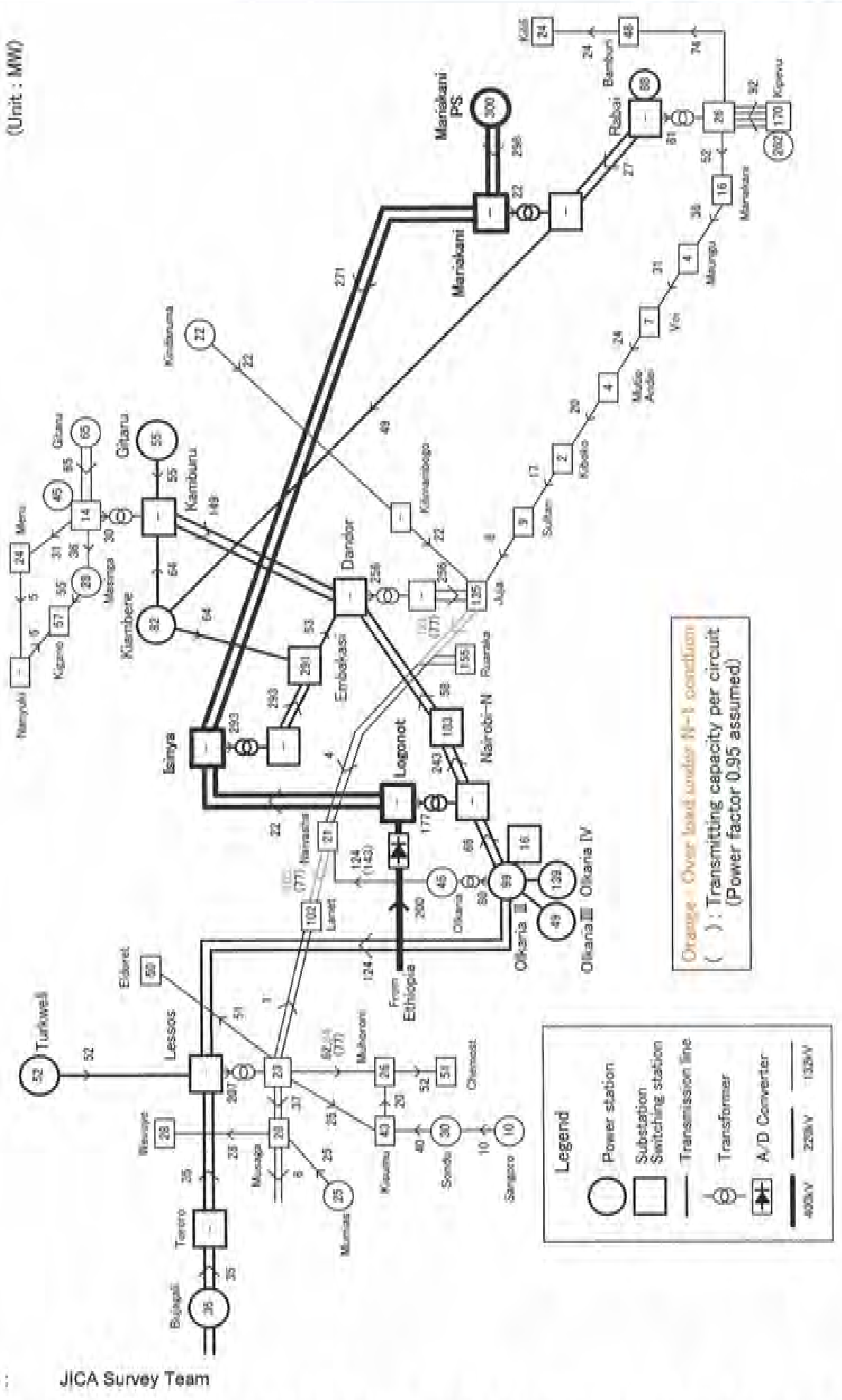
Source : JICA Survey Team

Fig. 5-2.4 Load Flow Analysis for Year 2013（Before upgrading, Dry season with 50% hydropower output）



Source : JICA Survey Team

Fig. 5-2.5 Load Flow Analysis for Year 2013（After upgrading, Wet season）



Source : JICA Survey Team

Fig. 5-2.6 Load Flow Analysis for Year 2013 (After upgrading, Dry season with 50% hydropower output

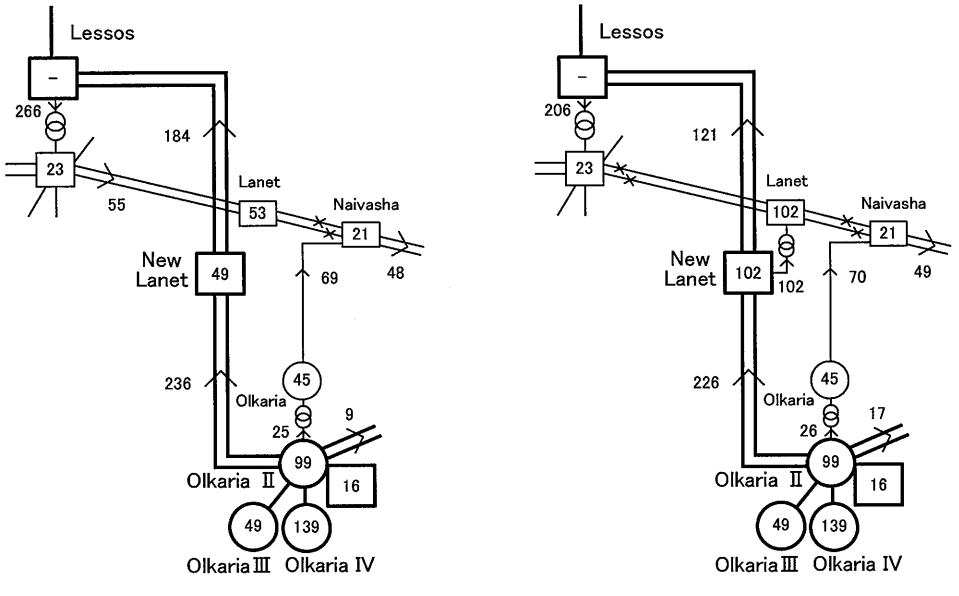
5.2.3 Measures of overload on the line between Naivasha and Lanet

As indicated in Table 5-2.1 and Figure 5-2.6, the overload occurs on existing 132kV line from Naivasha to Lanet during the dry season even after completion of the upgrading of the line between Olkaria and Lessos. This overload is caused because the transmission capacity of the conductor for the line between Navasha and Lanet is only 77MW, but the demand of Lanet Substation at the end of this line is 102 MW. For this countermeasure, it is proposed that the transmission line for feeding Lanet Substation may be operated under 220kV, as mentioned in the following two cases.

Case1: The Existing Lanet substation supply the load up to 2009 level, without any augmentation. Future increased load after 2009 is supplied partly by New Lanet 220kV substation which is to be constructed below the new 220kV Olkaria—Lessos Line after the Project. In this case, the existing Naivasha—Lanet Line will be normally opened.

Case2: 220/132kV New Lanet substation is constructed and connected with the new 220kV Olkaria—Lessos Line. And 220/132kV New Lanet substation is constructed after the Project and connected to the existing 132kV Lanet substation. Then all loads in the existing Lanet substation are supplied by the new 220kV transmission line. In this case, the existing Naivasha—Lanet and Lanet—Lessos Lines will be normally opened.

Figure 5-2.7 shows the load flow during the extremely dry season when overload condition is severe, after this countermeasure. Of course, the overload of existing 132kV transmission line Naivasha—Lanet is resolved in both case.



Case1 Case2

Source: JICA Survey Team

Fugure 5-2.7 Load Flow around Lanet S/S (2013, Extremely Dry Season) (MW)

Comparison of Case 1 and Case 2 is made hereunder. Case 1 has more advantages and thus, is recommended.

- New Lanet substation is expected to be constructed near the existing Lanet substation for distribution purpose. However, as explained in 8.1.1 of Chapter 8, the recommended route of 220kV Olkaria－Lessos line gets around Nakuru city to reduce the resettlement and to minimize environmental impact. Inevitably New Lanet substation have to be located far away from the existing Lanet substation. Case 2 requires construction of another 132kV transmission line between the new and existing Lanet substations, while Case 1 only require distribution lines, the construction of which is much easier.
- If Case 2 is employed, the existing 132kV Naivasha－Lessos line will become only the interconnection line and not the feeder.
- If Case 1 is employed, the existing 132kV Naivasha－Lessos line will become the feeder line for the existing Lanet substation and will be efficiently used. Hence, the load of the new 220kV Olkaria－Lessos line will be decreased by the load of the existing Lanet substation. The life time of New Lanet substation will be extended because the expected time of overload of the new substation is to be prolonged.

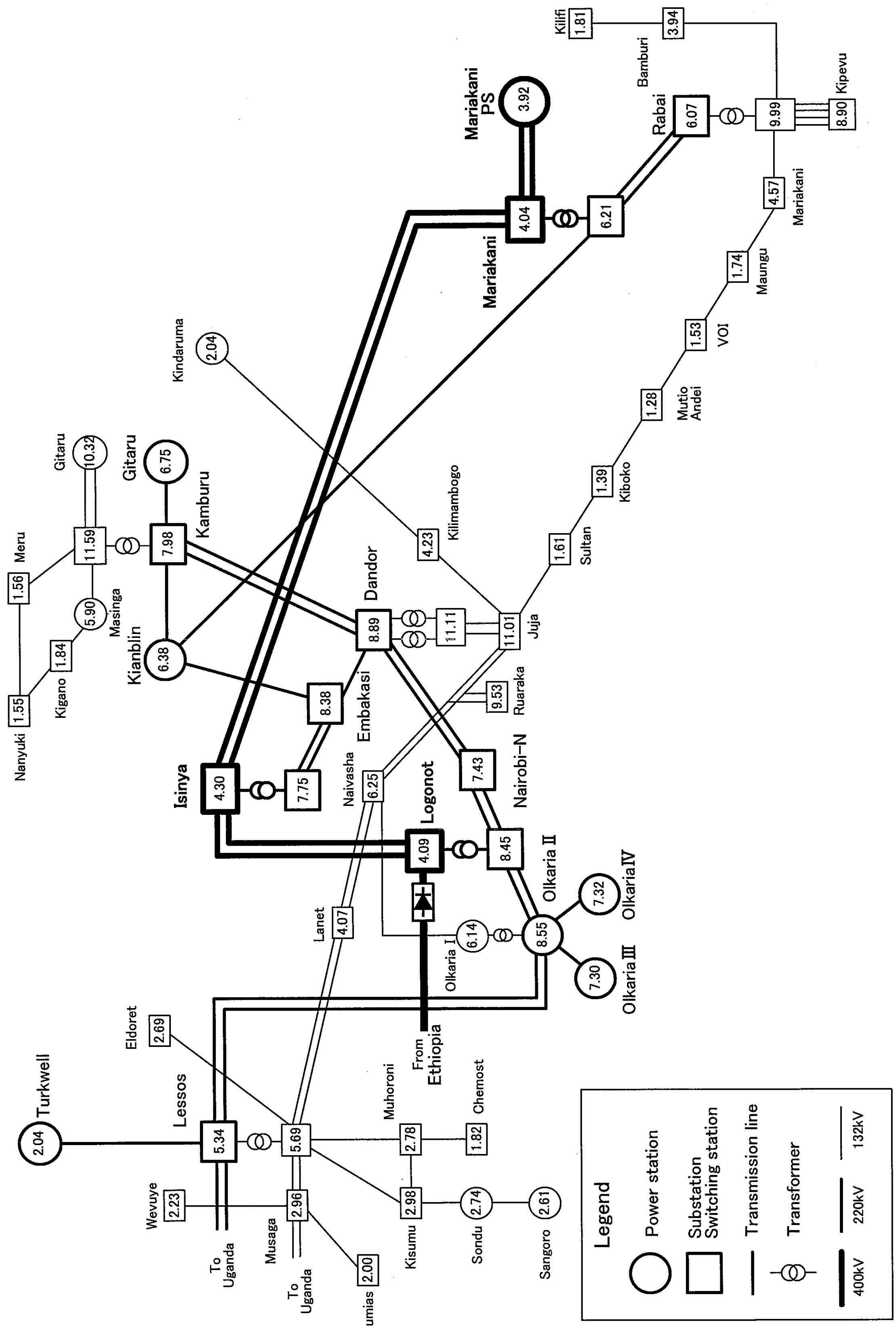
5.2.4 Result of Fault Current Analysis

Figure 5-2.8 and Table 5-2.2 show the result of fault current analysis. Since the interconnection with Ethiopia is planned as D.C. operation, this interconnection itself will not increases the fault current. Hence, the fault current will be comparatively small such as 4.30kA at 400kV Isinya Substation, 8.89kA at 220kV Dandor Substation and 11.59 kA at 132kV Kamburu Substation. Those current values are less much than the rating 40kA of circuit breakers.

Table 5-2.2 Fault Current Analysis（for the year of 2013）

400kV			220kV			132kV		
Name	Fault current (kA)	Rated breaking current (kA)	Name	Fault current (kA)	Rated breaking current (kA)	Name	Fault current (kA)	Rated breaking current (kA)
Isinya	4.30	Planned	Kamburu	7.98	40	Kamburu	11.59	40
Logonot	4.09	Planned	Dandor	8.89	40	Dandor	11.11	31.5
Mariakani	4.04	Planned	Nairobi-N	7.43	31.5	Juja	11.01	40
			Olkaria Ⅱ	8.55	50	Olkaria Ⅰ	6.14	12.5
			Lessos	5.34	31.5	Lessos	5.69	31.5
			Rabai	6.07	40	Kipevu	8.90	31.5

Source: JICA Survey Team



Source: JICA Survey Team

Fig. 5-2.8 Fault Current Analysis（for Year of 2013）

5.2.5 Stability Analysis

(1) Conditions for Stability Analysis

Kenya Grid Code regulates that the fault breaking time is at 100ms for 400kV, 120ms for 220kV and 120ms for 132kV according to Article S3.1.9 of Schedule 3.1.

Therefore, the stability analysis was conducted under the conditions that transients were initiated by three phase faults on the system, and the circuit breaker will open the circuit in 100ms or 120ms, then the faulted circuit will be isolated.

In addition, the location of line fault was determined in the following manner.

The planned 220kV transmission line of Olkaria－Lessos will connect the central and western region in the grid of the country. The existing 132kV transmission lines Juja－Naivasha－Lanet－Lessos, and Olkaria I－Naivasha have the same function so that the analysis of stability also applied to those lines. In addition, since transmission lines with heavy load tend to be in severe condition under the stability analysis, 220kV transmission line Logonot–Nairobi North, and 400kV transmission line Logonot and Ishinya were also considered in analysis. The transmission lines of 220kV Olkaria II–Lessos, and 132kV Lessos–Kisumu to be upgraded were also analyzed.

(2) Result of Stability Analysis

Table 5-2.3 shows the result of stability analysis, and Figure 5-2.9 (attached after 5.2.6 of this Chapter) indicates Phase-voltage fluctuation curve in generator. The outline of result of analysis is mentioned below.

[Before the upgrading of planned transmission lines]

During the wet season, since the supply of power by hydropower plants is secured, the load flow from east to west, which normally occurs, is relatively small. Even when a line fault happens, the fluctuation may continue for some period but will fade away in time. All the cases are stable.

During the dry season with 70% rated output by hydropower plants, since the load flow from the east to the west increases, the conditions for stability becomes severe. The swing transient may occur and be damped for a long period except the case #10. In case #10 that a fault happened on the 132kV transmission line Olkaria I to Naivasha, the swing transient will occur and increase, then stability cannot be secured.

During the extremely dry season with 50% rated output by hydropower plants, all the cases will be unstable. Especially, in case of the fault at 132kV Naivasha－Lanet（case #14）、132kV Olkaria I －Naivasha (case #16) and 220kV Logonot－Nairobi North (case #17), the phase-voltage fluctuation increases in a very short period and becomes unstable.

[After the upgrading of planned transmission lines]

During both wet and dry seasons including extremely dry season, the swing of the phase-voltage fluctuation is small, and is capable to be dampened until stable condition.

Table 5-2.3 Result of Stability Analysis（for the year of 2013）

Season	Fault line	Fault point	Power flow before fault	Stability	Case No.
Before augmentation of lines					
Wet	132kV Juja-Naivasha	Naivasha	146MW	Stable	1
	132kV Naivasha-Lanet	Naivasha	92MW	Stable	2
	132kV Lanet-Lessos	Lessos	14MW	Stable	3
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	123MW	Stable	4
	220kV Logonot-Nairobi N	Nairobi N	247MW	Stable	5
	400kV Logonot-Isinya	Isinya	142MW	Stable	6
Dry (70%)	132kV Juja-Naivasha	Naivasha	187MW	Stable	7
	132kV Naivasha-Lanet	Naivasha	162MW	Stable	8
	132kV Lanet-Lessos	Lessos	49MW	Stable	9
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	154MW	Unstable	10
	220kV Logonot-Nairobi N	Nairobi N	259MW	Stable	11
	400kV Logonot-Isinya	Isinya	99MW	Stable	12
Dry (50%)	132kV Juja-Naivasha	Naivasha	225MW	Unstable	13
	132kV Naivasha-Lanet	Naivasha	229MW	Unstable	14
	132kV Lanet-Lessos	Lessos	105MW	Unstable	15
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	187MW	Unstable	16
	220kV Logonot-Nairobi N	Nairobi N	279MW	Unstable	17
	400kV Logonot-Isinya	Isinya	46MW	Unstable	18
After augmentation of lines					
Wet	132kV Juja-Naivasha	Naivasha	133MW	Stable	19
	132kV Naivasha-Lanet	Naivasha	66MW	Stable	20
	132kV Lanet-Lessos	Lessos	39MW	Stable	21
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	110MW	Stable	22
	132kV Lessos-Kisumu	**Lessos**	**2MW**	**Stable**	**23**
	220kV Olkaria Ⅱ -Lessos	**Olkaria Ⅱ**	**26MW**	**Stable**	**24**
	220kV Logonot-Nairobi N	Nairobi N	240MW	Stable	25
	400kV Logonot-Isinya	Isinya	137MW	Stable	26
Dry (70%)	132kV Juja-Naivasha	Naivasha	146NW	Stable	27
	132kV Naivasha-Lanet	Naivasha	84MW	Stable	28
	132kV Lanet-Lessos	Lessos	22MW	Stable	29
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	115MW	Stable	30
	132kV Lessos-Kisumu	**Lessos**	**14MW**	**Stable**	**31**
	220kV Olkaria Ⅱ -Lessos	**Olkaria Ⅱ**	**71MW**	**Stable**	**32**
	220kV Logonot-Nairobi N	Nairobi N	241MW	Stable	33
	400kV Logonot-Isinya	Isinya	86MW	Stable	34
Dry (50%)	132kV Juja-Naivasha	Naivasha	155MW	Stable	35
	132kV Naivasha-Lanet	Naivasha	97MW	Stable	36
	132kV Lanet-Lessos	Lessos	10MW	Stable	37
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	120MW	Stable	38
	132kV Lessos-Kisumu	**Lessos**	**22MW**	**Stable**	**39**
	220kV Olkaria Ⅱ -Lessos	**Olkaria Ⅱ**	**110MW**	**Stable**	**40**
	220kV Logonot-Nairobi N	Nairobi N	253MW	Stable	41
	400kV Logonot-Isinya	Isinya	30MW	Stable	42

Source: JICA Survey Team

5.2.6 Outline of Power Flow Analysis

The summary of result of power system analysis is shown in Table 5-2.4.

Since the 132kV transmission line Juja to Ruaraka is to be judged out of the project scope, overload on this line was not considered.

According to the result of this analysis, it is concluded that the planned 220kV transmission line Olkaria II to Lessos and 132kV transmission line Lessos to Kisumu are essential for dissolution of overload condition as well as maintain the reliability of the transmission system. It shall be noted that individual solutions are additionally necessary for 132kV Naivasha－Lanet line and 132kV Lessos－Muhoroni line.

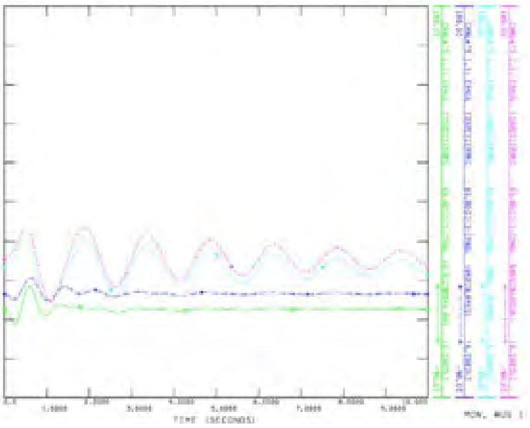
Table 5-2.4 Conclusion of Analysis

Item	Season	Before augmentation of lines	After augmentation of lines
Overload line	Wet	132kV Naivasha-Lanet 132kV Lessos-Muhoroni	132kV Lessos-Muhoroni
	Dry(70%)	132kV Naivasha-Lanet 132kV Olkaria Ⅰ-Naivasha 132kV Lessos-Muhoroni	132kV Naivasha-Lanet 132kV Lessos-Muhoroni
	Dry(50%)	132kV Naivasha-Lanet 132kV Olkaria Ⅰ-Naivasha 132kV Lessos-Muhoroni 132kV Lanet-Lessos	132kV Naivasha-Lanet 132kV Lessos-Muhoroni
Stability	Wet	Stable	Stable
	Dry(70%)	Unstable	Stable
	Dry(50%)	Unstable	Stable

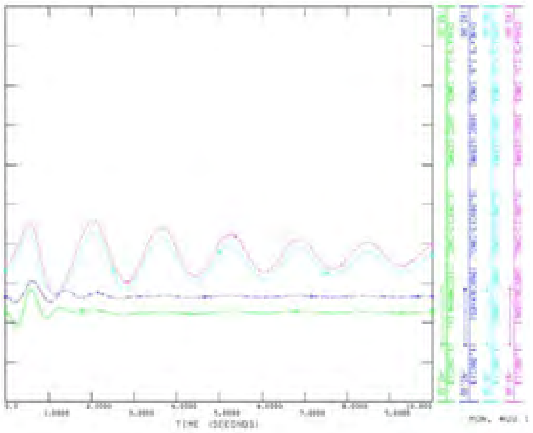
Red:Overload under normal condition Orange:Overload under N-1 condition

Source: JICA Survey Team

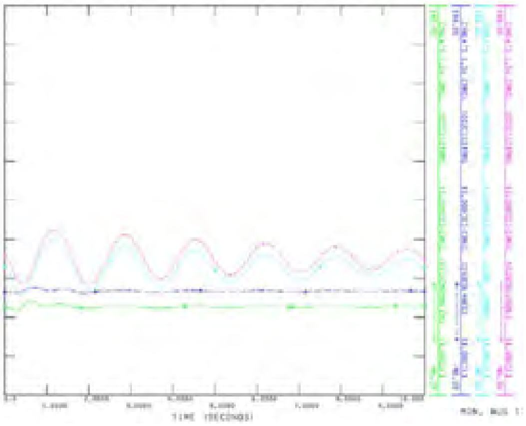
Case 1



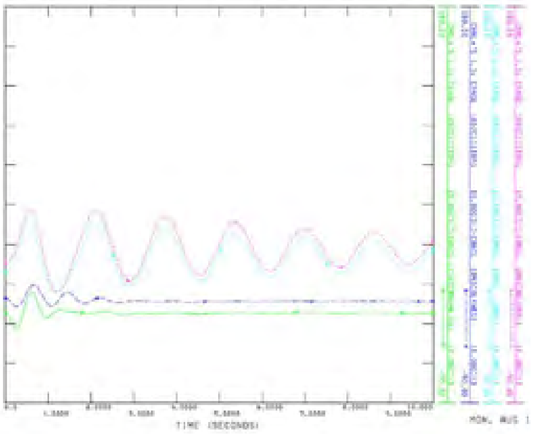
Case 2



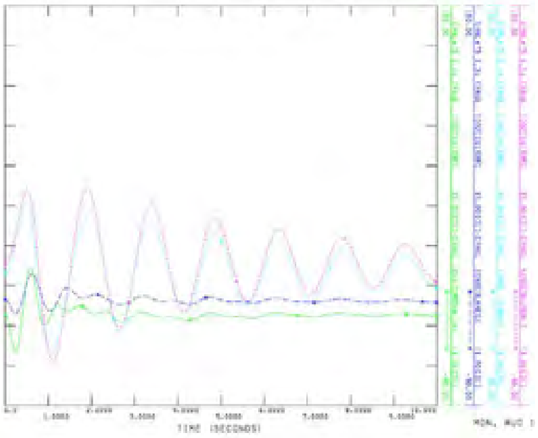
Case 3



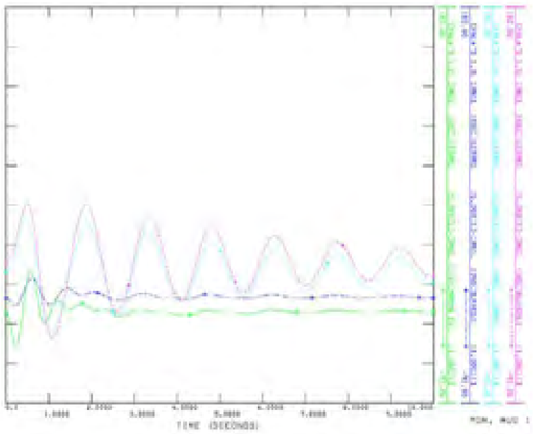
Case 4



Case 5



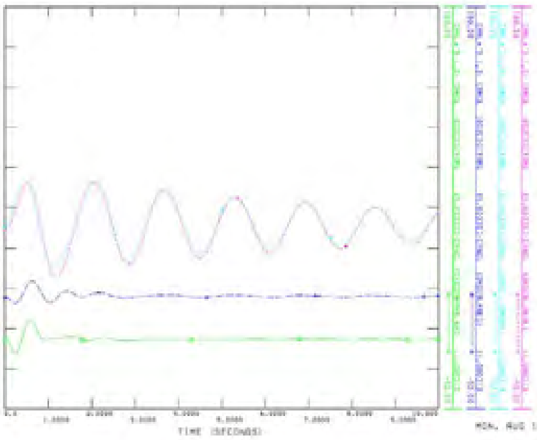
Case 6



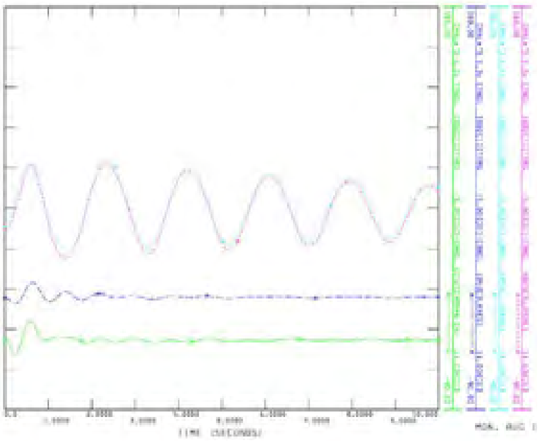
Source: JICA Survey Team

Fig. 5-2.9 (1) Phase-Voltage Fluctuation Curve in Generator (1)

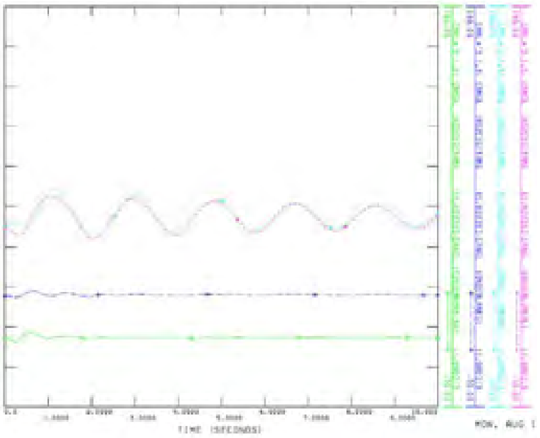
Case 7



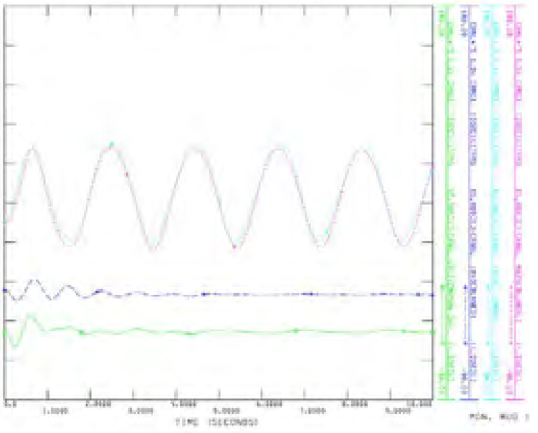
Case 8



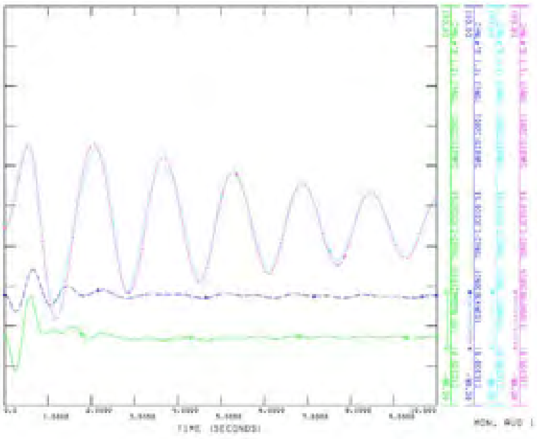
Case 9



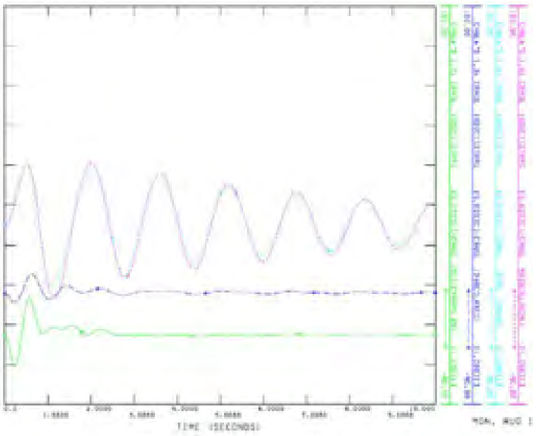
Case 10



Case 11



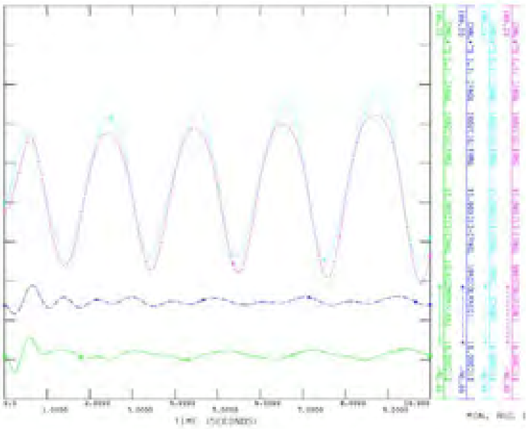
Case 12



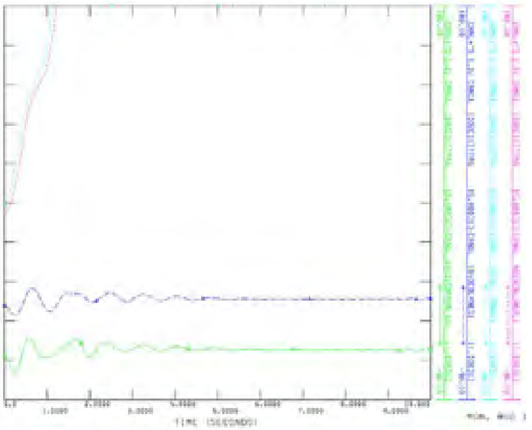
Source: JICA Survey Team

Fig. 5-2.9 (2) Phase-Voltage Fluctuation Curve in Generator (2)

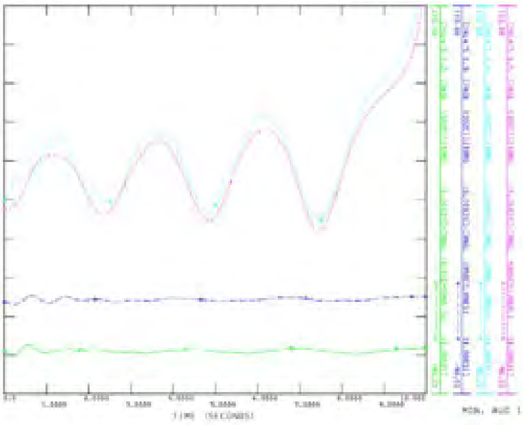
Case 13



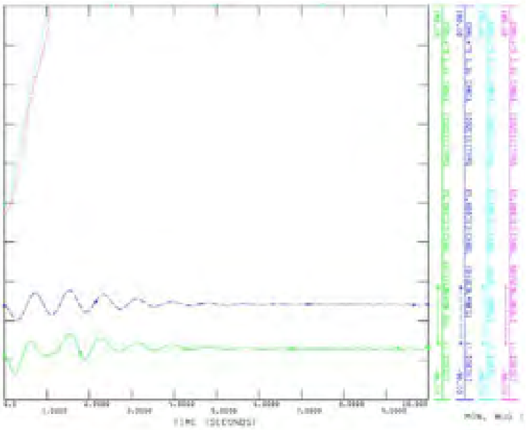
Case 14



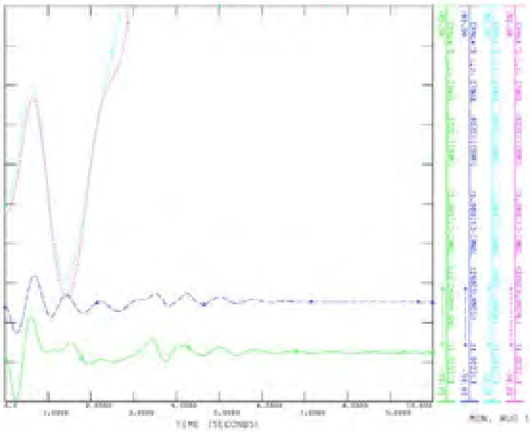
Case 15



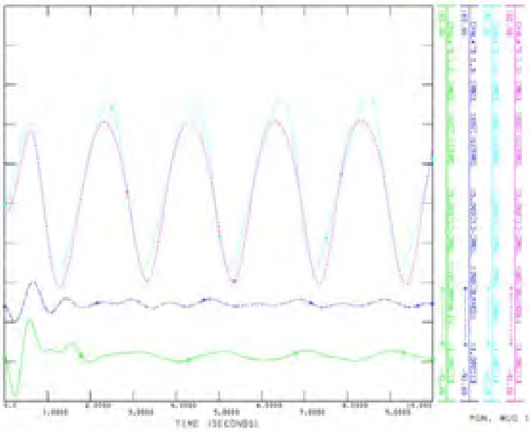
Case 16



Case 17



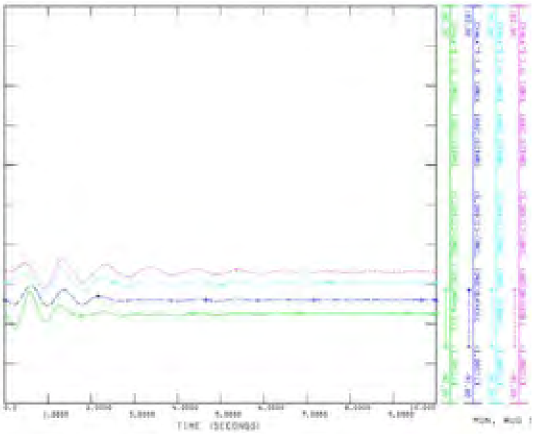
Case 18



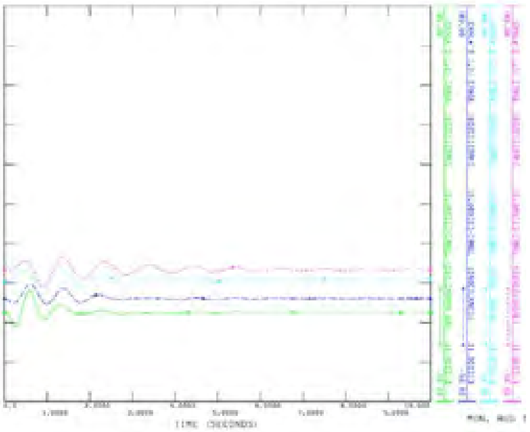
Source: JICA Survey Team

Fig. 5-2.9 (3) Phase-Voltage Fluctuation Curve in Generator (3)

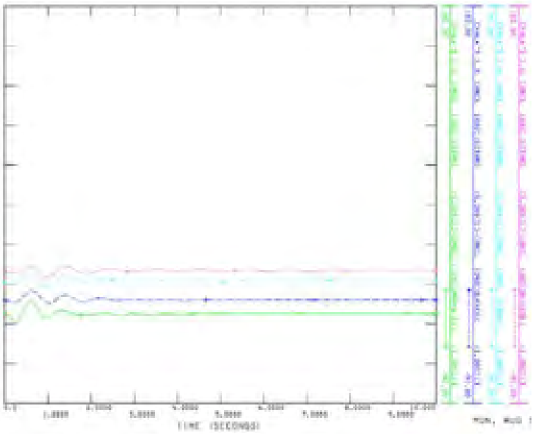
Case 19



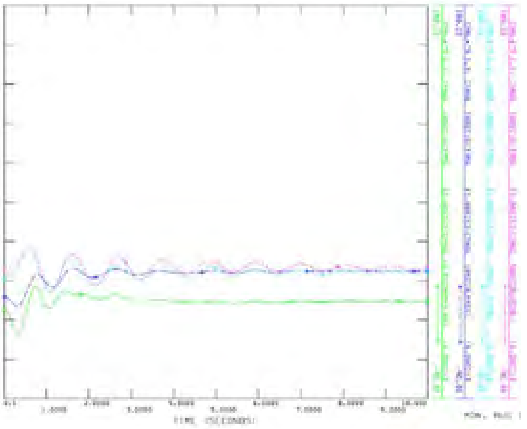
Case 20



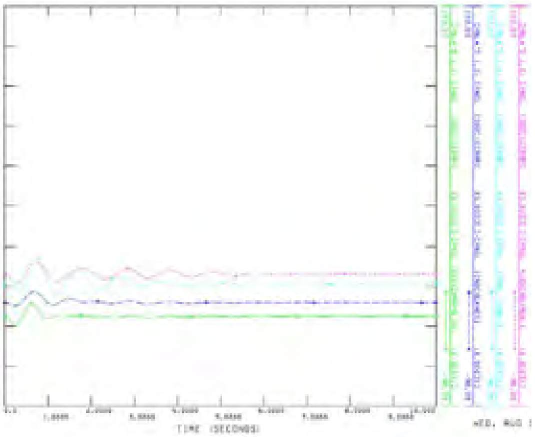
Case 21



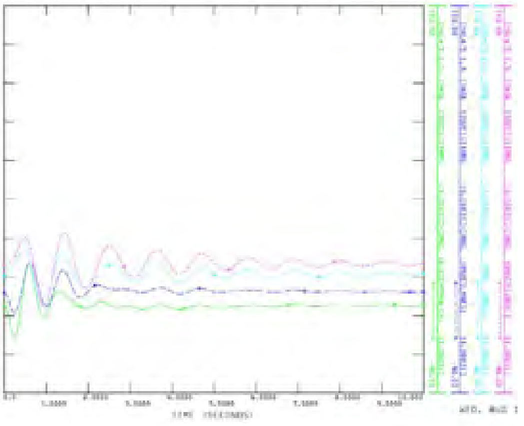
Case 22



Case 23

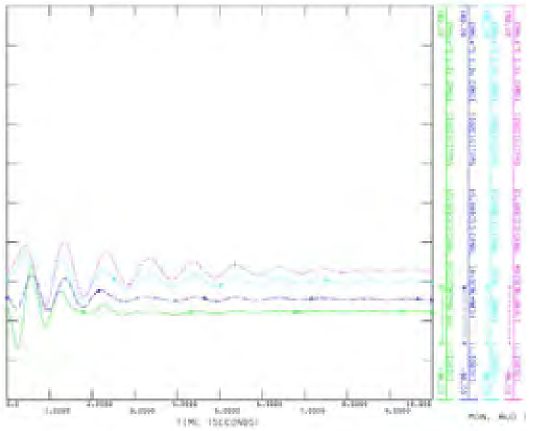
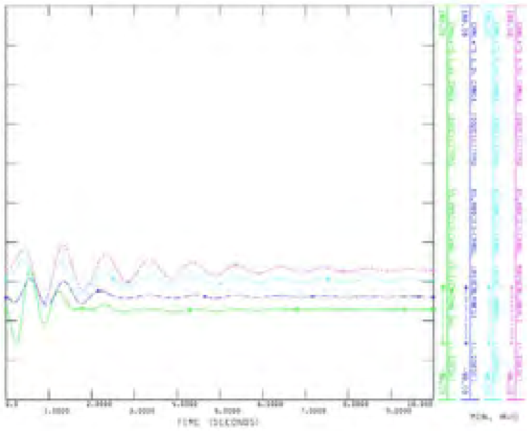
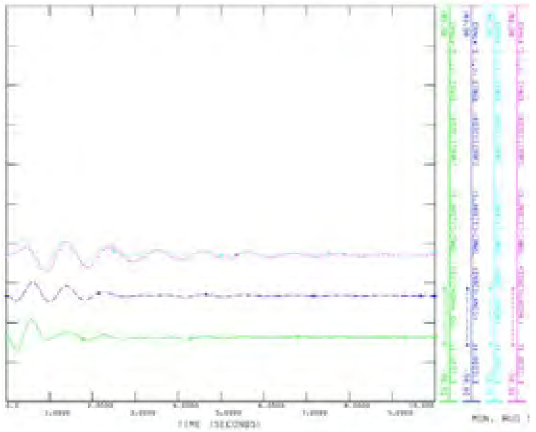
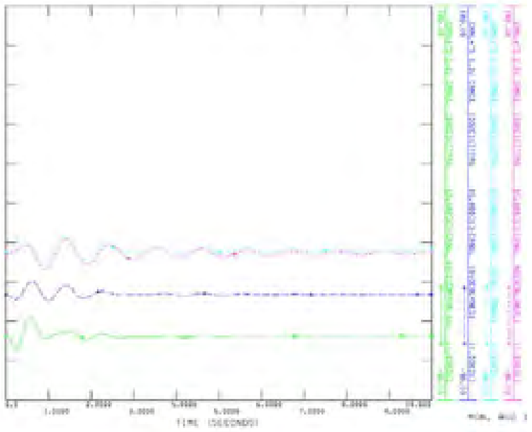
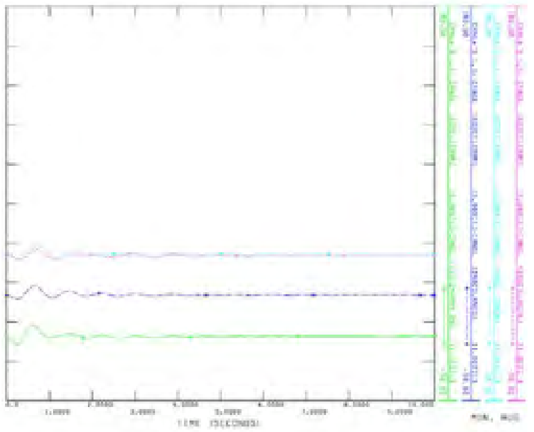
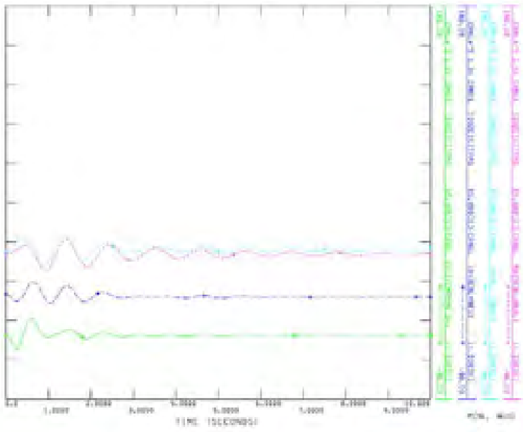


Case 24



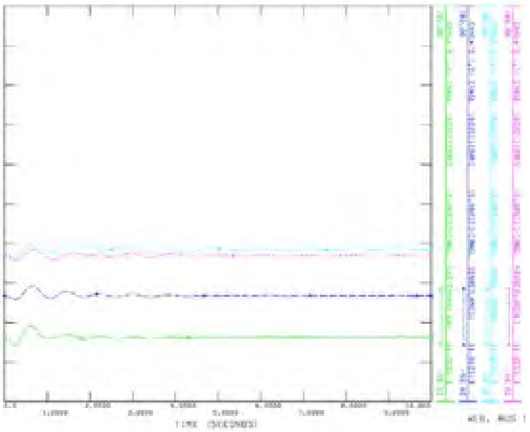
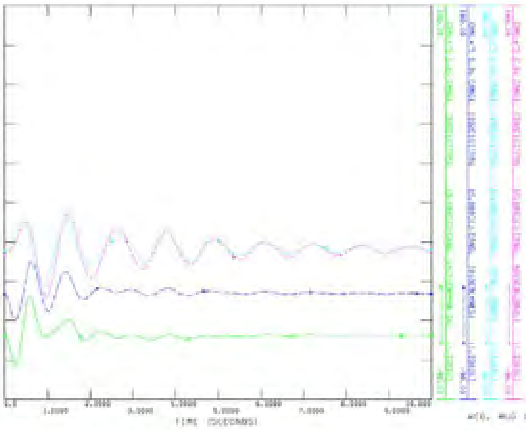
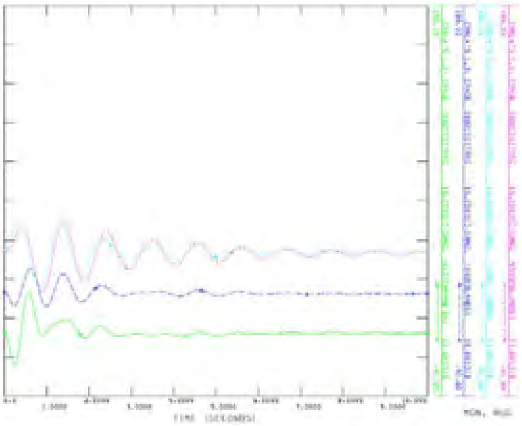
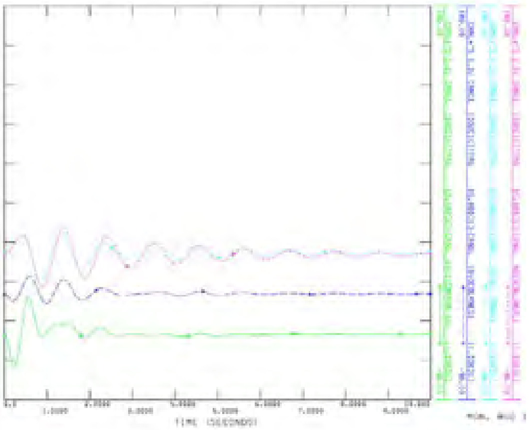
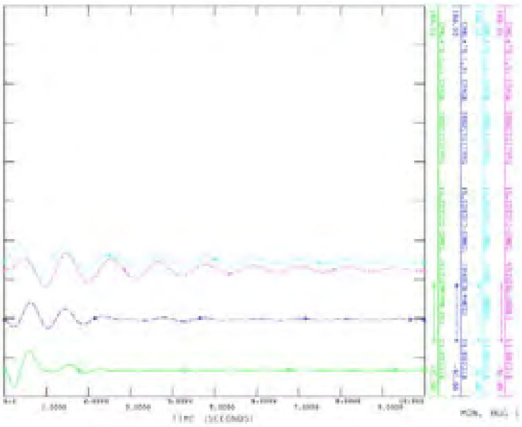
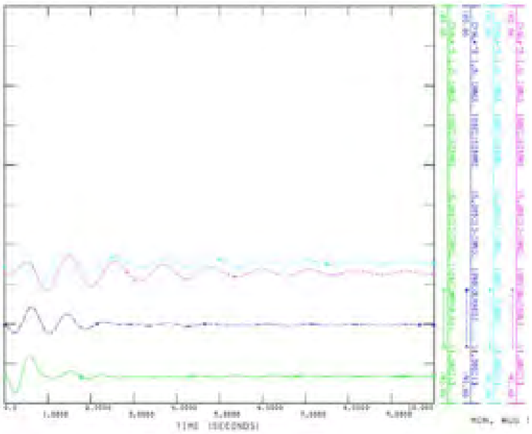
Source: JICA Survey Team

Fig. 5-2.9 (4) Phase-Voltage Fluctuation Curve in Generator (4)

Case 25	Case 26
	
Case 27	Case 28
	
Case 29	Case 30
	

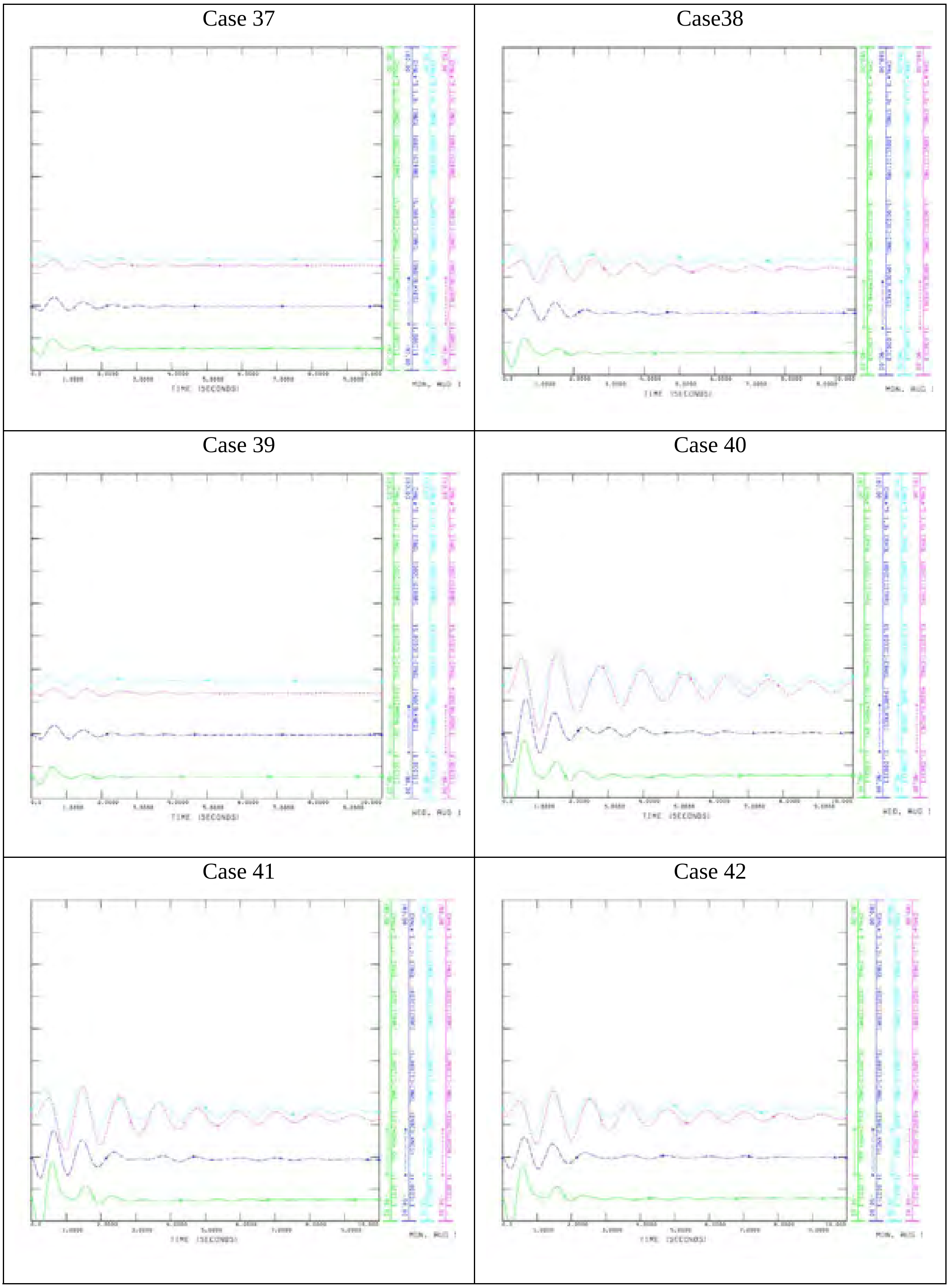
Source: JICA Survey Team

Fig. 5-2.9 (5) Phase-Voltage Fluctuation Curve in Generator (5)

Case 31 	Case 32 
Case 33 	Case 34 
Case 35 	Case 36 

Source: JICA Survey Team

Fig. 5-2.9 (6) Phase-Voltage Fluctuation Curve in Generator (6)



Case 37

Case38

Case 39

Case 40

Case 41

Case 42

Source: JICA Survey Team

Fig. 5-2.9 (7) Phase-Voltage Fluctuation Curve in Generator (7)

5.3 Result of Power Flow Analysis of 2020

The analysis of the 2020 system was conducted in order to verify the long term serviceability after the completion of the planned upgrading of the Olkaria－Lessos and Lesson－Kisumu transmission lines. Two cases of power generation by the hydropower station were selected because the hydropower generation varies in accordance with seasons, namely, wet season and extremely dry season.

Case 1 described in 5.2.3 is assumed to be the supply method to the New Lanet Substation. Furthermore, the Survey Team studied the transmission method of the new Menengai geothermal power plant, which will be located at the northern area of Nakuru City, with an output of 140 MW in 2019 and another 140 MW in 2020, totaling 280 MW. The result of the analysis is mentioned below.

5.3.1 Result of Load Flow

It is envisaged that Menegai geo-thermal power plant is connected to 220kV transmission line Olkaria－Lessos, because Menegai Power Plant will be located northern area of Nakuru and near the 220kV transmission line Olakaria－Lessos and the generating power of Menegai geo-thermal power plant will be as large as 280MW. Therefore, the Survey Team studied two cases of the connection of Menegai geo-thermal power plant for analysis, one is to connect to New Lanet substation as mentioned in 5.2.3, and another is to connect to 220kV Olkaria II substation.

Table 5-3.1 shows the result of load flow analysis on major transmission lines. Figures trough 5-3.1 to 5-3.4 indicate the results of load flow analysis for scenarios of (i) Wet and (ii) Extremely dry with 50% rating of hydropower.

Table 5-3.1 Load Flow of Major Transmission Line, 2020

Interconnection of Menengai	**Season**	220kV Olkaria-New Lanet	220kV New Lanet-Lessos	132kV Lessos-Kisumu	132kV Lessos-Muhoroni	132kV Muhoroni -Chemost	Fig. No.
Menengai to New Lanet	Wet	248	370	55	137	108	5-3.1
	Dry 50%	384	501	77	160	108	5-3.2
Menengai to Olkaria II	Wet	545	372	56	135	108	5-3.3
	Dry 50%	705	516	79	162	109	5-3.4
Transmitting Capacity		Planned	Planned	Planned	77	77	

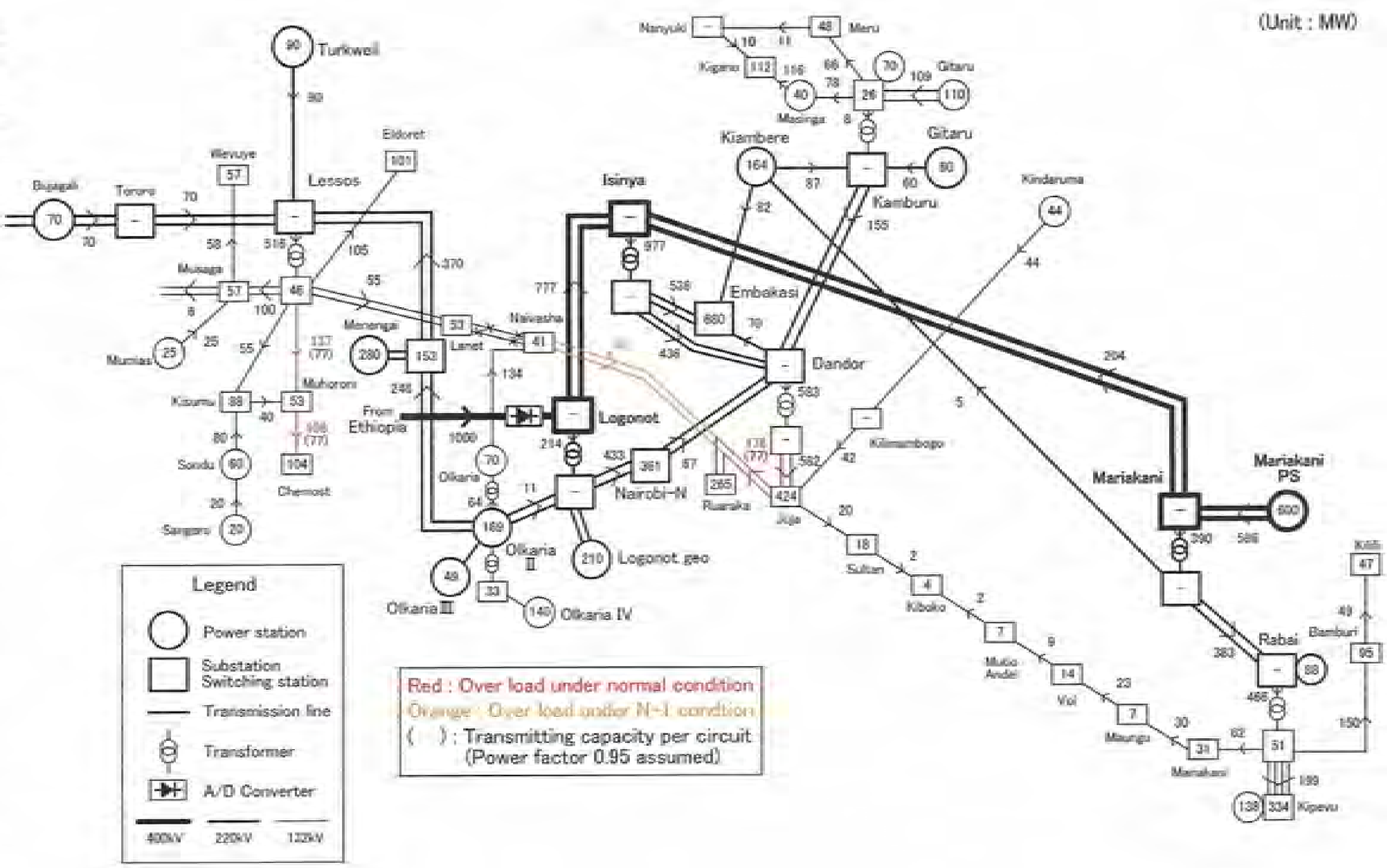
Source: JICA Survey Team

Red: Overload under normal operation

In case of the extremely dry season with 50% rating of hydropower, the 220kV transmission line OlkariaII－Lessos transmits the largest power flow. In case that Menegai geo-thermal power plant is connected to New Lanet substation, the load flow between New Lanet substation and Lessos substation is 501MW, whereas in case that Menegai geo-thermal power plant is connected to Olkaria II power plant, the load at the Olkaria II power plant and New Lanet substation is 705MW. Consequently, connecting Menengai geo-thermal power plant to New Lenat Substation is recommended because the load flow will be less and the transmission length is shorter than the connection to Olkaria II power plant.

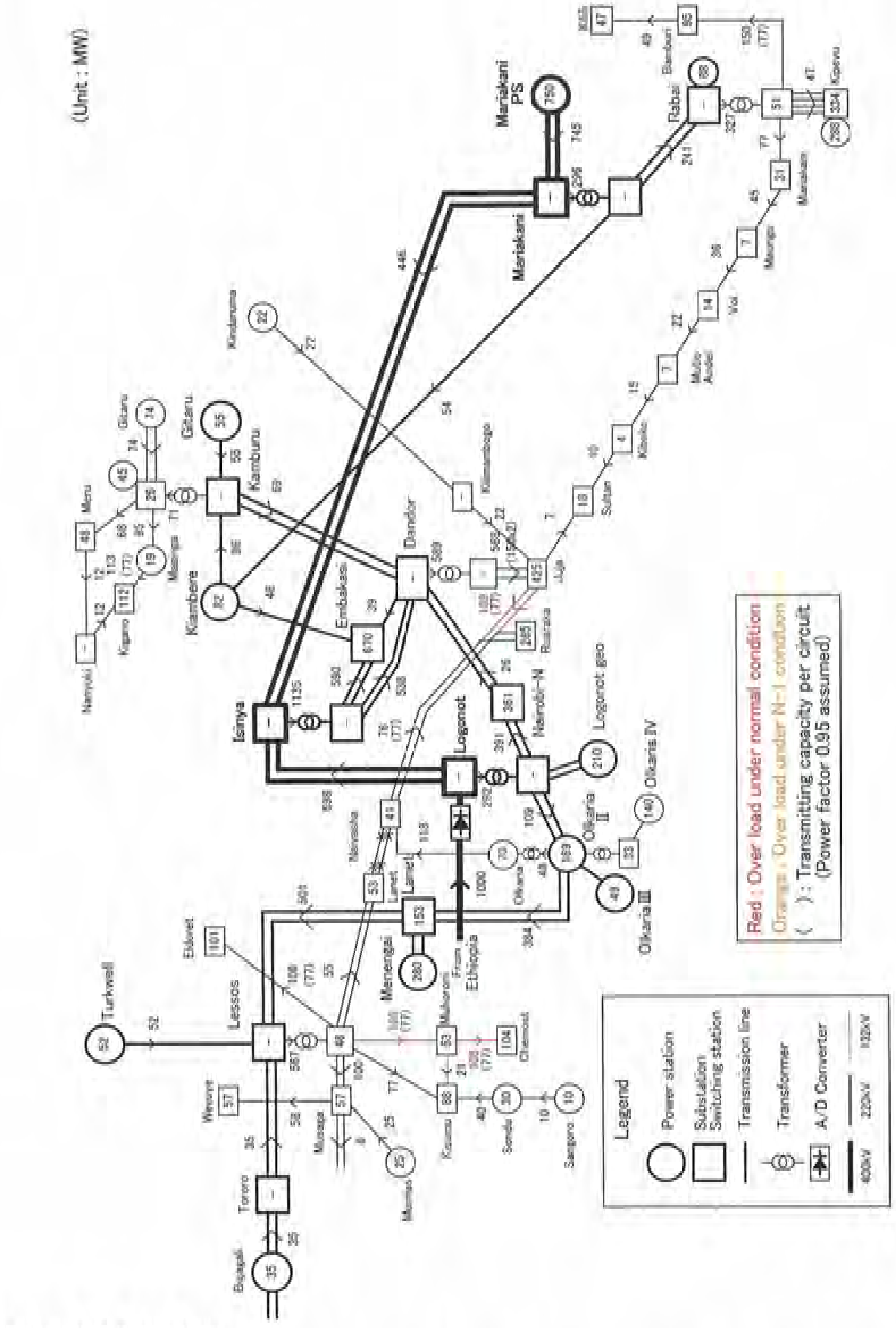
For the new lines Olkaria－lessos and Lessos－Kisumu, the conductor size and even voltage can be determined to suit the envisaged current to be loaded in future. However, the countermeasure for overloads of the existing transmission lines Lessos－Muhoroni and Muhoroni - Chemosit shall be considered. The countermeasure is described in 5.3.2.

As mentioned in 5.2.2, although the 132kV transmission line Juja－Naivasha will be overloaded in 2013 as well as 2020, this problem should be resolved separately, and would not be considered in this survey.



Source: JICA Survey Team

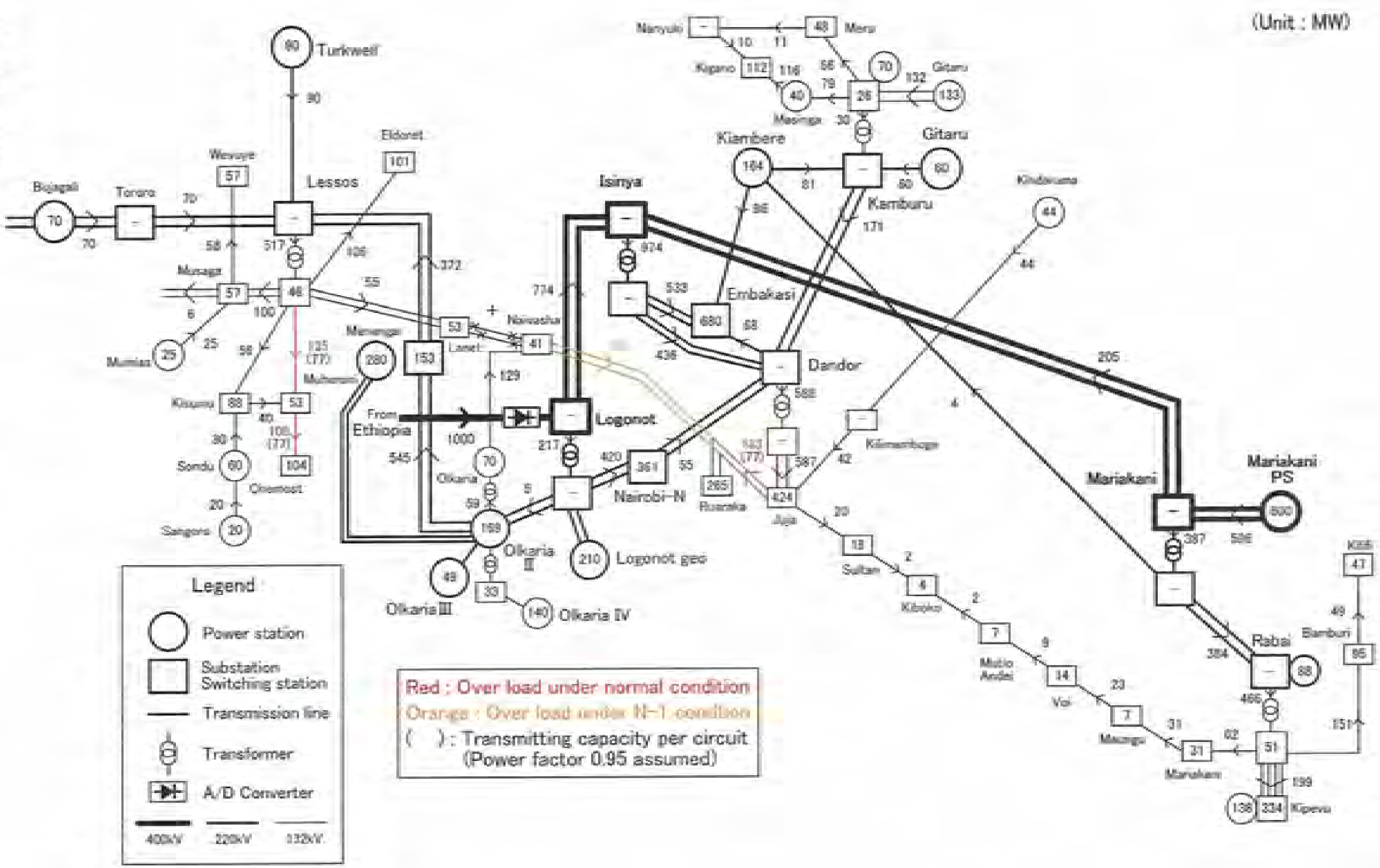
Figure 5-3.1 Load Flow Analysis for Year 2020 (Menengai to New Lanet, Wet Season)



Source: JICA Survey Team

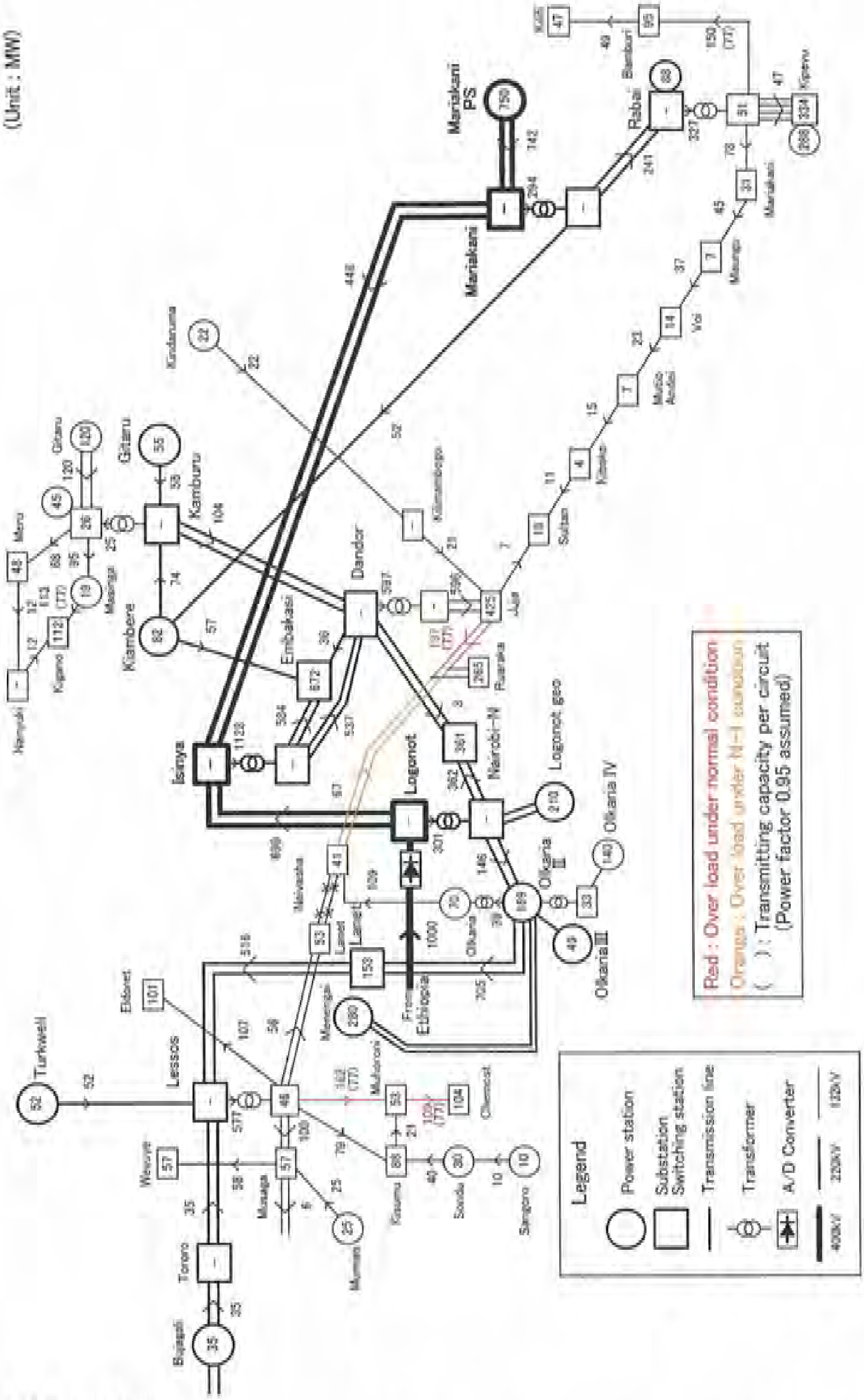
Figure 5-3.2 Load Flow Analysis for Year 2020 (Menengai to New Lanet, Extremely Dry Season)

(Unit : MW)



Source: JICA Survey Team

Figure 5-3.3 Load Flow Analysis for Year 2020 (Menengai to Olkaria II, Wet Season)



Source: JICA Survey Team

Figure 5-3.4 Load Flow Analysis for Year 2020 (Menengai to Olkaria II, Extremely Dry Season)

5.3.2 Measures of Overload on 132kV Line between Lessos and Muhoroni

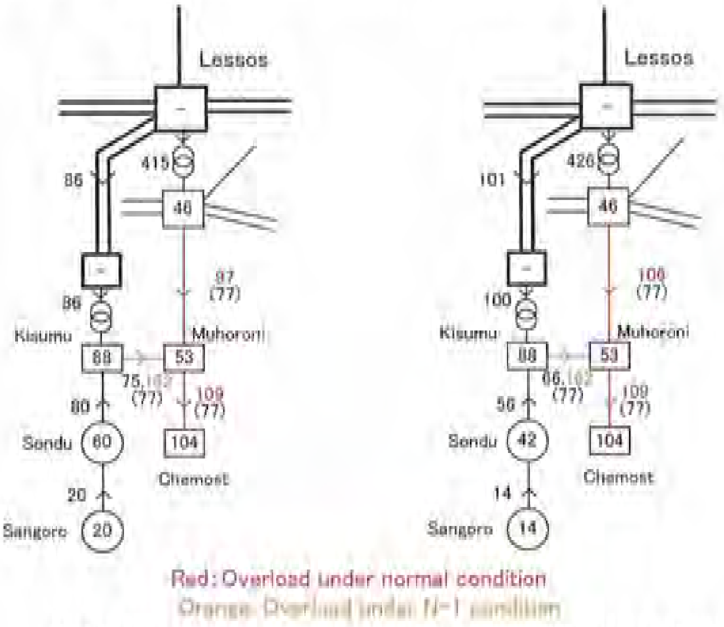
In case the transmission line Kisumu−Lessos of this project applies 132kV and one circuit as originally requested, the countermeasure of existing 132kV transmission line Lessos − Muhoroni will be necessary even during the wet season because the power flow for this line will be overloaded against the transmission capacity 77MW under normal operating conditions as indicated in Figure 5-3.1.

Until now, although the voltage of transmission lime Kisumu−Lessos has been assumed as 132kV, the Survey Team recommends to apply 220kV. Figure 5-3.5 shows the case that the transmission line Kisumu−Lessos applies 220kV and two circuit. The transmission line Lessos−Muhoroni during both of wet and dry season will be overloaded by 97MW and 106MW respectively against the transmission capacity 77MW under normal operating conditions.

Furthermore, the line of Kisumu−Muhoroni will be overloaded at 162MW under N-1 condition.

Therefore, at the appropriate timing after augmentation of the 220kV transmission line Kisumu −Lessos, the transmission line of Lessos−Muhoroni or Kisumu−Muhoroni shall have countermeasures, for example, to add another circuit, or to replace size of conductor having larger capacity.

Additionally, the existing 132kV line Muhoroni−Chemosit will also be overloaded under normal operating conditions, and since this transmission line is the only supply line to Chemosit substation which has 104MW load, the same countermeasure is necessary.



Wet Season

Dry Season (70% Hydro output)

Source: JICA Survey Team

Fig. 5-3.5 Power Flow of Case of 220kV TL Kisumu-Lessos, Year 2020.

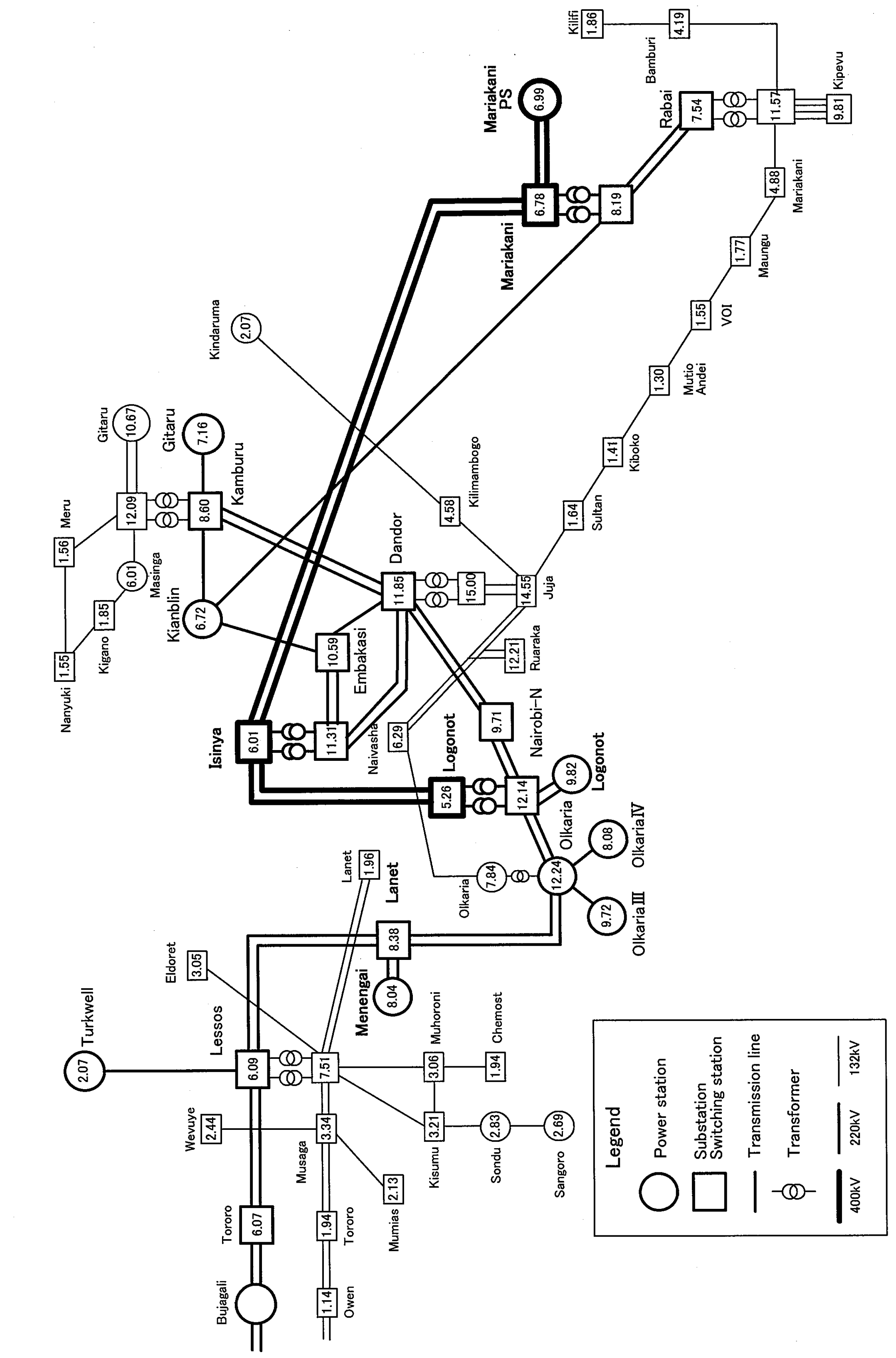
5.3.3 Result of Fault Current Analysis

Table 5-3.2 and Figure 5-3.6 show the result of fault current analysis as of 2020. Compared with the system of 2013 as shown in Table 5-2.2, the increase of fault current is relatively small although the system scale will become doubled. The maximum fault current is comparatively estimated small such as 6.78kA at 400kV Mariakani Substation, 12.24kA at 220kV Olkaria II Power Plant, and 15.00kA at 132kV Dandor Substation. Those current values are less than the rating 40kA or 31.5kA of circuit breakers.

Table 5-3.2 Fault Current Analysis (for the year of 2020)

400kV			220kV			132kV		
Name	Fault current (kA)	Rated breaking current (kA)	Name	Fault current (kA)	Rated breaking current (kA)	Name	Fault current (kA)	Rated breaking current (kA)
Mariakani	6.78	Planned	Kamburu	8.60	40	Kamburu	12.09	40
Isinya	6.01	Planned	Dandor	11.85	40	Dandor	15.00	31.5
Logonot	5.26	Planned	Nairobi-N	9.71	31.5	Juja	14.55	40
			Olkaria Ⅱ	12.24	50	Olkaria Ⅰ	7.84	12.5
			Lanet	8.38	Planned	Lessos	7.51	31.5
			Lessos	6.09	31.5	Rabai	11.57	31.5
			Rabai	7.54	40			

Source: JICA Survey Team



Source: JICA Survey Team

Fig. 5-3.6 Fault Current Analysis (for Year of 2020)

5.3.4 Result of Stability Analysis

As mentioned in 5.3.1, the recommended transmission methods from Menengai geo-thermal power plant is to connect itself to New Lanet Substation, and this method is also applied to the stability analysis. In addition to the wet season, the extremely dry season with 50% rating of hydropower is applied to the stability analysis. The conditions of analysis are the same as the system of 2013 in 5.2.5, which is very strict.

Table 5-3.3 shows the result of stability analysis, and Figure 5-3.7 (1) to (7) indicate phase-voltage fluctuation curve in generator. The outline of result of analysis is mentioned below.

After the fault, the swing of the phase-voltage fluctuation in all cases is relatively large because the power flow in dry season is severer than wet season. However, the swing of all the cases will fade away in time andbecome stable, and then the effect of augmentation of transmission line can be confirmed. The stability will be severe when the fault occurs at the transmission lines having a long length and a large power flow. The reason is because the fault line is opened and the power flow before the fault on the faulted line will be additionally loaded on the transmission line without fault. The swings of the phase-voltage fluctuation of 132kV line Juja－Naivasha (case #1 and #8), 220kV line Olkaria II－New Lanet (case #4and #11) and 220kV Logonot－Nairobi North (case #5 and #12) are relatively large. These transmission lines are having large power flow before the fault and a long length, but it is no problem about stability.

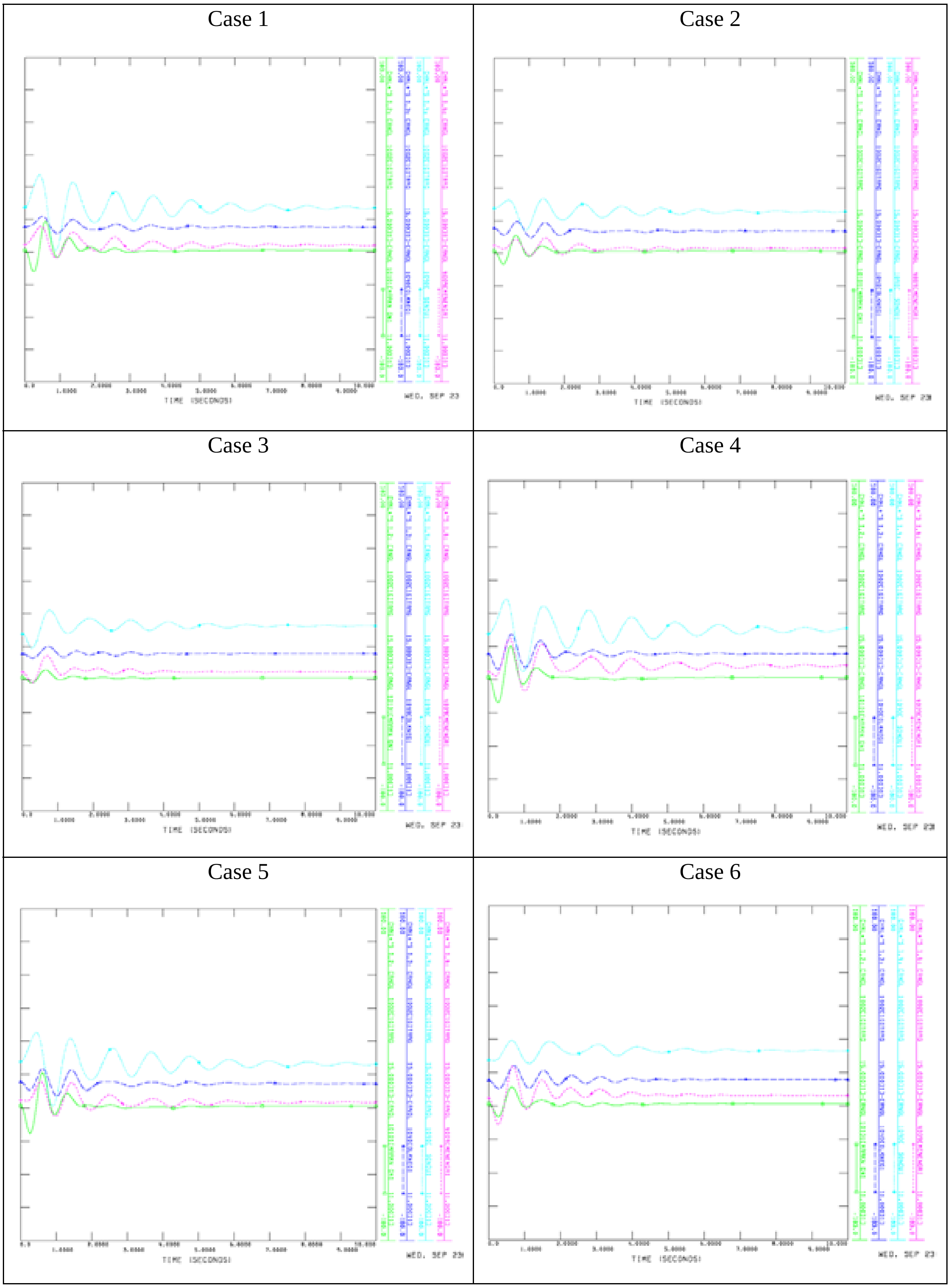
Table 5-3.3 Result of Stability Analysis (for the year of 2020)

Season	Fault line	Fault point	Power flow before fault	Stability	Case No.
Wet	132kV Juja-Naivasha	Juja	178MW	Stable	1
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	134MW	Stable	2
	132kV Lessos-Kisumu	Lessos	55MW	Stable	3
	220kV Olkaria Ⅱ -New Lanet	Olkaria Ⅱ	248MW	Stable	4
	220kV Logonot-Nairobi N	Logonot	433MW	Stable	5
	220kV New Lanet-Lessos	New Lanet	370MW	Stable	6
	400kV Logonot-Isinya	Logonot	777MW	Stable	7
Dry (50%)	132kV Juja-Naivasha	Juja	189MW	Stable	8
	132kV Olkaria Ⅰ -Naivasha	Olkaria Ⅰ	118MW	Stable	9
	132kV Lessos-Kisumu	Lessos	77MW	Stable	10
	220kV Olkaria Ⅱ -New Lanet	Olkaria Ⅱ	384MW	Stable	11
	220kV Logonot-Nairobi N	Logonot	391MW	Stable	12
	220kV New Lanet-Lessos	New Lanet	501MW	Stable	13
	400kV Logonot-Isinya	Logonot	698MW	Stable	14

Source: JICA Survey Team

5.3.5 Outline of Power Flow Analysis

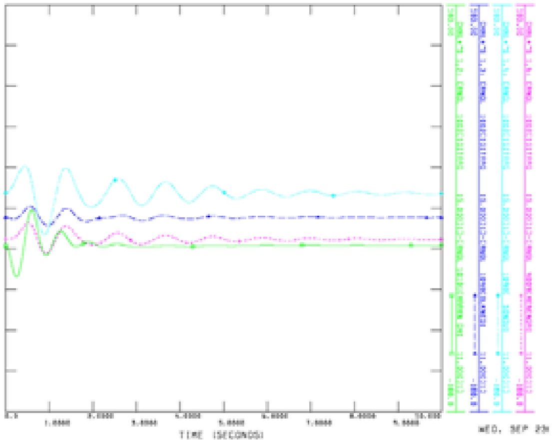
It has been found out that, by implementing the proposed Project, all the problems in respect to overloading, fault current, and stability, can be solved in long term.



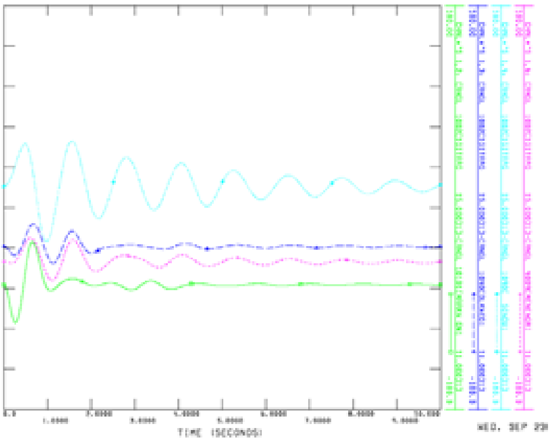
Source: JICA Survey Team

Fig. 5-3.7 (1) Phase-Voltage Fluctuation Curve in Generator of 2020

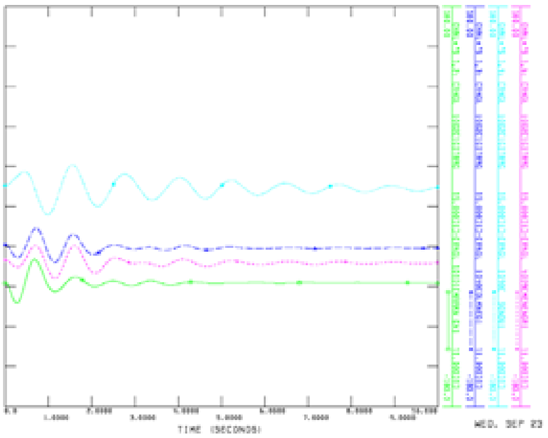
Case 7



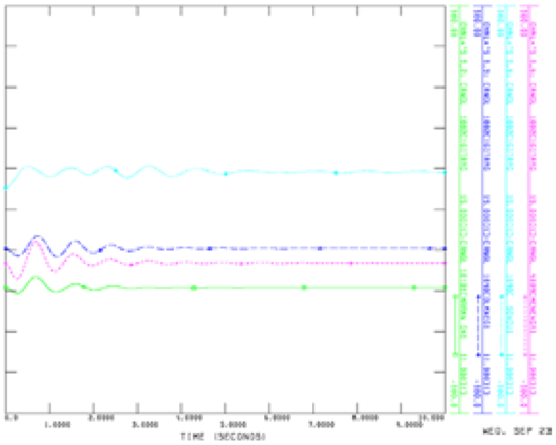
Case 8



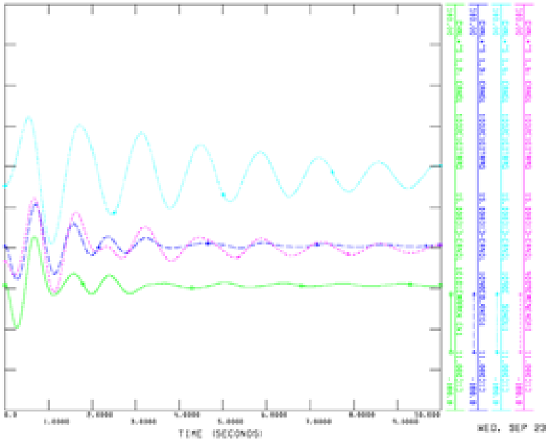
Case 9



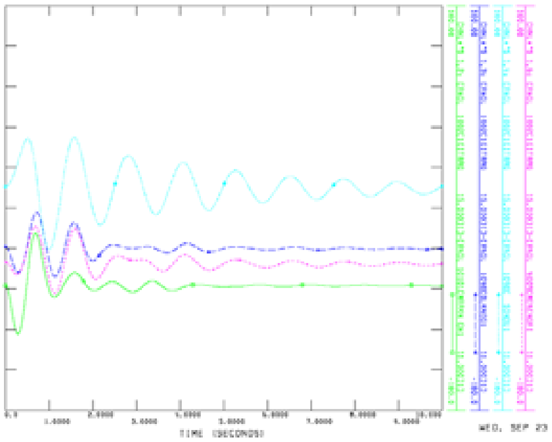
Case 10



Case 11

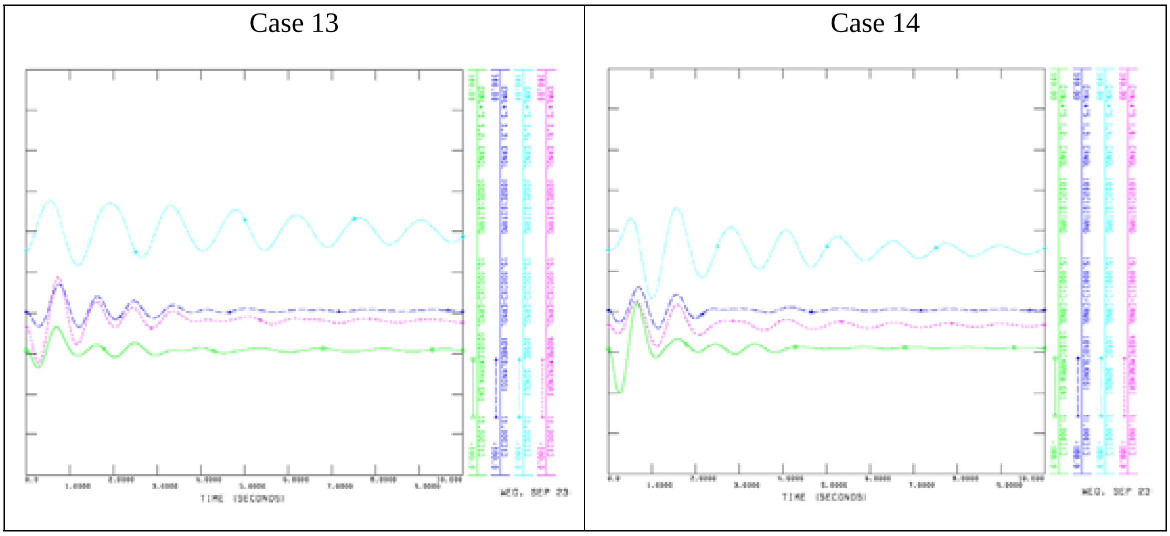


Case 12



Source: JICA Survey Team

Fig. 5-3.7 (2) Phase-Voltage Fluctuation Curve in Generator of 2020


Case 13

Case 14

Source: JICA Survey Team

Fig. 5-3.7 (3) Phase-Voltage Fluctuation Curve in Generator of 2020

5.4 Necessary Transmission Capacity and The Scale of Transmission Line

When augmentation of the system facility is made to select the excessive capacity, it will not be economical because the facility cannot be fully utilized until its lifetime ends. Meanwhile, to select the insufficient capacity also is not economical because it will soon be overloaded and the augmentation of the facility will be necessary again. Therefore, it is important to select the facility's capacity adequately. The Survey Team studied the necessary transmission capacity of Olkaria II－Lessos and Kisumu－Lessos.

As mentioned in 5.3.1, the 220kV transmission line Olkaria-II－Lessos in 2020 will carry 501MW power flow. And the transmission line Kisumu－Lessos under N-1 conditions during dry season will carry 237MW flow when the transmission line Lessos－Muhoroni is opened by a fault.

To calculate the power flow to the transmission line in long term future is not practical because the power generating plans and system augmentation plans in far future are not correctly determined.

The necessary transmission capacity will be determined by calculation the balances between demand and supply while the transmission loss can be small enough to be ignored.

5.4.1 Demand and Supply of Kenya Western Region

The 220kV transmission line Olkaria-II－Lessos supplies to the power demands in the area of West Region, North-Rift Region and Lanet Substation in Central-Rift Region as shown in Table 5-4.1. Whereas, the power stations which located in the areas off Wesr Region and North-Rift Region are hydropower stations of Sondu/Miriu, Sang’oro and Turkwell, and Mumias Co-genetation power station. In addition, there is an imported power from Bujagari hydropower station in Uganda. As mentioned in 5.3.1, Figures 5-3.1 and 5-3.2, since the Survey Team assumed that Menengai geo-thermal power plant which will operate on 2019 and 2020 is to be connected to Lanet Substation planned to be located at the middle of transmission line of Olakaria II－Lessos, the transmission line Olkaria II－Lessos will increase its power flow by the rate of the balance between the generating power of Menengai geo-thermal power plant and the loads of New Lanet Substation.

At the transmission line Olkaria－Lessos, the power flow of transmission line of the New Lanet-Lessos will be larger than that of the line of Olkaria－New Lanet until the load of New Lanet Substation exceed the generating power of Menengai geo-thermal Power Plant (280MW).

Table 5-4.1 Demand and Supply of Kenya West Region, 2020

Demand		Supply [ ]:Normal dry season		
Substation	Load (MW)	Power plant	Type	Effective cap. (MW)
New Lanet	153	Menengai	Geo-	280
Lanet	53	Sondu	Hydro	60 [42]
Kisumu	88	Sangoro	Hydro	20 [14]
Chemost	104	Turkwell	Hydro	90 [73]
Wevuye	57	Mumias Co-gen.	Thermal (Biomass)	25
Musaga	57	Bujagari (Uganda)	Hydro	70 [49]
Muhoroni	53			
Lessos	46			
Eldoret	101			
Total	712	Total		545 [483]

Source: LCPDP, December 2008, and Digital Data of System Analysis from KPLC

5.4.2 Necessary Transmission Capacity of Olkaria-Lessos Line

(1) Power Flow Forecast of Olkaria-Lessos Line

Table 5-4.2 shows the forecast of balance of power demand and supply in the Kenya West Region and the forecasted power flow of transmission line Olkaria－Lessos. This table put down with the demand forecast based on LCPDP of KPLC, average annual growth 10.2% between 2009 and 2029, and the forecast of IMF base, average annual growth 7.2% between 2009 and 2029.

The forecasted power flow of transmission line Olkaria-Lessos in 2020 based on LCPDP demand forecast is 229MW at Olkaria－New Lanet and 356MW at New Lanet－Lessos. However, power flow at Olkaria－New Lanet will overtake after 2025 when the load of New Lanet Substation exceed the generated power of Menengai geo-thermal power plant

(280MW). The power flow of transmission line of Olkaria－New Lanet will become 1,192MW at 2029.

Table 5-4.2 Forecast of Balance of Demand and Supply in Kenya West Region and Expectation Power Flow of Transmission Line Olkaria - Lessos

Unit: MW

Year (based on LCPDP's forecast)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Year (based on IMF base forecast)	2025	2027	2028	2029	2031	2032	2033	2035	2036	2037
Demand (a)	712	783	863	949	1044	1148	1262	1387	1525	1675
Demand in New Lanet (b)	153	175	198	224	251	282	315	351	391	435
Supply (c)	483	483	483	483	483	483	483	483	483	483
Menengai output (d)	280	280	280	280	280	280	280	280	280	280
Power flow (a-c) Olkaria－New Lanet	229	300	380	466	561	665	**779**	904	1042	**1192**
Power flow (a-b-c +d) New Lanet－Lessos	356	405	461	523	590	664	744	833	930	1037

Source: JICA Survey Team

(2) Necessary Transmission Capacity of Olkaria-Lessos Line

Based on the demand forecast of LCPDP, the forecasted power flow in 2029 which means final year of this study will be extremely large as much as 1,192MW. However, demand forecast based on the Survey Team (IMF base forecast), the power flow in 2033, 20 years after construction of the transmission line, will be 779MW. Average annual growth 7.2% of the demand forecast of the Survey Team between 2009 and 2029 can be reasonable, because, from the past example, the economic growths in many countries have repeated the growth and stagnation. Thus, since the new facility is expected to be utilized effectively over 20 years, 700MW of design capacity for the new transmission line is recommended.

(3) Recommended Transmission Line Scale

Table 5-4-3 shows the relation of transmission line conductor and their transmission capacity of double-conductor per phase. Although the conductor of existing 220kV transmission line which has been applied by KPLC is single conductor of Canary, the Survey Team adopt double–conductor because a single conductor cannot secure the transmission capacity in future need.

Permissible highest temperature of conductor is 75 degree C of KPLC but 90 degree C in Japan considering the fatal deterioration of conductor due to heat. Higher permissible temperature increases the transmission capacity drastically, if it is technically allowed. This is because the transmission capacity is determined by the conductor temperature and ambient temperature. Cooling efficiency of the conductor is determined by the balance of conductor temperature and ambient temperature. Whereas, the sag and the stretch of the transmission line conductors are also increased with its temperature rise. Therefore, it is necessary to heighten the tower in order to secure enough ground clearance. In case that the permissible highest temperature of conductor becomes 90 degree C, additional tower height of only 0.5m will be necessary and it will not significantly increase the construction cost as against the drastic increase of transmission capacity..

As above, employing double-conductor of Grackle, 604mm^2, and 90 degree C permissible temperature is recommended. Transmission capacity of Grackle is 788MVA (748MW), when power factor 95% is applied, it is big enough for necessary transmission capacity (700MW).

Table 5-4.3 Conductor and Transmission Capacity, Double-Conductor

Conductor name	Cross section (mm^2)	Permissible highest temperature		Remarks
		75℃	90℃	
Hawk	364	340 MVA	440 MVA	
Canary	456	502 MVA	659 MVA	
Grackle	**604**	**594 MVA**	**788 MVA**	Recommended
Falcon	806	706 MVA	945 MVA	

Source: JICA Survey Team

5.4.3 Necessary Transmission Capacity of Kisumu - Lessos Line

(1) Expectation Power Flow of Kisumu - Lessos Line

The transmission line Kisumu－Lessos will be loaded by the difference between the loads of Kisumu Substation, Muhoroni Substation, and Chemosit Substation as the demand, and the power sources of Sondu/Miriu Hydropower Station and Sang’oro Hydropower Station as the supply. Table 5-4.4 shows the demand and supply forecasted in Kisumu area in 2020. Table 5-4.5 shows the forecasted balance of demand and supply in Kisumu area and the forecasted power flow of transmission line Kisumu－Lessos. This Table put down with the year of demand forecast based on LCPDP and JICA Survey Team as well as Table 5-4.2.

Table 5-4.4 Demand and Supply in Kisumu Area, 2020

Demand		Supply [ ]:Normal dry season		
Substation	Load (MW)	Power plant	Type	Effective cap. (MW)
Kisumu	88	Sondu	Hydro	60 [42]
Chemost	104	Sangoro	Hydro	20 [14]
Muhoroni	53			
Total	245	Total		80 [56]

Source: LCPDP, December 2008

Table 5-4.5 Forecasted Balance of Demand and Supply in Kisumu Area and Forecasted Power Flow of Transmission Line Kisumu-Lessos

Unit: MW

Year (based on KPLC's forecast)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Year (based on JICA survey team's forecast)	2025	2027	2028	2029	2031	2032	2033	2035	2036	2037
Demand (a)	245	268	295	325	357	393	432	474	521	573
Supply (b)	56	56	56	56	56	56	56	56	56	56
Power flow (a-b)	189	212	239	269	301	**337**	376	418	465	**517**

Source: JICA Survey Team

(2) Necessary Transmission Capacity of Kisumu-Lessos Line

Based on the demand forecast of LCPDP, the forecasted power flow is 517MW in 2029 which is the final year of the target period of this study. It is extremely large and it requires ultra large conductor. As well as Olkaria－Lessos line described in paragraph 5.4.2 (2), 350MW of design capacity is recommended so that the new facility can be fully utilized for more than 20 years without over-design.

(3) Recommended Transmission Line Scale

132kV is not practically high enough to carry the target transmission capacity of 350MW, it is suggested that the transmission line operates by 132kV at the initial stage during small power flow and then substations of the both ends shall be augmented by 220kV facilities at later stage. Such operation strategy is sometimes used for cost saving purpose.

Table 5-4.6 shows the transmission capacity of 220kV single-conductor. As well as Olkaria－Lessos line, the conductor of Grackle (but single conductor) and 90 degree C permissible temperature is recommended. The transmission capacity of Grackle is 394MVA (374MW), under power factor of 95%. It is enough for the design transmission capacity (350MW).

Table 5-4.6 Conductor and Transmission Capacity, Single-Conductor

Conductor name	Cross section (mm^2)	Permissible highest temperature		Remarks
		75℃	90℃	
Hawk	364	170 MVA	220 MVA	
Canary	456	251 MVA	330 MVA	
Grackle	**604**	**297 MVA**	**394 MVA**	
Falcon	806	353 MVA	473 MVA	

Source: JICA Survey Team