

UNIVERSITY OF NAIROBI

**TITLE: OPERATIONAL PLANNING FOR KENYA
POWER GRID SYSTEM**

PROJECT NUMBER: PRJ 105

BY

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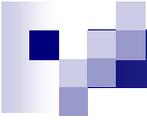
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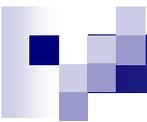
Objectives of the project

- Determine the available power generating plants feeding the KPGS.
- Determine various planning criteria used to ensure grid stability and load balancing.
- Research on operations done by KPLC which enable the company meet its objectives.
- Use load flow analysis for KPGS and analyze it and draw comments and conclusion from it.



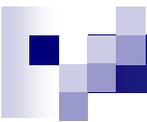
A good operational tool has the following benefits to KPLC

1. It enables mutual transfer of energy from surplus zone to deficit zone economically.
2. Enables lesser overall installed capacity to meet the peak demand.
3. It permits the generation of energy at the most efficient and cheapest generating station at every time.
4. It reduces the capital cost, operating cost and cost of energy generated.
5. Enables supply with minimal interruption of power in case of a major breakdown of a generating system.



Load balancing

- Transmission systems provides for base load and peak load capability, with safety and fault tolerance margin.
- Generation has to be matched to the load to prevent overloading failures of the equipment. Multiple sources and loads can be connected to the transmission system and should be controlled to provide orderly transfer of power.
- The drop in the line frequency is an indication that the increased load is causing the generator to slow down



Failure protection

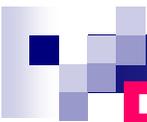
- Under excess load conditions, the systems can be designed to fail gracefully rather than all at once.
- **Rolling blackouts**, or **load shedding** are intentionally engineered electrical power outages used to distribute insufficient power when the demand for electricity exceeds the supply.
- Rolling blackout is the last result measure used by Kenya power and lighting company in order to avoid a total black out of the power system.
- Rolling blackout usually result from two causes:-
 - Insufficient generation capacity
 - Inadequate transmission infrastructure to deliver the sufficient power to the area where it is needed.



Power outage

This refers to long or short term loss of electric power to an area.

- **A drop out**
- **A brown out**
- **Blackouts**



Restoring power after a wide-area outage

- In the total absence of grid power, black start needs to be performed to bootstrap the power grid into operation.
- Typically, transmission company will establish a localized power islands which are then coupled together.
- To maintain supply frequencies within tolerable limits during this process, demand must be reconnected at the same pace that the generation is restored.



Transmission planning

- The system conditions should include changing demand patterns, generation changes and equipment outages (planned or unplanned).
- KPLC operates on scheduled dispatch to meet the load demand without failure and with the maximum efficiency thus to reduce cost per unit of kWhr to its customers and reduce their operation cost.



Network planning

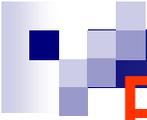
- Involves determining which facilities and procedures to be provided to satisfy and promote appropriate future demands for electricity.
- These include availability of electricity to all potential users at the lowest possible cost, minimum environmental damage, high levels of safety and reliability



Technical criteria for planning purpose

Technical criteria used by KPLC in transmission system planning can be divided into three main categories

- System reliability,
- Steady state performance and Stability



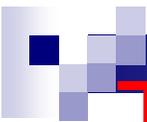
For KPGS to be said stable, KPLC should ensure the following:

- **Satisfactory state** it should supply aggregate electrical demand and energy requirements of the customers at all times.
- **Adequacy-** should supply aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.
- **Security-** the electric systems to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements.
- **Secure state-** it should satisfy the test for system adequacy for all reasonably expected conditions including scheduled outages of system elements and return to a satisfactory state after a sudden disturbance.



N-1 security criterion

- the system is in a secure state with all transmission facilities in surface and in a satisfactory state following credible single contingency events.



The single contingencies to be considered under N-1 are:

- Loss of a single transmission circuit
- Loss of a single bus section
- Loss of interconnecting transformer
- Loss of a single generating unit provided that the system can be maintained in a secure state.



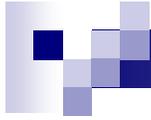
Steady state criteria

Steady State Voltage Limits:

The network is designed to achieve a continuous network voltage at a user connection not exceeding the design limit $\pm 8\%$ of nominal voltage during normal and maintenance conditions for KPGS.

Frequency Limits:

Under emergency conditions the network frequency may vary between 49.7 ó 50.2 Hz, (this is the region of frequency at which KPGS is allowed to operate at)



Network Planning Methodology

- “ Business planning
- “ Long-term and medium-term network planning
- “ Short-term network planning



Load forecasting as an operational tool

- Load forecasting explains the drivers, factors and uncertainties influencing future electricity demand in the country.
- A low load forecasted load leads to an under expanded power system which can lead to brownouts or black outs in the power system.
- over forecasted load leads to an over expanded power system



Operational maintenance of lines and substations

- Thermal vision inspection
- KPLC has annual line inspection

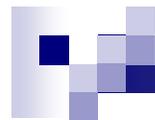
Station KENGEN	Machine Rating (MW)	Installed Capacity (MW)	Effective Capacity (MW-Normal)
Hydropower plants			
Masinga	No.1&2 = 20	40	40
Kamburu	No. 1,2,3 = 31.4	94.2	88
Gitaru	No. 2&3 = 72.5 No.1= 80	145 80	216
Kindaruma	No.1&2 = 22	44	40
Turkwel	No.1&2 = 53	106	106
Sondu	No.1&2 = 30	60	60
Tana	No. 1&2 = 2 No.3 = 2.4 No. 5&6 = 4	Retired 2.4 8	10
Wanjii	No. 1&2 = 2.7 No. 3&4 = 1	7.4	7.4
Gogo	No. 1&2 = 1.125	2.25	2
Ndula	No. 1&2 = 1.0	2	2
Sagana	No. 1,2&3 = 0.5	1.5	1.5
Mesco	0.38	0.38	0.36
Sossiani	No. 1&2 = 0.2	0.4	0.4
Total Hydro		745.53	729.66

Steam/Geothermal-KENGEN	MACHINE RATING (MW)	INSTALLED CAPACITY	EFFECTIVE (MW)
Ol-Karia 1	No. 1,2&3 = 15	45	45
Ol-Karia 2	No. 1&2 = 35	70	70
Kipevu Steam	No.6 = 29 No.7 = 33	Retired Retired	
Total		115	115

Gas-KENGEN STATION	MACHINE RATING (MW)	INSTALLED CAPACITY (MW)	EFFECTIVE CAPACITY (MW)
GT Kipevu KVN	No. 1&2 = 30	60	60
GT N/South Fiat	13.5	13.5	10
Gas Total		73.5	70
Diesel-KENGEN			
Kipevu DP1	No.1 to 6 = 12.5 Effective = 10.0	75	60

IPPs Station	Machine Rating (MW)	Installed Capacity (MW)	Effective Capacity (MW)
N/South Iberafrica	No. 1 to 8 = 5.46 No. 9&10 = 6.0	55.68	55.68
Orpower4	No. 1,2&3 = 4.33 No. 4, 5 & 6 =12	12.99 36.00	12.99 36.00
Tsavo	No. 1 to 7 = 10.77	75.39	75.39
Mumias Sugar	2	2	2
IPPs Total		182.6	182.6

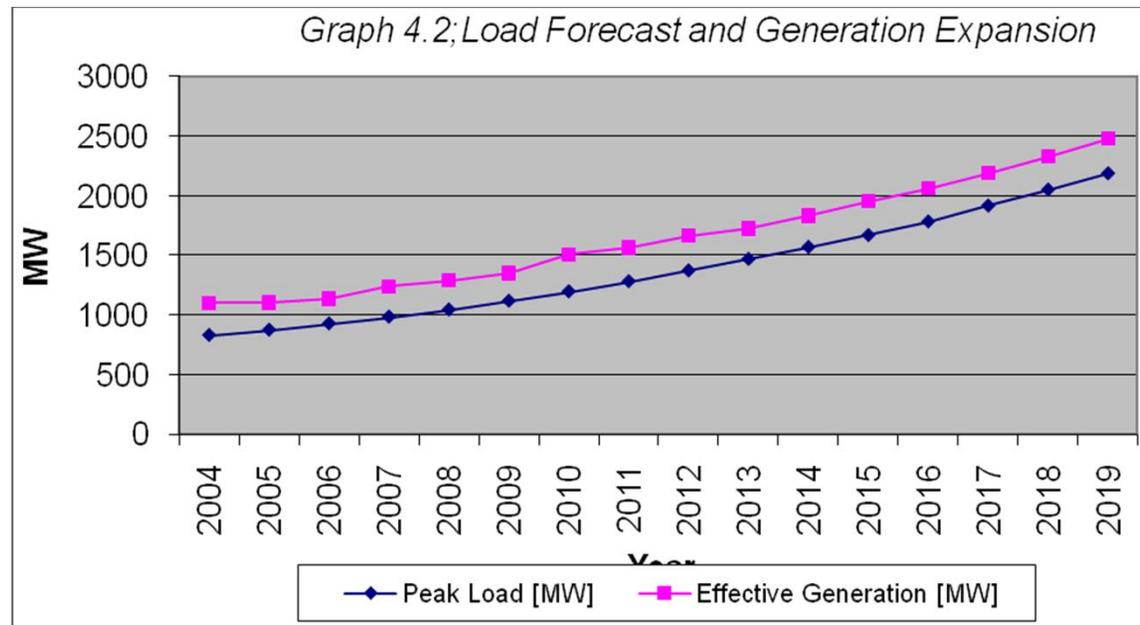
EPPs Station	Installed Capacity (MW)	Effective Capacity (MW)
Aggreko Embakasi 1	60	60
Aggreko Embakasi 2	50	50
Aggreko Eldoret	36	36
EPPs Total	146	146



Dispatch merit order for KPLC for March 2009 based on cost for February 2009 data

STATION	(A) 1	(B) 2	(C) 3	(A+B) 4	(D) 5	(E) 6	(E-D) 7	$\beta(A+B)$ 8
Orpower4	2.019	0.000	13.429	2.019	1.661	3.894	2.233	1
Geothermal	2.690	0.000	0.000	2.690	2.360	3.894	1.534	2
Hydro	2.690	0.000	0.000	2.690	2.360	3.894	1.534	2
Wind (Ngong)	2.690	0.000	0.000	2.690	2.360	3.894	1.534	2
Mumias	2.133	1.027	0.000	3.160	1.793	3.894	2.101	3
Tsavo	0.739	5.441	2.755	6.180	0.809	3.894	3.085	4
Kipevu Diesel 1	2.690	7.484	0.000	10.173	2.637	3.894	1.257	5
Aggreko (Embakasi)	1.760	9.376	0.000	11.136	1.795	3.894	2.099	6
Aggreko-Eldoret	1.760	10.005	0.000	11.765	1.818	3.894	2.076	7
Iberafrica	0.685	11.961	2.051	12.646	1.006	3.894	2.888	8
UETC Day & Peak	4.873	11.092	0.000	15.965	4.420	3.894	-0.526	9
UETC Night	4.873	11.092	0.000	15.965	4.420	3.894	-0.526	9
Thermal KVNGT1	2.690	18.213	0.000	20.903	3.034	3.894	0.860	10
Thermal KVNGT2	2.690	18.213	0.000	20.903	3.034	3.894	0.860	10
Fiat GT	2.690	49.597	0.000	52.287	4.195	3.894	-0.301	11

Load forecast





Load flow transmission line loss analysis

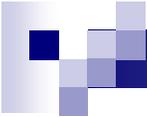
- A maximum peak Demand value so far 568.06 MW, more than 50% of national demand is concentrated in Nairobi region.
- In Nairobi, available generation capacity is 176MW
- Western region up to date peak value amounts to 217.13 MW (20%)
- Generation at Mount Kenya area exceed the regional demands and as such transmission losses there are expected to be minimal.

Contribution of Kindaruma Station at system peak to KPGS with reference to Juja control centre

Generation (MW)	Line loading %			Transmission losses (MW)		
	Kind-juja	Dand 1	Dand 2	220	132	Total
20	33	80	79	19.47	13.42	32.89
20	42	78	77	18.87	13.64	32.51
40	53	77	75	18.34	14.15	32.49

Contribution from Iberafrica at system peak

Generation (MW)	Line loading %		Transmission losses (MW)		
	Dandora line-1	Dandora L2	220	132	Total
25.3	86	85	21.74	14.44	36.18
50.6	80	79	19.47	13.42	32.89
55.7	79	77	19.08	13.25	32.33
(Fiat gas turbine)12	76	75	18.18	13.23	31.41



Contribution from Ol-Karia at system peak

Generation (MW)	Line loading %			Transmission losses (MW)		
	Juja- Naiv	Dand 1	Dand 2	220	132	Total
(Orp 4 & 1) 42.8	16	80	79	19.47	13.42	32.89
(Orp 4 & 1) 57.8	18	77	76	18.4	12.87	31.27
(Orp 4 , 1,2) 77.6	19	73	72	17.26	12.65	29.91
(orp 4,1,2) 92.6	22	71	70	16.52	12.84	29.36

Contribution from Turkwel at system peak

Generation (MW)	Line loading %			Transmission losses (MW)		
	Juja- Naiv	Dand 1	Dand 2	220	132	Total
90	27	82	81	19.31	14.44	33.75
100	22	80	79	19.41	13.48	32.89
104	20	79	78	19.49	13.19	32.68

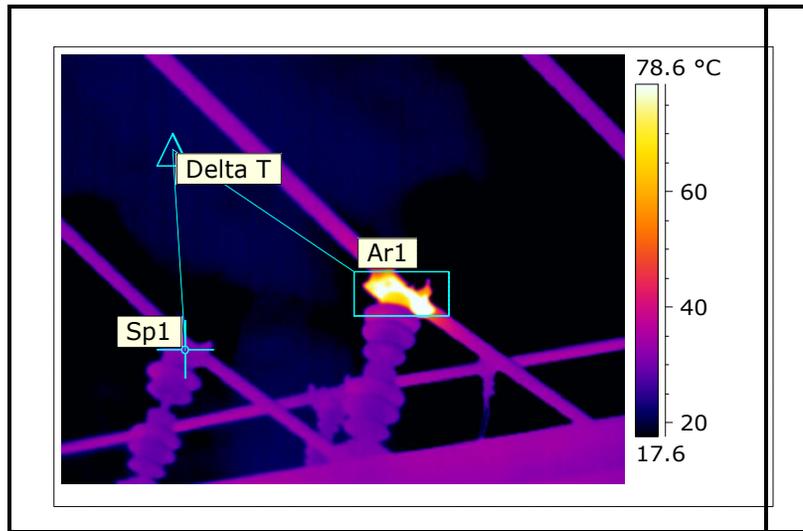
Contribution from Generation at Kipevu

Generatio n (MW)	Line loading %				Transmission losses (MW)
	Kiambere -Rabai	Rabai- Juja	220	132	Total
103.2	18	29	20.27	13.2	33.47
113.2	15	33	19.8	13.34	33.14
123	12	36	19.46	13.56	33.02
126.6	11	38	19.36	13.67	33.03
131.6	10	39	19.26	13.83	33.09

Thermography inspection results



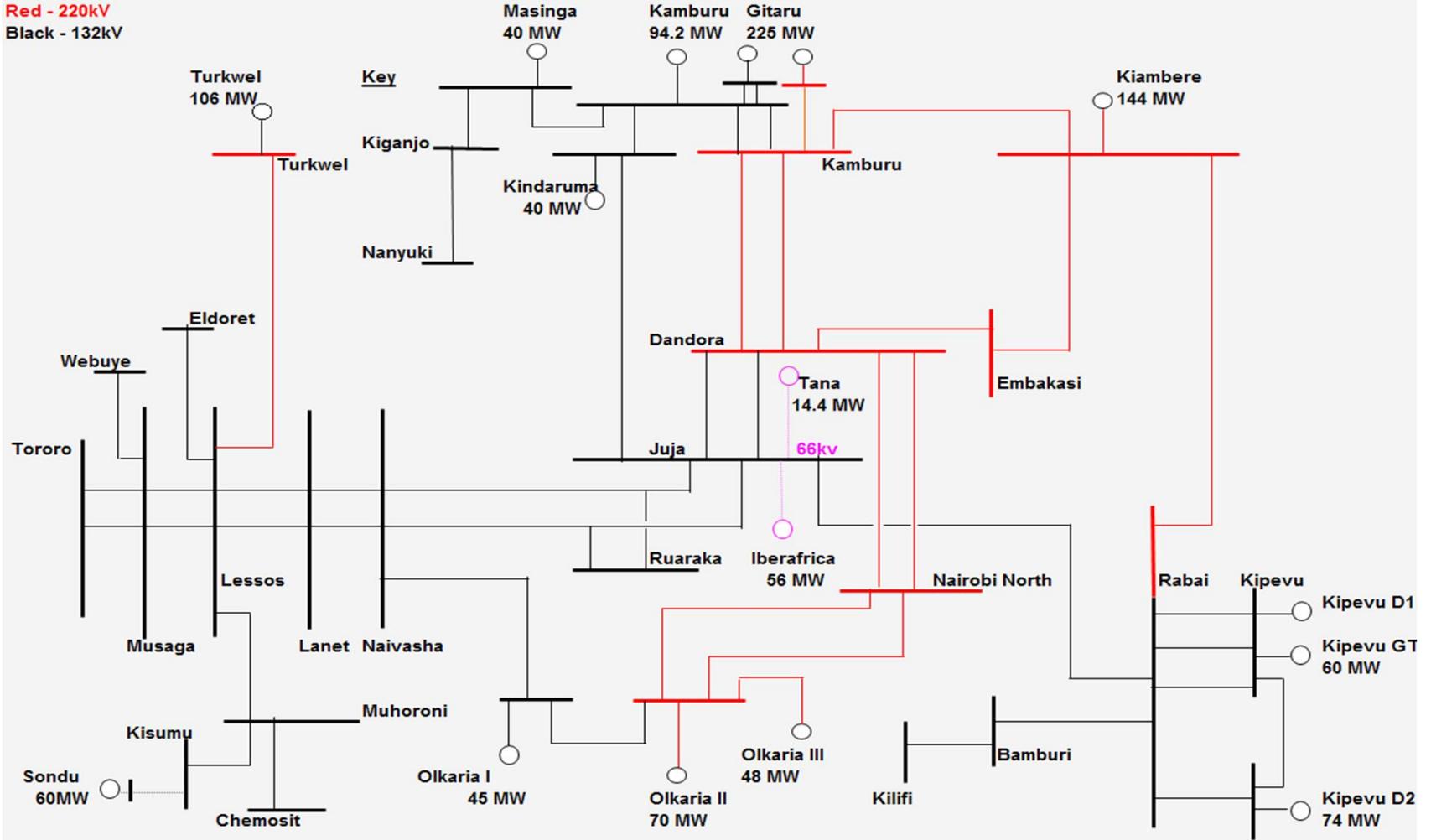
Location	33Kv side
Equipment	Beyond 1T0
Type	Pin insulator
Fault	1



Object Parameters	Value
Atmospheric Temperature	20.0 °C
Sp1 Temperature	30.8 °C
Ar1 Max. Temperature	262.8 °C
Delta T Value	232.0

copper tube connection clamp on the yellow phase has a serious hotspot.

Red - 220kV
 Black - 132kV



Stations with Transmission Transformers (132/220kV)

1. Dandora
2. Kamburu
3. Rabai
4. Lessos
5. Olkaria 2



Summary

- All Operations carried out by KPGS operators are aimed at meeting the following:
- Maintain the electric power system frequency within +0.2 and -0.3 range of 50Hz.
- Maintain the transmission busbar voltage levels within 8% error margin of the nominal value at Juja road, Rabai and Lessos substation.
- Facilitate all planned transmission and generation equipment outage at a monthly target of 95%.
- Operate the transmission system accident free through compliance with safety and operational standards.
- Guarantee effective response to all system contingencies.



Recommendations for further work

- Database for line inspection
- Pattern recognition algorithm for tower top and pole-top of the overhead power lines.
- Recognition algorithms for other specific inspection features need to be developed based on the inspection requirements.

This will help KPLC to analyse the aerial line defects quite easily and thus save time for straining the inspection engineers and pilot.



END

THANK YOU.

QUESTIONS

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