2020 Electricity Supply Plan

for the Ghana Power System

a Power Supply Outlook with Medium Term Projections

2020 ELECTRICITY SUPPLY PLAN FOR GHANA

An Outlook of the Power Supply Situation for 2020 and Highlights of Medium Term Power Requirements

ACKNOWLEDGEMENT

We hereby wish to acknowledge the members of the Supply Plan Committee who worked to develop the 2020 Electricity Supply Plan (ESP). The Supply Plan Committee is made up of technical experts from the Energy Commission, GRIDCo, VRA, BPA, ECG and NEDCo as follows:

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The Electricity Supply Plan (ESP) for 2020 is being submitted by the Electricity Supply Plan Committee as per the requirement in Section-7 of the National Electricity Grid Code.

The 2020 ESP presents an outlook of electricity demand and supply for 2020. It presents a review of the Ghana power system performance in 2019, the 2020 demand forecast and the outlook for power supply, taking into consideration all the existing sources of generation as well as ongoing projects.

It assesses available hydro generation capacities, taking into consideration reservoir elevations at Akosombo and Bui at the beginning of the season. Additionally, it presents fuel requirements and associated cost for thermal generation needed to meet electricity demand in 2020 and evaluates the associated evacuation requirements to ensure reliable power supply.

The 2020 ESP, further highlights the potential challenges to electricity service delivery in Ghana in 2020 and makes recommendations for actions to be taken to mitigate the potential challenges and ensure reliable power supply in 2020. Finally, it provides a medium-term outlook of electricity demand and supply for the subsequent five year period (2021 – 2025).

Review of 2019 Performance

Peak and Energy Demand

The Ghana power system recorded a coincident peak demand of 2,803.7 MW in 2019. This occurred on December 3, 2019. The 2019 peak represents an increase of 278.7 MW over the 2018 peak of 2,525 MW (growth of 11.04%).

The total energy consumed including losses was 17,887 GWh as against the projected of 18,014 GWh. A total of 15,960 GWh was consumed during the same period in 2018, thus, the consumption in 2019 represented a 1, 927 GWh increase over that of 2018 (growth of 12.07%).

Energy Supply

The total energy supplied (including imports from Côte d'Ivoire) over the period was 17,887 GWh. It comprised 7,252 GWh from hydro, 10,508 GWh from thermal and 127 GWh of Imports.

The generation mix at the end of the period was therefore 40% hydro, 59% thermal and 1% import.

Transmission Losses

The total system transmission loss recorded over the period was 844 GWh which is 4.72% of total energy transmitted (17,887 GWh).

In 2018 on the other hand, the network recorded total transmission loss of 707 GWh or 4.43%. The 2019 energy loss thus represents a 19.4 % increase over that of 2018.

Transmission Lines and Feeder Availability

The Average Feeder Availability (AFA) in 2019 was 99.84 % and the System Average Availability (SAA) for the NITS was 99.41% whereas the System Average Availability (SAA) for the NITS was 99.58 % in 2018.

2020 Demand Outlook

The projected system peak demand for 2020 is 3,115 MW. This represents an increase of 311 MW or in percentage terms, a growth of 11 % over the 2019 peak demand of 2,804 MW which occurred on December 3, 2019.

The projected energy consumption including transmission system losses for 2020 is 19,594 GWh. This compared to the 2019 actual consumption of 17,887 GWh represents a projected growth of 9.5% (an increase of 1,707 GWh).

2020 Supply Outlook

Hydro Power Generation for 2020

The total projected hydro generation for 2020 is 6,229 GWh. This would be made up of 4,646 GWh, 819 GWh and 764 GWh for Akosombo, Kpong and Bui Generating Stations respectively.

Akosombo Hydro Elevation

The recorded maximum lake elevation at the end of 2019 inflow season was 264.76 feet, which is 24.76 feet above the minimum operating level of 240 feet. The total net inflow recorded in 2019 was 33.43 MAF, which implies a 8.43 MAF increase over the average inflow of 25 MAF.

Bui Hydro Elevation

With a year-start elevation of 180.37 MASL in 2020, and the total estimated total energy production of 764 GWh for 2020, the year-end elevation is projected at 177.65 MASL.

Thermal Power Generation for 2020

The Projected Dependable Thermal Capacity in 2020 is 3,292 MW. This is made up of 3,138 MW from existing and 144 MW of from Early Power Plant expected to be commissioned by April 2020. The projected total thermal energy generation for 2020 is 13,308 GWh.

Renewable Energy (RE) Generation for 2020

The total installed RE generation capacity in Ghana for 2020 is projected at 42.6 MWp. This is made up of 2.5 MWp VRA Solar (Navrongo), 20.0 MWp BXC Solar (Winneba), 20.0 MWp Meinergy Solar (Gomoa Onyaadze) and 0.1 MW Safi Sana. The total projected RE generation is 54.7 GWh.

All of these utility-scale Solar PV plants are connected on the medium voltage distribution system.

Imports

In 2020, no programmed electrical power import is expected. However, short term program could be arranged in case of a contingency, such as a gas supply interruption, etc. that would lead to shortage of internal power generation.

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
Akosombo GS	1020	900	Hydro
Kpong GS	160	105	Hydro
TAPCO (T1)	330	300	LCO/Gas
TICO (T2)	340	320	LCO/Gas
TT1PP	110	100	LCO/Gas
TT2PP	80	70	Gas
KTPP	220	200	Gas/ Diesel
VRA Solar Plant	2.5	0	Solar
TOTAL VRA	2,263	1,995	
Bui GS	404	360	Hydro
CENIT	110	100	LCO/Gas
AMERI	250	230	Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LCO/Gas
KAR Power	470	450	HFO
AKSA	370	350	HFO
BXC Solar	20	0	Solar
Meinergy Solar	20	0	Solar
Genser	60	60	Gas
CEN Power	360	340	LCO/Gas
Amandi	190	190	LCO/Gas
TOTAL IPP	2,780	2,558	
TOTAL (VRA, Bui & IPPs)	5,043	4,553	

Existing and Committed generation capacity for 2020

Natural Gas Quantities and Availabilities

Two main supplies of natural gas were considered as follows:

Nigeria Gas – Average supply of 60 mmscf/day is assumed from January to December 2020.

Ghana Gas

- ✓ Jubilee Fields- a maximum of 73 mmscf/day in 2020;
- ✓ TEN Fields –a maximum of 24 mmscf/day in 2020;
- ✓ Sankofa Fields –a maximum of 180 mmscf/day in 2020.

National Interconnected Transmission System

The National Interconnected Transmission System (NITS) is capable of evacuating all the power that is projected to be generated from all enclaves. As at the end of 2019, the total circuit length was 6,472.23 km with a total transformation capacity of 8,959.6 MVA with some 65 Bulk Supply Points.

As of now, the Aboadze enclave is the biggest generation enclave having an installed capacity of 1540MW. Transmission system losses are expected to be higher than the PURC benchmark since there will be maximized power generation from the West to consume indigineous gas. Loss increase will be driven by the old 161kV transmission lines in the west, overload of the 330/161kV autotransformers in Tema, congestion on the 161kV Anwomaso – Kumasi transmission line linking the 330/161kV infrastructure and the unavailability of the 40MVar STATCOM at Tamale. Another critical constraint that will be experienced is the limitation on the heavily loaded 161kV Volta – Achimota corridor that supplies power to the Capital and its environs.

In order to mitigate these transmission constraints there is an urgent need to complete the upgrade of the 161kV Volta – Achimota corridor and to complete the A4BSP Substation at Pokuase on time. To mitigate the constraints in Kumasi, GRIDCo needs to complete the 330kV Anwomaso – Kintampo transmission lines to relieve the high loadings on the 161kV Anwomaso-Kumasi line. Also the 40MVar STATCOM in Tamale needs to be repaired.

Distribution Outlook in 2020

ECG Network

Based on sub-transmission reliability studies undertaken by ECG, a number of interventions and projects were initiated in 2019 and are expected to be completed in 2020 to resolve various constraints of low voltages, feeder and transformer overloads during firm and non – firm conditions. Some of the key projects under construction are the following:

- ✓ Installation Voltage of Regulators at Nsawam, Mampong / Aburi , Chirano and Kasoa to improve voltage pofiles.

- ✓ Construction of the Pokuase BSP, this project is under construction- Upon completion it will boost voltage support to Dodowa, Mampong/Aburi,Adenta, Agbogba, Kwabenya, Gimpa, UGMC, Anyaa, Nsawam and Ofankor. it will also improve reliability by serving as an alternative/relieving BSP to Achimota,Mallam ,A3BSP and Afienya BSPs.

- ✓ Expansion of Sogakope BSP- this will boost voltage and distribution capacityat Sogakope and sorounding communities.

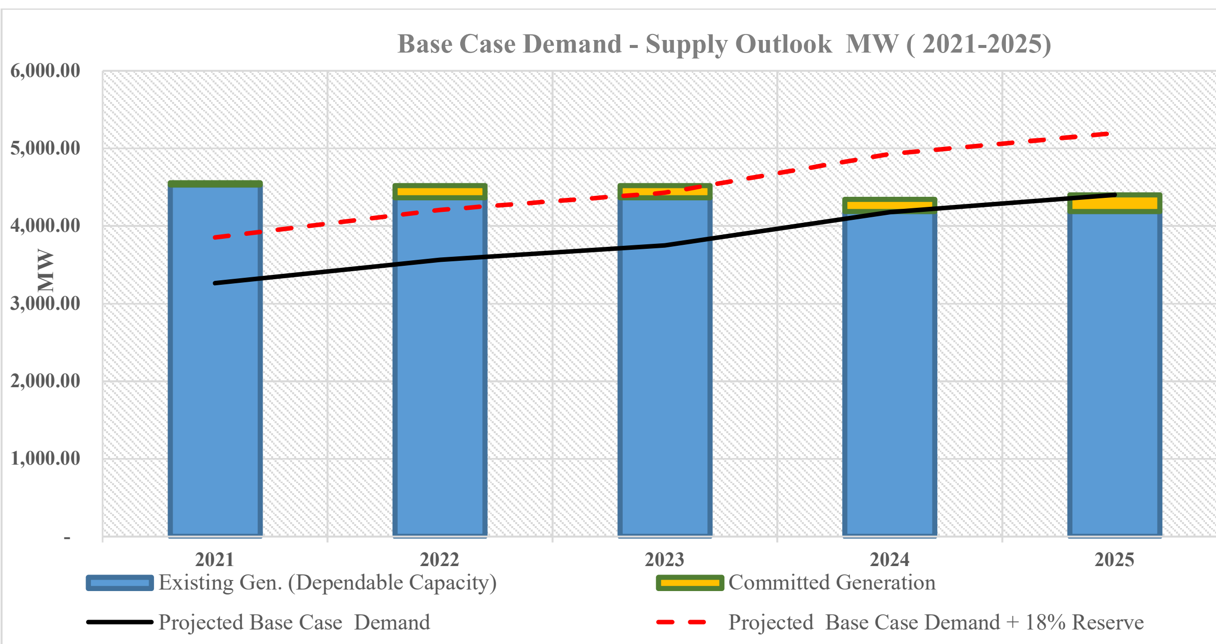
The completion of these Projects is expected to improve supply reliability to the various ECG customers.

NEDCo Network

Power supply reliability in NEDCo Areas is generally good. However, reliability in some areas of the network has been lower than expected due to over extension of these lines and over-ageing resulting in high technical losses. Some of these lines have been extended, as part of Self Help Electrification Program (SHEP) implementation, beyond technically allowable distances. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them.

Medium-Term (2021 – 2025) Demand and Supply Outlook

The Medium-Term (2021-2025) Demand and Supply Outlook as shown in the Figure below suggests that there will be adequate generation to meet demand for the period 2021-2023. However, an additional generation capacity of about 225 MW and 480 MW will be required for the years 2024 and 2025 respectively to meet the demand including the 18% reserve margin requirement.



Strategic Medium Term Transmission Infrastructure Requirements

The results of the extensive system network analyses carried out using the projected demand and supply scenario indicates that there would be the need for the following transmission lines and equipment additions in the medium term to meet the required supply reliability indices, and this is in addition to the investment identified under Section 5. The following are the critical transmission equipment additions required:

- ✓ Upgrade of 161kV Aboadze – Takoradi – Tarkwa – Prestea circuit
- ✓ 2nd Circuit 330 kV Prestea – Dunkwa – Kumasi
- ✓ 330/161 kV Dunkwa substation
- ✓ 161kV Pokuase – Mallam line
- ✓ 161kV Aboadze – Mallam line Upgrade
- ✓ 161kV Bogosu – Dunkwa – New Obuasi upgrade
- ✓ 161 kV Dunkwa – Asawinso upgrade
- ✓ 2nd Circuit 330 kV Aboadze – Pokuase
- ✓ Accra (Pokuase) – Kumasi (Anwomaso) 330 kV line
- ✓ Eastern Transmission Corridor Projects:
    - 161kV Kpando – Juale Line
    - 161kV Juale – Yendi Line
- ✓ Kumasi third Bulk Supply Point
- ✓ Transformers and Compensation devices
- ✓ SCADA upgrade project
- ✓ Replacement of interconnection transformers with phase shifting transformers (Prestea and Nayagnia)

CONCLUSION

Demand and Supply Outlook

a) The 2020 total system demand is projected to be 3,115 MW representing a 11 % growth over the 2019 peak demand of 2,804 MW. The corresponding projected energy consumption for 2020 is 19,594 GWh of which:

b) Hydro supply will be 6,229 GWh representing 32% of the total energy supply;
- ✓ Thermal supply will be 13,308 GWh representing 67.9% of total energy supply; and
- ✓ Renewables supply will be 51 GWh representing 0.1% of total energy supply

c) Total projected energy exports are 1,652 GWh for 2020.

d) VALCO is expected to operate on two pot lines with projected total consumption of 1,230 GWh.

e) There is the need to dispatch Akosombo and Bui Hydro Plants conservatively throughout 2020 to ensure that the two reservoirs are not drawn down below their minimum operating levels to guarantee sustainable operations in the coming years.

f) In terms of fuel, the following quantities of the various fuel types are required;
- ✓ Natural Gas - 114,784,040 MMBtu
- ✓ HFO - 212,858 barrels
- ✓ LCO - 136,147

g) In terms of fuel cost, an annual total of approximately **740.81** Million USD is required, averaging a monthly total of some US$ **61.7** Million.
h) In 2020, Tema industrial zone will be the largest generation enclave in Ghana with an installed capacity of 1,978.5 MW
i) Under maximum west generation scenario with KarPower in the West, the autotransformers at Volta will become overloaded leading to low voltages in the East (Accra/Tema Area).

Requirements for Grid Reinforcement

a) The transmission system has inadequate available transfer capacity to meet the demand requirements of the major load centres (of Accra, Kumasi, Tarkwa, etc.) particularly at peak. This situation would result in low voltages, overloading of lines and increased overall transmission system losses.
b) For radial lines and single transformer stations, significant percentage of network loads could be islanded in the event of outage of such lines and transformers.
c) In normal operation, there would be congestion on the Volta –Accra East – Achimota - Mallam transmission corridor especially when there is high generation in the east.
d) Low voltages would be experienced at Kumasi, Accra and surrounding areas due to poor customer-end power factors.
e) A fair East-West balance in generation provide better system stability and minimal overall transmission system losses.

Distribution Systems

a) The commissioning of the Accra Central BSP has increased the level of reliability and distribution capacity to meet the growing demand within the ECG network in Accra. This has resolved the loading constraints on selected 33 kV feeders and reduce technical losses within the ECG Accra network.
b) In a bid to improve voltages in Nsawam and Mampong/Aburi, ECG has installed a number of 33 kV Voltage Regulators to improve on reliability and quality of supply. Also, additional 33 kV Voltage Regulators are under construction at Chirano and Kasoa to improve the voltage profiles in the associated distribution networks. Furthermore, a number upgrade projects have either been commissioned into service or under construction. This is to increase distribution capacity and reliability of supply customers.
c) Power supply reliability in NEDCo operational areas is generally good. However, reliability in some areas of the network has been lower than expected due to some excessively long feeder circuits and over-aged equipment resulting in high technical losses. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them.

Medium Term Supply

a) For the high growth scenario, it is expected that with the operationalisation of all current committed generation projects, dependable generation capacity will be adequate to serve projected demand for the period 2021 - 2023 with a maximum reserve margin of 23%.

b) The system peaks demand is projected to be 4,177 MW and 4,403 MW with corresponding dependable generation capacities of 4,705 MW and 4765 MW by 2024 and 2025 respectively. Hence, to meet the reliability requirement of the Ghana power system, an additional reserve margin of 18% representing 752 MW and 793 MW are required for years 2024 and 2025. This adds up to a total projected peaks demand of 4,929 MW and 5,196 MW respectively for the same periods. This compared to the projected supply capacity implies a deficit of approximately 224 MW and 430 MW. Thus, there is the need to procure an additional generation capacity of 225 MW in time to be commissioned by January, 2024 and additional 200 MW by January 2025 to preserve the security of supply in Ghana.

RECOMMENDATIONS

Based on the above conclusions, the following recommendations are made:

a) Ongoing transmission expansion projects should be expedited and completed in 2020 to ensure evacuation capacity adequacy for the peak demand. These are:
   - ✓ Volta – Achimota – Mallam Transmission Line Upgrade Project
   - ✓ Aboadze – Prestea – Kumasi 330 kV Transmission Line Project
   - ✓ Kumasi – Bolgatanga 330 kV transmission line Project;

b) Installation of the third 330kV/161kV autotransformer at Volta Substation to be expedited;

c) A well-coordinated maintenance programme should be pursued by both GRIDCo and the Generating Companies (GENCOs);

d) Fuel supply security and adequacy remains the single most important risk to power supply reliability in Ghana. In this vein, it is strongly recommended that all the relevant sector agencies stakeholders work conscientiously together to ensure that fuel supply is adequate and secure at all times;

e) For the medium term, the reserve margin for the 2024 and 2025 falls short of the required reserve margin of 18% (for reliability of supply). Therefore, additional generation capacity would need to be procured in time for commissioning by the beginning of 2024 and 2025;

f) In order to meet the transmission reliability indices, the following are the critical transmissions additions and upgrades are required:
   - ✓ Upgrade of 161kV Aboadze – Takoradi – Tarkwa – Prestea
   - ✓ Construction of a second 330 kV Prestea – Dunkwa – Kumasi line
   - ✓ Upgrade of 161kV Aboadze – Mallam transmission lines

- ✓ 161 kV Mallam – A4BSP transmission line link
- ✓ Construction of a second 330 kV Aboadze – A4BSP circuit
- ✓ Construction of a double circuit 330 kV line from A4BSP to Kumasi
- ✓ Construction of a 330 kV substation at Dunkwa with a link to the existing 161 kV substation.

Table of Tables

Chapter 1

INTRODUCTION

1 INTRODUCTION

The 2020 Electricity Supply Plan (ESP) presents an outlook of electricity demand and supply on the Ghana power system for the year 2020, taking into consideration all the committed and existing generation sources as well as transmission infrastructure.

It assesses available hydro generation sources taking into consideration reservoir elevations at the Akosombo and Bui dams. Following above average inflows into the hydro reservoirs during the inflow season in 2019, the reservoir elevations at Akosombo and Bui dams are appreciably high. The hydro generation strategy for 2020 should therefore be such as would prudently utilise enough of the headwater in order to avert the need for massive spilling during the inflow season in 2020 should we experience another year of heavy inflows and yet, especially for Bui Power Plant, avert excessive drafting on the reservoir and risk running the headwater level below the Minimum Operating Level (MOL) before the next inflow season.

It also considers thermal generation and its fuel requirements. Due to high installed capacities, not all thermal generating facilities would be first choice for dispatch. Security constrained merit order methodology is employed to schedule the available generation resources to serve the projected demand. This will provide inputs for the Least-Cost Fuel Procurement policy for electricity generation in Ghana.

The relocation of the Karpowership from its original location at Tema where it was originally connected at the Smelter II substation to its new location at the Sekondi Naval Base and connected at the new 330 kV Amandi substation has changed the power-flow dynamics on the Ghana power system. This Supply Plan takes a look at the impact of the relocation of the Karpowership on the capability of the Ghana power system to evacuate electrical energy produced from its generation sources to end users in 2020 and in the medium-term.

Additionally the Supply Plan asserts anticipated challenges that could potentially hamper the ability to supply the Ghana demand in 2020. For example, planned work by the West African Gas Pipeline Co. to carry out an Intelligent Pigging exercise on the West African Gas Pipeline (WAGP) in the first quarter of the year is expected to curtail gas supply to Thermal Power Plants in Tema. The ESP finally makes appropriate recommendations to address the anticipated challenges to ensure reliable power supply for all consumers in Ghana in 2020.

Chapter 2

REVIEW: 2019 POWER SYSTEM PERFORMANCE

In this chapter, we carry out a review of the Ghana Power System performance in 2019, including amongst others, the comparison of the actual peak demand, consumption and energy generation against the projections made for the period. It also assesses the performance of the power system with respect to voltages, system frequency and transmission losses.

2.1 Capacity Review

In this section we take a look at the Ghana peak demand for 2019 and analyse it with respect to:

- Load that made up the peak demand,
- Generation facilities in service at the time the peak occurred.

2.1.1 Peak Demand (MW)

The coincident peak demand for the year 2019 was 2,803.7 MW which occurred at 18.45 h on December 3, 2019. This represents only a marginal difference of 6.8 MW (0.24%) compared with the projected 2019 coincident peak of 2,796.92 MW[1] . This recorded peak for 2019 compared to the peak for 2018 represents a growth of 11.04%.

The summary of projected versus actual monthly peak demand for 2019 is shown in Table 2.1.

Month	Projected Demand(MW)	Actual Demand (MW)		Difference
		System	Domestic	(Projected-System)
19-Jan	2,674.24	2,526.00	2,356.00	148.24
19-Feb	2,715.83	2,691.00	2,418.00	24.83
19-Mar	2,742.73	2,650.00	2,450.00	92.73
19-Apr	2,776.37	2,677.00	2,425.00	99.37
19-May	2,734.21	2,781.00	2,439.00	-46.79
19-Jun	2,611.64	2,635.00	2,367.00	-23.36
19-Jul	2,462.27	2,484.00	2,192.00	-21.73
19-Aug	2,527.25	2,503.00	2,381.00	24.25
19-Sep	2,588.57	2,471.00	2,295.00	117.57
19-Oct	2,658.51	2,548.00	2,362.00	110.51
19-Nov	2,796.92	2,733.00	2,587.00	63.92
19-Dec	2,767.01	2,804.00	2,612.58	-36.99

Table 2.1: System Projected and Actual Peak Demand for 2019

[1] Refer to 2019 Electricity Supply Plan, Page 13, www.gridcogh.com.

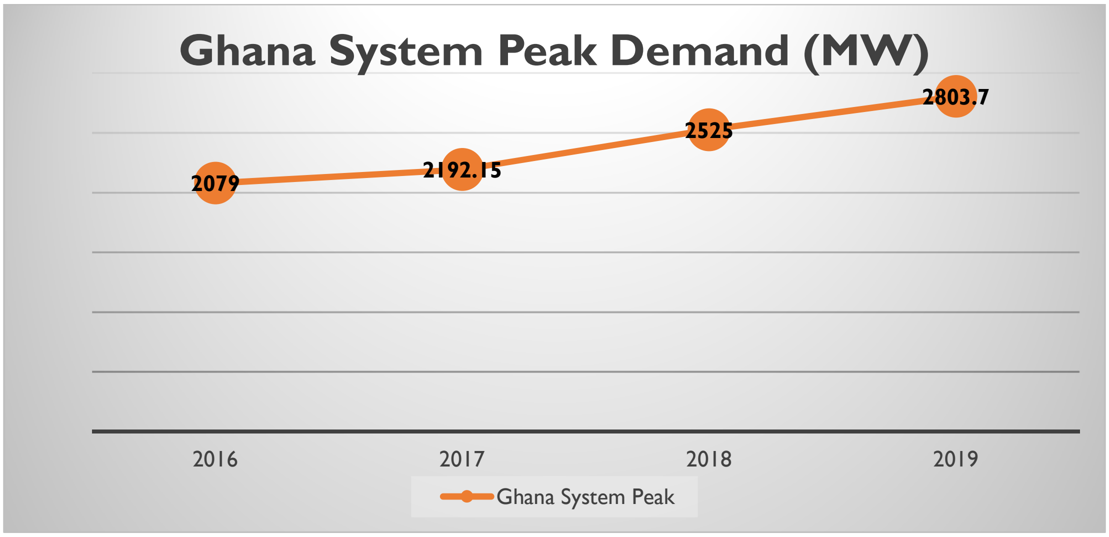


Figure 2.1: Ghana System Peak Demand (2016 - 2019)

The Ghana peak demand has grown from 2,079 MW in 2016 to 2,803.7 MW in 2019 at a cumulative annual average of 10.5 %. This cumulative annual growth is high compared to the long term cumulative annual average growth rate of 4.8% (2005-2019). The high growth rate is attributable to an increase in the installed generation capacity coupled with the increased availability of natural gas for thermal generation especially in the western corridor. Additionally, the high growth rate can be attributed to increased exports. Power exports to Togo/Benin and Burkina increased significantly, facilitated by the construction of the 330 kV transmission circuit.

2.1.2 Supply at Peak (MW)

The generation facilities in service at the time the 2019 Peak Demand occurred that contributed to the attainment of the coincident peak demand of 2,803.7 MW are as shown in table 2.2.

		Dispatched Capacity			
Plants		MW		MVAr	
HYDRO		1,187.1		335.0	
	Akosombo GS		*826.4*		*312.5*
	Kpong GS		*98.0*		*30.0*
	Bui GS		*262.7*		*-7.5*
THERMAL (EAST)		560.5		191.0	
	TT2PP		*24.3*		*11.3*
	KTPP		*100.0*		*37.0*
	AKSA		*16.0*		*2.4*
	CENIT		*107.0*		*19.0*
	SAPP		*313.2*		*121.3*
THERMAL (WEST)		1,056.1		253.3	
	TAPCO (T1)		*151.0*		*45.0*
	TICO (T2)		*339.0*		*68.0*
	AMERI		*117.2*		*20.6*
	KAR Power		*254.9*		*57.8*
	Amandi		*194.0*		*61.9*
Thermal (WEST + EAST)		1,616.6		444.3	
TOTAL SUPPLY		2,803.7		779.3	

Table 2.2: Plants dispatched to meet Peak Demand for 2019

This was made up of 1,187.1 MW (42%) hydro generation and 1,616.6 MW (58%) thermal generation; between the Western and the Eastern thermal enclaves, the generation contributions were: 1,056.1 MW (38%) from the Western enclave and 560.5 MW (20%) from the Eastern enclave. There was no import at the time.

2.2 Energy Review

2.2.1 Energy Consumed including Losses

The total energy consumed in the year 2019 was 17,887 GWh representing an increase of 1,926 GWh (12.07%) on energy consumed in 2018 (15,960 GWh). The total energy consumed in 2019 was only 0.71% below the 2019 Electricity Supply Plan total projected energy for the year 2019 of 18,014 GWh. A breakdown of the energy consumed over the period is as shown in Table 2.3.

Customer	Projection (GWh) 2019	Actual (GWh) 2019	Actual (GWh) 2018	% Growth (2019-2018)
ECG	11,833.41	11,487.24	10,869.87	5.67%
NEDCo	1,473.29	1,410.51	1,326.93	6.30%
Mines	1,173.47	1,318.94	1,090.78	20.91%
VALCO	1,283.80	892.55	815.19	9.49%
Export	1,065.33	911.04	739.50	93.43%
Direct Cust.	438.58	1,014.27	401.95	23.14%
Network Usage	9.65	9.45	8.81	7.25%
Losses	736.44	842.85	707.33	19.27%
Total Energy Transmitted	18,013.97	17,886.85	15,960.36	12.07%

Table 2.3: Energy supplied for 2019

a. Domestic Consumption

ECG recorded a growth rate of 5.67% and accounted for 73.57% of the total domestic consumption. The actual consumption was however 3% lower than the projected consumption for the year. VALCO consumption grew by 9.49% due to the ramping in of the second potline. NEDCo recorded a growth of 6.30% and accounted for 9.03% of the total domestic consumption. Other Direct Customers and the Mines recorded 23.14% and 20.91% growth respectively. A breakdown of the energy consumption by consumption class is shown in Table 2.4.

Customer	Projection (GWh) 2019	Actual (GWh) 2019	Actual (GWh) 2018	% Growth (2019-2018)
ECG	11,833.41	11,487.24	10,869.87	5.67%
NEDCo	1,473.29	1,410.51	1,326.93	6.30%
Mines	1,173.47	1,318.94	1,090.78	20.91%
VALCO	1,283.80	892.55	815.19	9.49%
Direct Cust.	438.58	1,014.27	401.95	23.14%
Network Usage	9.65	9.45	8.81	7.25%
Total Domestic Consumption	16,212.20	16,132.96	14,513.53	11.16%

Table 2.4: Domestic Consumption

b. Energy Export

The total energy exported during the period was 1,430.39 GWh. This was made up of 777.45 GWh export to CEB, 76.40 GWh to CIE and 576.54 GWh to SONABEL (figure 2.2)

Customer/Year	2018	2019
Export to CEB (GWh)	384.95	777.45
Export to CIE (GWh)	77.48	76.40
Export to SONABEL (GWh)	277.07	576.54

Figure 2.2: Export 2019 Vrs 2018

Total power export increased by 93% from 739.50 GWh in 2018 to 1,430.39 GWh in 2019. The growth was largely due to increased exports to CEB and SONABEL.

c. System Losses

In this section, we take a look at transmission losses and distribution losses.

- Transmission losses

A monthly breakdown of transmission losses recorded during the period is shown in Table 2.5.

Month	Total Generation (MW)	Losses (MW)	% Loss
Jan	1,495.25	73.86	4.94%
Feb	1,411.19	69.56	4.93%
Mar	1,545.41	84.60	5.47%
Apr	1,520.35	86.16	5.67%
May	1,584.74	90.74	5.73%
Jun	1,446.05	88.92	6.15%
July	1,426.26	66.62	4.67%
Aug	1,400.97	61.63	4.40%
Sept	1,383.07	58.17	4.21%
Oct	1,465.18	51.22	3.50%
Nov	1,560.94	50.02	3.20%
Dec	1,647.44	62.11	3.77%

Table 2.5: Monthly Transmission Losses for 2019

The total transmission losses recorded during the period was 844 GWh which is 4.95% of the total energy transmitted in 2019 (17,887 GWh).

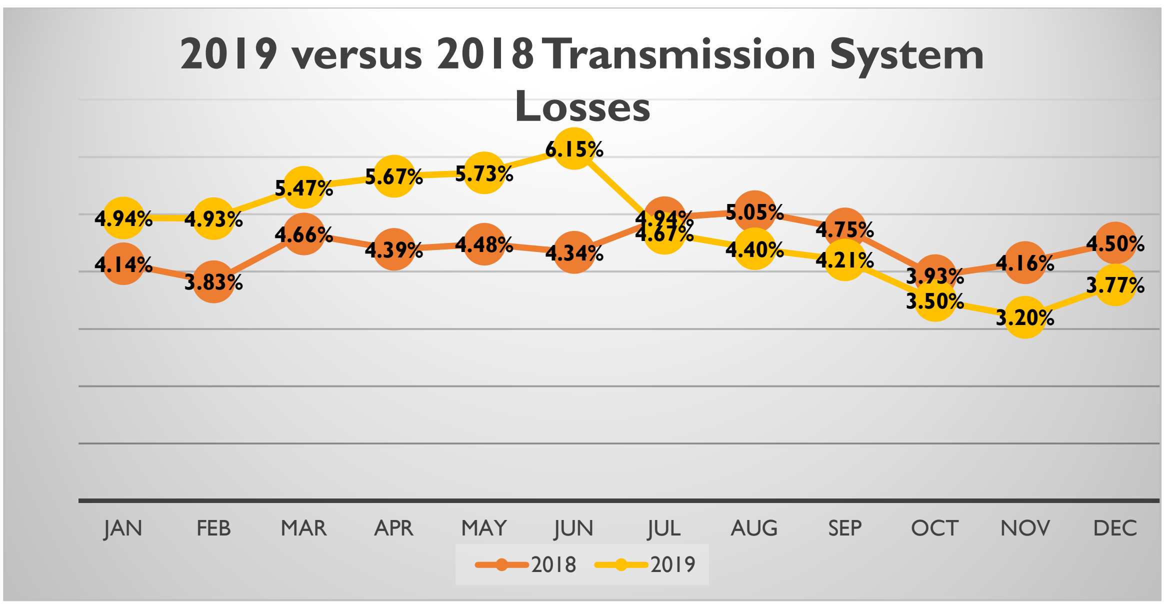


Figure 2.3: Comparison of 2019 and 2018 transmission losses

A comparison of 2019 and 2018 losses indicate increases in system losses in 2019, which is attributable to increase in system load and congestion in some sections of the transmission network. The reduction in system losses in the second half of the year was due to the commissioning of some major transmission lines, especially the 330 kV Aboadze – Anwomaso line, the 330 kV Kintampo – Adubiyili – Nayagnia line circuit as well as the 161 kV Juabeso – Mim line.

- **ECG Distribution losses**

ECG distribution losses are presented in Table 2.6[2]

[2] Please note that data for the last quarter of 2019 was not ready at the time of preparing this report.

Month	Purchases (GWh)	Sales (GWh)	Monthly System Losses (%)	Cummulative Purchases (GWh)	Cummulative Sales(GWh)	Cummulative System losses (%)
Jan-19	1,019.32	756.80	25.8%	1,019.32	756.80	25.8%
Feb-19	940.85	736.46	21.7%	1,960.17	1,493.25	23.8%
Mar-19	1,020.02	741.46	27.3%	2,980.19	2,234.71	25.0%
Apr-19	985.22	735.03	25.4%	3,965.41	2,969.74	25.1%
May-19	984.10	728.54	26.0%	4,949.51	3,698.28	25.3%
Jun-19	897.76	712.04	20.7%	5,847.27	4,410.31	24.6%
Jul-19	902.42	688.35	23.7%	6,749.69	5,098.66	24.5%
Aug-19	892.69	676.35	24.2%	7,642.38	5,775.01	24.4%
Sep-19	888.51	725.96	18.3%	8,530.88	6,500.98	23.8%
Oct-19	938.88	709.77	24.4%	9,469.77	7,210.74	23.9%

Table 2.6: ECG's Distribution System Losses 2019

Distribution losses within the ECG network averaged 24.42% over the period January – September 2019. A month by month comparison of losses within the ECG network in 2019 with losses in 2018 is shown in Figure 2.4.

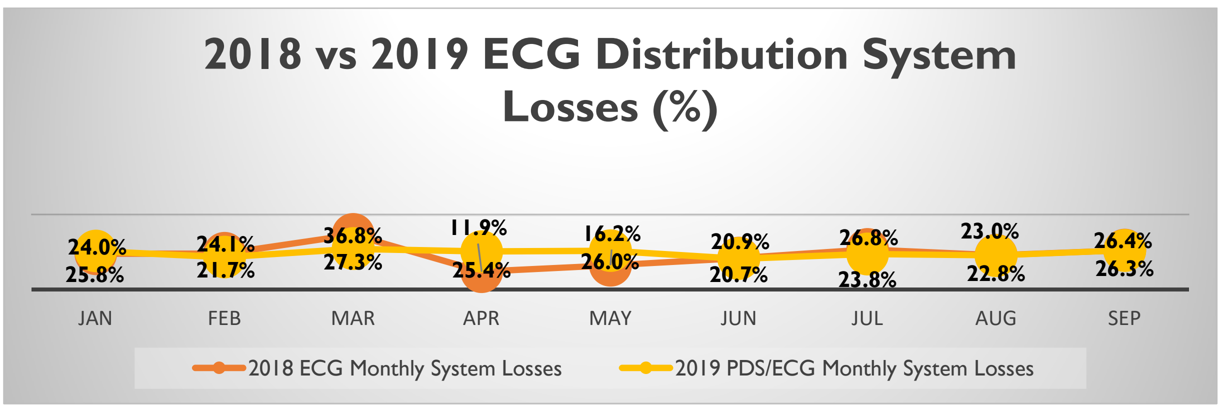


Figure 2.4: ECG Distribution System Losses, 2018 Vrs 2019

A comparison of losses within the ECG network indicate an increase from 23.27% in the period January – October 2018 to 23.86% over the same period in 2019.

- **NEDCo Distribution losses**

The NEDCo 2019 distribution network losses are presented in the Table 2.7.

Month	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Energy Purchased	112.6	111.3	128.5	124.0	128.0	116.0	111.7	111.5	108.6	115.9	124.7	120.0	1,412.8
Sales	65.5	64.8	72.4	76.9	74.8	72.3	67.7	66.1	68.9	67.7	71.3	77.4	845.8
Street light	13.3	13.2	15.3	14.7	15.2	13.7	13.1	13.2	12.9	13.8	14.8	14.2	167.4
Illegal recovery	0.7	0.7	0.7	0.9	1.2	1.3	0.9	1.3	0.9	0.7	1.4	0.9	11.6
Total Energy Accounted	79.5	78.7	88.3	92.5	91.2	87.4	81.8	80.6	82.7	82.2	87.5	92.5	1,024.9
% Energy Loss (Monthly)	29%	29%	31%	25%	29%	25%	27%	28%	24%	29%	30%	23%	27%
% Energy Loss (Com.)	29%	29%	30%	29%	29%	28%	28%	28%	28%	28%	28%	27%	

Table 2.7: NEDCo Distribution system losses 2019

Table 2.7 shows that total NEDCo distribution losses in 2019 was 388 GWh representing 27.46% of total energy purchased from Bulk suppliers.

2.2.2 Energy Generation

A summary of actual monthly energy generation against the projected in 2018 is shown in Table 2.8 and Figure 2.5.

Months	Projected (GWh)					Actual (GWh)			
	Total Hydro (GWh)	Total Thermal (GWh)	Total Solar (GWh)	Import (GWh)	Total (GWh)	Hydro (GWh)	Thermal (GWh)	Import (GWh)	Total (GWh)
January	499.82	980.41	4.84	-	1,485.08	781.49	703.88	9.89	1,495.25
February	451.45	879.37	4.37	-	1,335.19	736.53	664.19	10.47	1,411.19
March	480.23	966.95	4.84	-	1,452.02	744.08	787.49	13.84	1,545.41
April	483.70	978.87	4.68	-	1,467.25	635.62	872.58	12.15	1,520.35
May	499.82	977.59	4.84	-	1,482.25	666.81	908.38	9.55	1,584.74
June	483.70	897.68	4.68	-	1,386.06	453.04	983.41	9.59	1,446.05
July	420.05	969.21	4.84	-	1,394.11	493.79	918.49	13.98	1,426.26
August	499.86	904.84	4.84	-	1,409.54	461.78	930.25	8.94	1,400.97
September	418.01	964.68	4.68	-	1,387.37	460.35	907.29	15.43	1,383.07
October	499.80	960.00	4.68	-	1,464.48	547.29	906.58	11.31	1,465.18
November	483.7	960.0	4.7	-	1,448.48	684.71	865.57	10.67	1,560.94
December	499.8	909.9	4.9	-	1,414.58	586.13	1,059.70	1.61	1,647.43
Total	5,719.96	11,349.49	56.96	-	17,126.41	7,251.63	10,507.80	127.41	17,886.84

Table 2.8: Monthly Energy Generation

Figure 2.5 shows the projected and the actual energy generated for 2019.

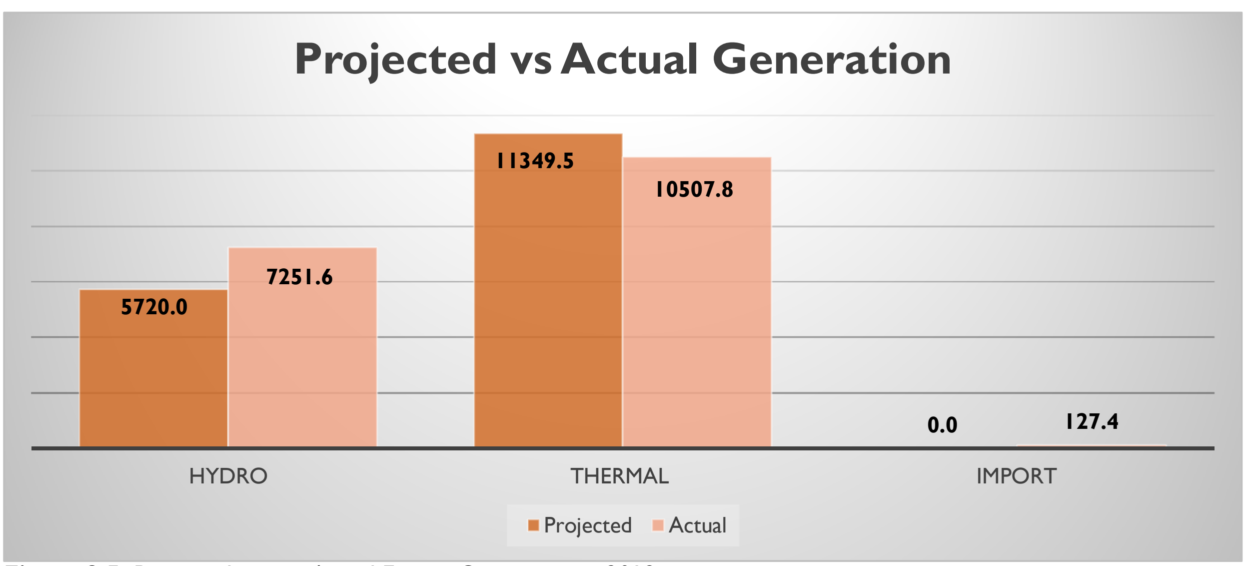


Figure 2.5: Projected versus Actual Energy Generation in 2019

The total energy generated over the period was 17,887 GWh; made up of 7,252 GWh from hydro generation, 10,508 GWh from thermal and 127 GWh imports. The imports were mainly inadvertent energy supplied from Côte d'Ivoire[3]. A restitiution program was intiated in December 2019 to restitute the inadvertent energy supplied. The corresponding percentage share of each generation type for the period was 40.54%, 58.75% and 0.71% for hydro, thermal and imports respectively. The generation mix at the end of the period is shown in Figure 2.6.

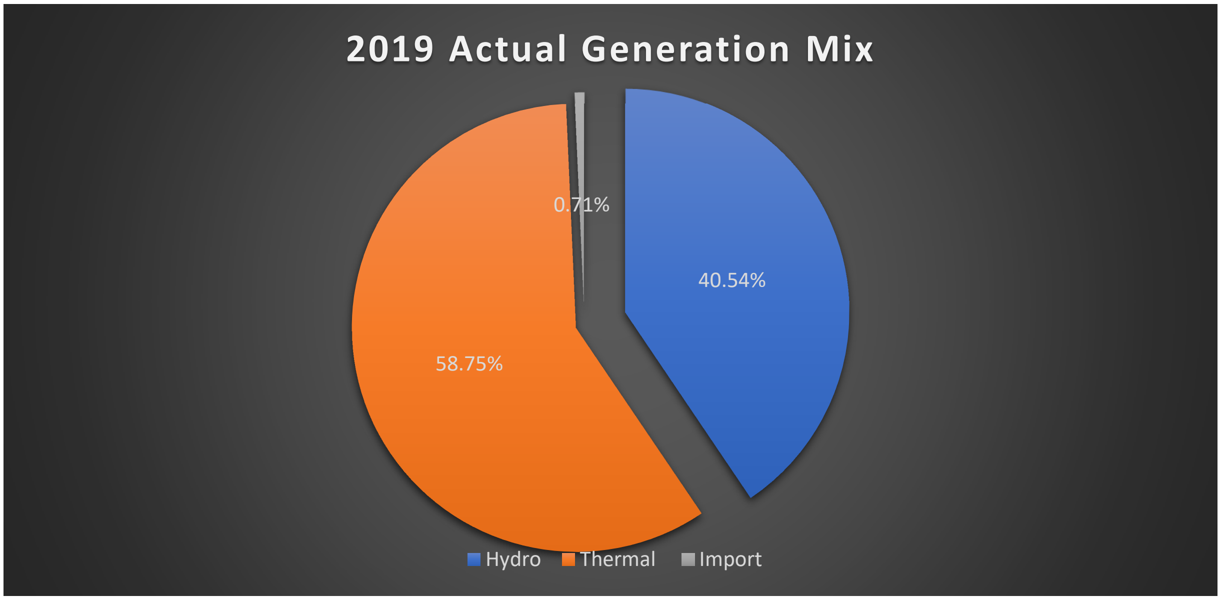


Figure 2.6: Actual Generation Mix in 2019

2.3 Generation Facilities

2.3.1 Hydro Facilities

The dependable capacities and the projected energies for the individual hydro plants are shown in Table 2.9.

Plants	Dependable Capacity (MW)	Projected Energy (GWh)	Actual Energy (GWh)	Variations	% Variations
Akosombo GS	900	4258.44	5365.77	1107.33	26.00%
Kpong GS	105	811.5	841.99	30.49	3.76%
Bui GS	360	650	1043.87	393.87	60.60%

Table 2.9: 2019 Projected and Actual Hydro Generation

From Table 2.8 it can be seen that the total hydro generated for 2019 was 7,252 GWh as against the projected of 5,720 GWh. This was made up of 5,366 GWh, 842 GWh and 1,044 GWh from Akosombo, Kpong and Bui Generating Stations respectively. The Bui Generating Station generated 60.6% more than was projected due to the high inflow of water into the reservoir exprienced during the inflow period and therefore the plant had to be dispatched to utilize the water. Similarly, the percentage energy variations for the Akosombo and the Kpong plants were to make up for the

[3] Unprogrammed energy supplied from Cote d'Ivoire

shortfall in thermal generation due to the unavailability of fuel, especially during periods where gas supply was interrupted due to maintenance, etc.

a. Akosombo & Kpong

The elevation of the Volta Lake at the start of the year 2019 was 79.81 m (261.85 feet). Based on this reservoir elevation, and the intent to store water in the reservoir, it was recommended to operate up to four (4) units during the off-peak period and up to five (5) units during the peak period in the year 2019.

However there were periods the plant did more than the projected due the unavailability of some thermal plants. As a result of this, the reservoir elevation dropped to a minimum of 76.89 m (252.25 feet) during the dry season in 2019.

The Kpong Generation Station (Kpong GS), was also planned to operate three (3) out of the four (4) generating units at the plant. The fourth unit was unavailable as it was undergoing major retrofit. The total average capacity that was available at Kpong GS was 105 MW.

Inflows in 2019

The reservoir elevation at the end of 2019 was 80.70 m (264.76 ft). This figure represents an increase of 3.80 ft above the projected figure elevation of 260.96 ft. The recorded maximum lake elevation at the end of year 2019 inflow season was 266.31 feet, a rise of 26.31 feet above the minimum operating level of 240 feet. The total net inflow recorded in 2019 was 33.43 MAF, which implies that net inflow obtained in 2019 was above the long term average of 25.21 MAF. Figure 2.7 shows the Akosombo reservoir trajectory for 2019 plotted against the trajectory for 2018 and the projected trajectory for 2019.

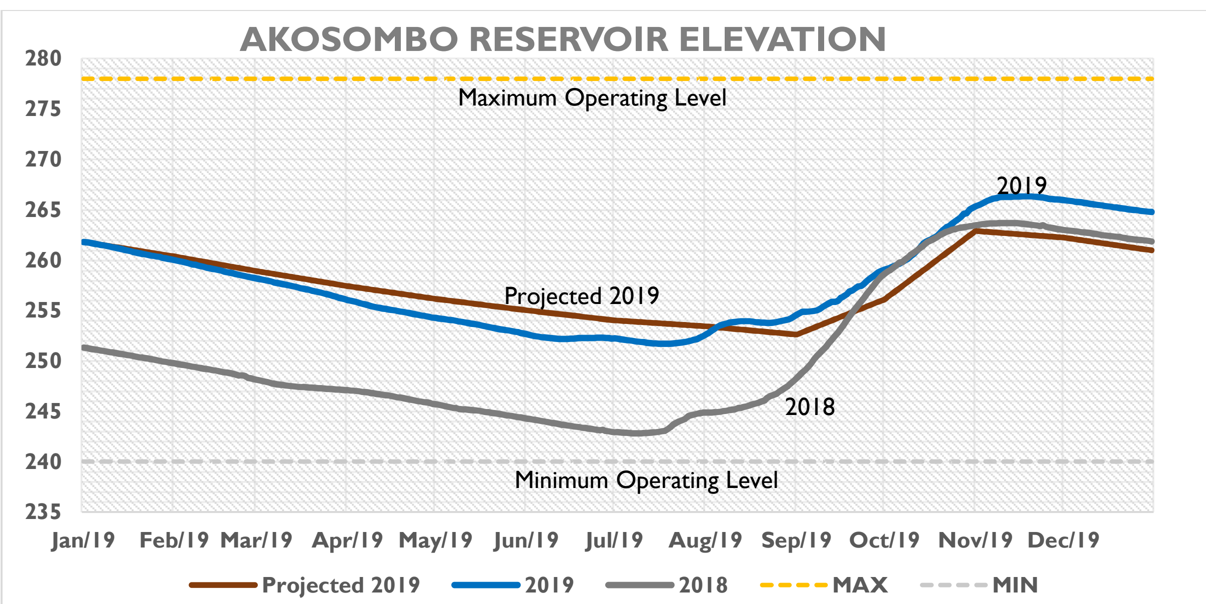


Figure 2.7: Akosombo Reservoir Elevation

b. Bui

The Bui Reservoir elevation at the beginning of 2019 was 176.97 MASL, dropping to a minimum of 168.66 MASL at the end of the dry season. The minimum level attained was thus 2.19 MASL lower than the projected minimum of 170.85 MASL for the year. The recorded maximum reservoir elevation at the end of year 2019 inflow season was 183.09 MASL, a rise of 15.09 meters above the minimum operating level of 168 MASL. The total net inflow recorded in 2019 was 14.43 meters.
The total energy generated from the plant in 2019 was 1,044 GWh compared to the projected of 645 GWh. The huge deviation from the projected generation was due to high inflows into the reservoir in the inflow season of 2019.

The recorded reservoir trajectory in 2019 is as shown in Figure 2.8.

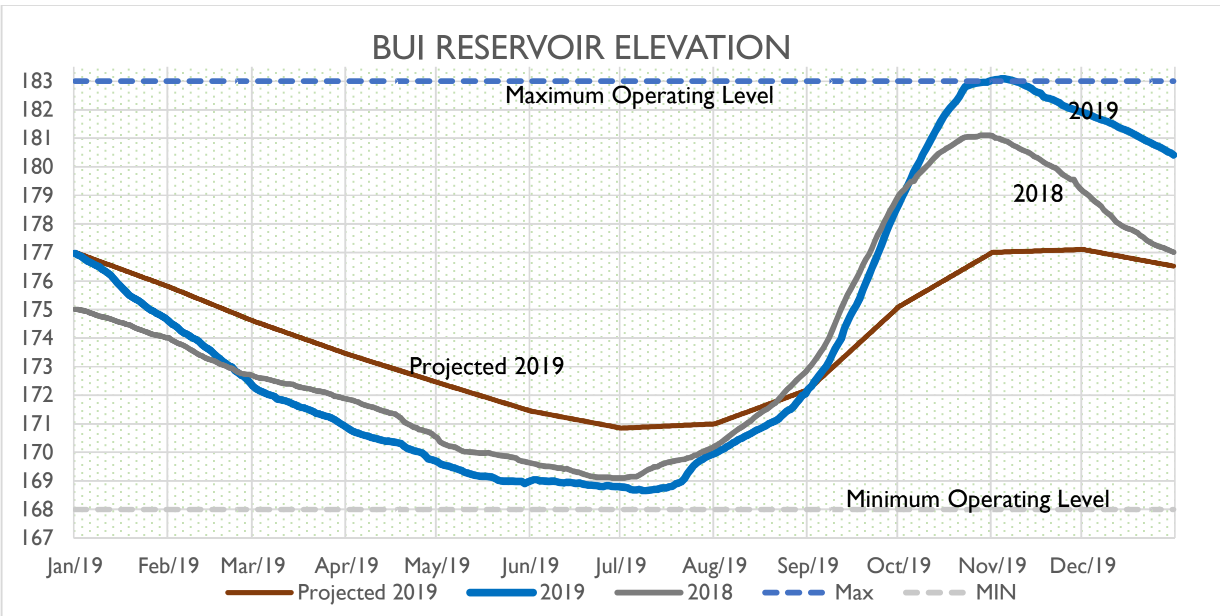


Figure 2.8: Bui Reservoir Elevation

2.3.2 Thermal Facilities

The Projected Dependable Thermal Capacities for 2019 was 3,456 MW which was made up of 2,906 MW from existing Units and 550 MW of committed Thermal Projects. The total thermal energy generation projected for the same year was 11,460 GWh, made up of generation outputs from VRA and IPP Plants. Table 2.10 details the capacities of the individual thermal plants and their energies delivered.

Plants	Dependable Capacity MW	Generated Energy GWh
VRA		

TAPCO (T1)	*300*	*847.15*
TICO (T2)	*320*	*1271.64*
TT1PP	*100*	*302.01*
TT2PP	*70*	*108.84*
KTPP	*200*	*322.22*
TOTAL	*990*	*2851.87*
Existing IPP'S		
CENIT	*100*	*28.75*
AMERI	*230*	*1305.24*
KAR Power	*450*	*1294.69*
Sunon Asogli	*520*	*2137.46*
AKSA	*350*	*559.83*
TOTAL	*1650*	*5325.96*
Committed IPP'S		
CEN Power	*340*	*359.00*
Amandi	*190*	*16.99*
TOTAL	*530.00*	*375.99*
TOTAL SUPPLY	3,170.00	8,553.82

Table 2.10: Projected 2019 Thermal Capacities and Energies

Figure 2.9 represents the percentage generation of the Thermal plants in the Eastern and Western corridors.

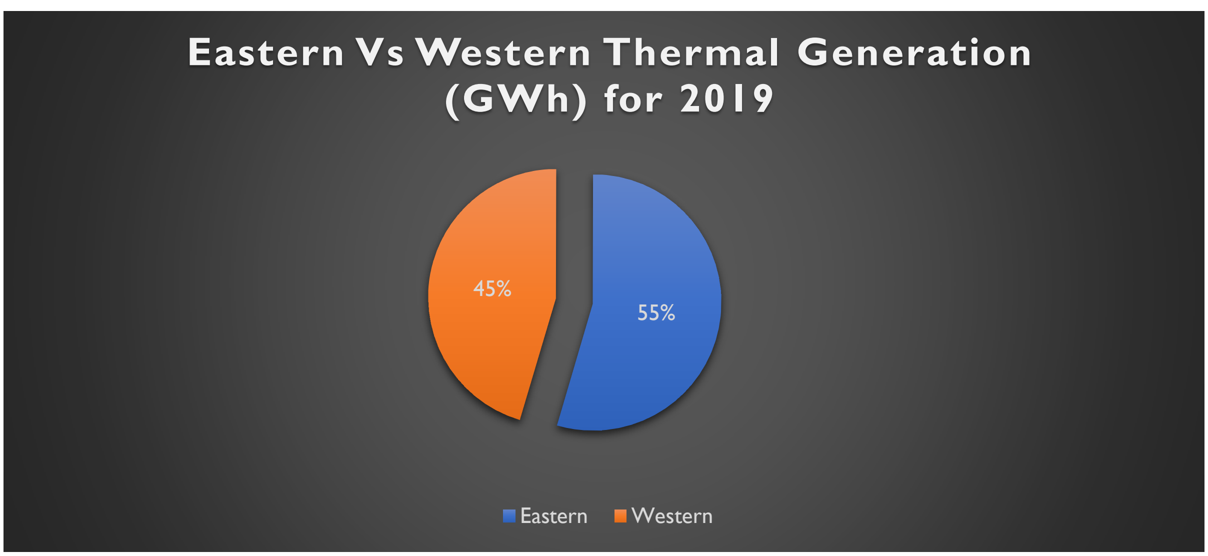


Figure 2.9: Eastern Vs Western Thermal Generation for 2019

a. Eastern Corridor Plants

The eastern corridor currently has seven (7) commissioned thermal plants with a total dependable capacity of 1,680 MW. The energy generated from the corridor was 5,695 GWh and represents 55% of the total thermal energy generation of 10,433 GWh generated for the year as seen in figure 2.9. This percentage generation compared to the 61% generation recorded in 2018 represents a drop in generation from the east and this was due to the relocation of the Karpower plant to the west.

Table 2.11 shows the thermal plants situated in the eastern enclave of the NITS. It details their dependable capacities, fuel type and owner.

Plants	Dependable Capacity (MW)	Fuel Type	Owner
TT1PP	100	LCO/Gas	
TT2PP	70	Gas	VRA
KTPP	200	Gas/ Diesel	
CENIT	100	LCO/Gas	SSNIT
SAPP	520	LCO/Gas	Sunon Asogli
AKSA	350	HFO	AKSA
CENPOWER	340	LCO/Gas	CENPOWER
TOTAL		1,680	

Table 2.11: Projected 2019 Thermal Capacities and Energies

b. Western Corridor Plants

The energy generated from the corridor at the end of year 2019 was 4,738 GWh representing 45% of the total thermal energy of 10,433 GWh as seen in figure 5. There was an increase in the percentage amount of generation compared to the 39% of generation recorded in 2018. This increase is due to the relocation of the Karpower plant from the east to the west.

Table 2.12 shows the thermal plants situated in the western enclave of the NITS. It details their dependable capacities, fuel type and owner.

Plants	Dependable Capacity (MW)	Fuel Type	Owner
TAPCO (T1)	300	LCO/Gas	VRA
TICO (T2)	320	LCO/Gas	
AMERI	230	Gas	METKA
KarPower	450	HFO	Karpower
Amandi	190	Gas/ Diesel	Amandi
TOTAL		1490	

Table 2.12: Projected 2019 Thermal Capacities and Energies

c. Natural Gas Supply

Gas supply to power plants over the period was from three main sources namely N-Gas, GNPC (Sankofa) and GNGC (Jubilee). Gas supply from Sankofa and Jubilee averaged 90 MMscfd and 57 MMscfd respectively in 2019. N-Gas supply ranged between 20 MMscfd and 120 MMscfd. The detailed 2019 gas supply trends for N-Gas, Jubilee and Sankofa are as shown in Figures 2.10 – 2.12.

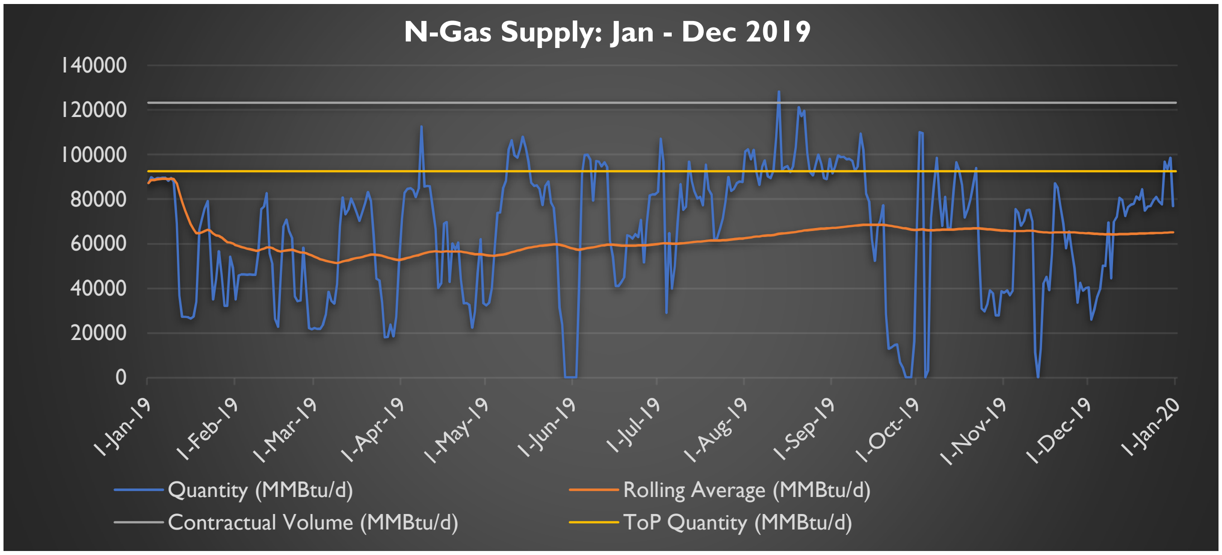


Figure 2.10: N-Gas Supply: January – December 2019

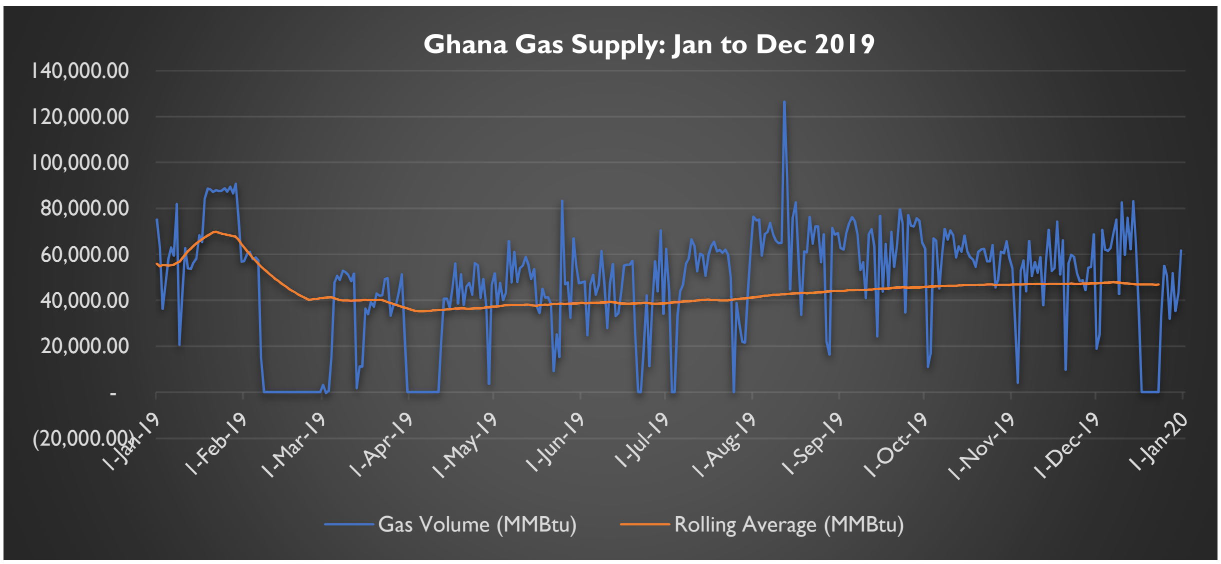


Figure 2.11: Ghana Gas Supply: January – December 2019

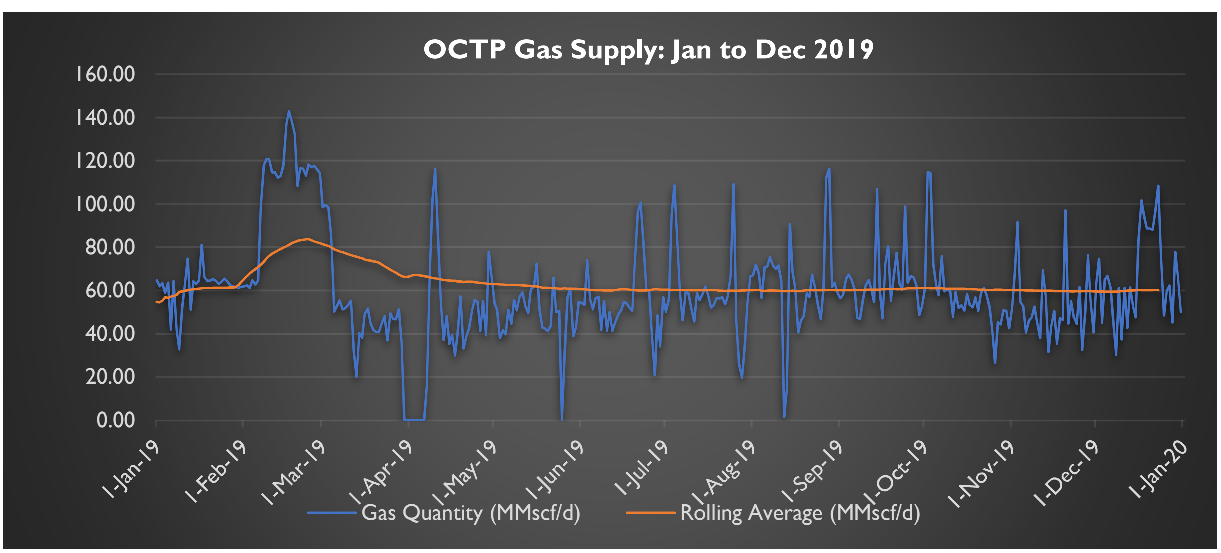


Figure 2.12: OCTP Gas Supply: January - December 2019

Supply from the three main sources was fairly stable over the period serving power plants both in Takoradi and Tema.

GNGC supply from Jubilee however experienced major challenges in the course of the year which accounts for the troughs in the graphical presentation. GNPC (Sankofa) gas was usually ramped up to make up for the shortfalls created by the unavailability of Jubilee gas. Examples of these gas supply interruptions from Jubilee occurred on April 20, June 27 and June 30, 2019. These interruptions led to the shutdown of gas fired plants in the Aboadze enclave.

N-Gas supply continued to serve the Tema enclave during the period under review and was only made available to Aboadze during the shutdown of domestic gas infrastructure for the TTIP works.

d. Karpower Relocation

The 450 MW Karpowership, Osman Khan, which was connected to the National Grid at Tema via two (2) 161 kV transmission lines was decommissioned on August 13, 2019 and relocated to the Sekondi Naval Base in the Western Region of Ghana. The plant was re-connected to the NITS 330 kV transmission lines at Aboadze. It was subsequently converted to run on natural gas.

2.3.3 Renewable Energy Sources

As at 12th November, 2019, about 130 Provisional Wholesale Electricity Supply Licences had been issued to potential Independent Power Producers (IPPs) who proposed to develop a total of 7,030.589MW of electricity from various renewable energy sources. Out of these, 63.8% are for solar photovoltaic (PV) generation.

About 40 licensees have moved to the Siting Permit stage of the licensing process of which about 30 are for solar PV. However, only 13 companies have been issued with Construction Permits with 11 being issued for the development of solar PV projects.

Four (4) Operational Wholesale Electricity Supply Licences have been granted to the following companies:

1. BXC (Ghana) Company Limited (20MW solar PV plant located at Gomoa Onyadze in the Central Region.)
2. Safi Sana Ghana Limited (100kW waste-to-energy plant located at Ashaiman in the Greater Accra Region).
3. Meinergy Technology Company Limited (20MW solar PV plant located at Gomoa Onyaadze in the Central Region).
4. Crossboundary Energy Ghana Limited (400kWp rooftop solar PV plant at Kasapreko Company Limited located at Spintex Road, Accra).

In view of the excess generation capacity, the Ministry of Energy issued a policy directive that, effective 1st July, 2019, all power (conventional and renewable) to be procured by any Government agency should be done through a competitive tendering process.

The Energy Commission, within its mandate to ensure the development and utilisation of the country's renewable energy resources, initiated the 200,000 National Rooftop Solar Programme in February 2016, which aimed at the installation of 200,000 solar PV systems for residential and small and medium enterprises (SMEs) and low-income off-grid communities in the country.

The overall goal of the National Rooftop Solar Programme is to ensure that solar energy technology contribute significantly to the national energy supply mix of the country by stimulating market growth and catalysing the growth of private sector interest in renewable energy technologies, especially solar PV. The Programme originally sought to help shave off about 200MW load with the use of solar PV technology as the country was then going through acute nationwide power crisis.

The first phase of the National Rooftop Solar Program (NRSP) was implemented in the urban centers and a total of 1068 systems estimated at about 20MWp were installed. The second phase focused on rural off-grid areas where solar systems had been installed for 200 rural households under a pilot programme.

2.4 Generating Plants Availabilities in 2019

Table 2.13 presents the actual availabilities of the generating plant recorded for the year 2019 as against the forecast.

Plant	Forecast (%) Availability	Actual (%) Availability
Akosombo Hydroelectric Plant	90	94.35
Kpong Hydroelectric Plant	72	71.57
Bui Generation Station	72	80.00
Takoradi Thermal Power Plant (TAPCo)	65	53.98
Takoradi Thermal Power Plant (TICo)	85	74.99
Tema Thermal Power Plant (TT1PP)	85	56.51
CENIT	90	32.86
Karpower	90	69.54
Tema Thermal Power Plant (TT2PP)	85	54.12
Sunon Asogli Power Plant	90	61.71
Ameri	90	70.82
Kpone Thermal Power Plant (KTPP)	85	63.79
AKSA	90	72.12

Table 2.13: Generating Plants' actual and estimated availability

Table 2.13 shows that Thermal Plants apart from the Ameri Plant generally recorded low availabilities for the year. This was due to unavailabitity of fuel to operate them and also in the case of Karpower, it was as a result of the relocation from the Tema enclave to the Aboadze enclave. It should be noted however that the plants' availability factors were calculated based on the total plant dependable capacity and fuel availability.

2.5 Quality of Supply

2.5.1 System Frequency

Figure 2.13 shows system frequency performance for the year 2019. It is seen from the graph that system frequency was within the normal range (49.8Hz – 50.2Hz) – 70.68% of the time which is lower than the 79.69% recorded in 2018. It was in the alert state for 28.88% of the time in the year 2019 as follows:

- ✓ 49.5 – 49.8Hz - 2.82% of the time.
- ✓ 50.2 – 50.5 Hz - 26.06% of the time.

It was in emergency state for 0.34% of the time in the entire year as follows:

- ✓ 49.0 – 49.5Hz - 0.24% of the time.
- ✓ 50.5 – 51.0Hz - 0.08% of the time.
- ✓ below 49.0Hz, 0.03% of the time.
- ✓ above 51.0Hz, 0.00% of the time.

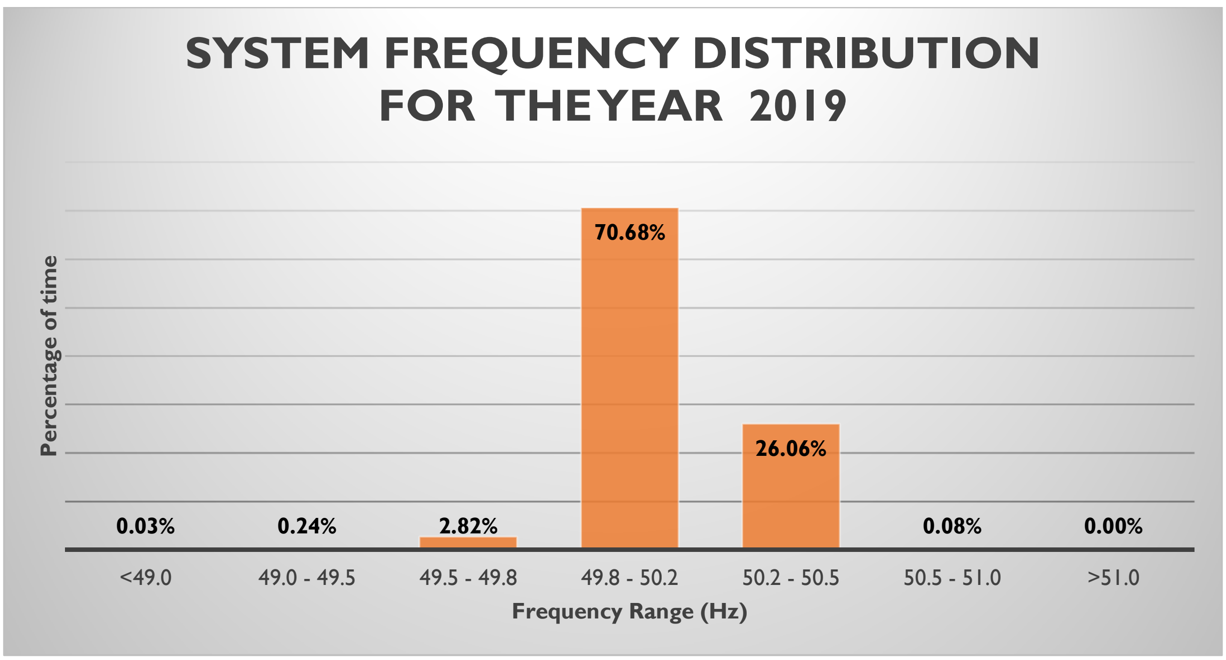


Figure 2.13: System Frequency for year 2019

2.5.2 System Voltages

An analysis of voltages at selected Bulk Supply Points (BSP) at peak time indicates that voltages across the NITS were largely within normal limits, except Kumasi as shown in Table 2.14.

Station	Number of Days of the Year			% of the Year		
	Normal	Below Normal	Above Normal	Normal	Below Normal	Above Normal
Achimota	351	12	1	96.43	3.30	0.27
Mallam	310	55	0	84.93	15.07	0
New Tema	355	1	9	97.26	0.27	2.47
Kumasi	236	129	0	64.66	35.34	0

Station	Number of Days of the Year			% of the Year		
	Normal	Below Normal	Above Normal	Normal	Below Normal	Above Normal
Takoradi	359	6	0	98.36	1.64	0
Tamale	359	2	4	98.36	0.55	1.10

Table 2.14: Bus Voltages at Bulk Supply Points in 2019

Kumasi voltages were below limits for the first half of the year 2019. The low voltages were largely due to poor customer (ECG) load power factors and the relatively long circuit distance from generating plants. Kumasi voltage profiles however improved following the commissioing of the Aboadze- Anwomaso 330kV transmission line.

2.6 Transmission Network Performance

2.6.1 Feeder Availability

The average feeder availability on the NITS in the year 2019 was 99.84%, indicating no change from that recorded in 2018.

2.6.2 Transmission Lines

The System Average Availability (SAA) for the transmission grid was 99.41% in 2019. The index of transmission reliability which indicates availability of transmission lines barring planned maintenance schedules on the lines was 99.62%. The breakdown of availability on the various voltage class is summarised in Table 2.15.

Voltage Class	Availability (%)
69kV	99.33%
161kV	99.47%
225kV	98.84%
330kV	99.25%
System Average Availability (%)	99.41%

Table 2.15: The percentage transmission line availability in 2019

2.7 Transformer Capacity

Over the period under review, transformer capacity on the NITS increased from **8,106.9 MVA** to **8,959.6 MVA**, an increase of **852.7 MVA**.

Table 2.16 shows the breakdown of transformer additions.

Substation	Transformer Code	Voltage level (kV)	Rating (MVA)
Berekum	63T1	161/34	33
Akwatia	16T1	161/34	19.9
330 kV Kintampo S/S	56T3	330/330	200

Substation	Transformer Code	Voltage level (kV)	Rating (MVA)
	56T4	330/330	200
330 kV Adubiyili	81T1	330/161	200
	81T2	330/161	200

Table 2.16: Transformer additions for year 2019

Table 2.17 shows typical transformer peak loadings in some major substations in 2019.

Substation	Transformer Code	Rating (MVA)	Peak Loading (MVA)	% of Rating
Achimota	5T1	66	67.04	102%
	5T2	66	70.94	107%
	5T3	66	70.95	108%
	5T4	66	71.94	109%
	5T5	66	70.34	107%
	5T6	66	71.9	109%
Mallam	37T1	66	55.73	84%
	37T2	66	65.16	99%
	37T3	66	59.25	90%
	37T4	66	55.98	85%
New Tema	4T1	66	45.24	69%
	4T2	66	50.74	77%
	4T3	66	28.3	43%
	4T5	66	55.61	84%
	4T5	20	0.03	0%
	4T6	20	3.2	16%
Kumasi	13T1	66	69	105%
	13T2	66	61.3	93%
	13T3	66	53.8	82%
	13T4	66	62.4	95%
Takoradi	8T1	33	47	142%
	8T2	33	19.28	58%
	8T3	33	21.75	66%

Table 2.17: Transformer ratings and peak loading

2.8 New installations in 2019

Table 2.18 shows the projects that were commissioned during the year 2019.

Equipment	Projects
Transmission Line	1. 161 kV Sunyani-Berekum line
	2. 161 kV Mim-Juabeso line
	3. 330kV Aboadze-Anwomaso
	4. 330kV Kintampo- Nayagnia
	5. 161 kV Buipe – Adubiliyi
	6. 161 kV Adubiliyi – Tamale
	7. 330 kV Kintampo-Adubiyili
	8. 330 kV Adubiyili-Nayagnia
	9. 330kV Karpowership -Takoradi Thermal Power Plant

Equipment	Projects
	10. 161 kV Bolga - Nayagnia
	11. 161 kV Bridge Power Plant – New Tema Line 1
	12. 161 kV Bridge Power Plant – New Tema Line 2
Substation/Transformers	33 MVA transformer at Berekum
	2X200 MVA autotransformers at Kintampo 330 kV S/S
	2x200 MVA autotransformers at t 330kV Adubiliyi S/S
	330 kV Adubiliyi Substation
Generating Plants	360 MW CENPOWER
	190 MW Amandi
	30 MW Brigde Power

Table 2.18: Commissioned Projects

Chapter 3

2020 DEMAND OUTLOOK

3.1 Introduction

Being a developing country, Electricity demand in Ghana is expected to increase in the year 2020 compared to demand in 2019. Electricity demand in Ghana can be grouped into:

- Domestic demand which refers to electricity demand within the control area of Ghana (excluding VALCO), including demand that is typically served through Distributing Companies such as the Electricity Company of Ghana and the Northern Electricity Distributing Company as well as the Mines, other bulk consumers who take supply directly from the NITS such as Diamond Cement, etc;
- VALCO; and
- Exports (such as CEB, SONABEL and CIE).

The month-on-month peak demand will vary depending on the severity of the various demand drivers such as economic growth, seasonal changes in weather, etc. In this chapter, we take a look at Demand Outlook for the year 2020.

3.2 2020 Peak Demand

It is projected that in 2020, the Ghana Power System will register a coincident peak demand of 3,115.15 MW. This projected 2020 peak demand represents an increase of 311.45 MW, a growth of 11 % over the 2019 peak demand of 2,804 MW which occurred on December 03, 2019.

The 2020 demand survey exercise carried out identified the following activities which are expected to contribute to achieve the projected 2020 peak demand:

- Demand increases attributable to ongoing distribution network expansion works intended to extend coverage and improve service quality to ECG and NEDCo customers;
- Expected completion and commissioning of various ongoing rural electrification projects within the ECG and NEDCo distribution zones in 2020;
- Increased VALCO demand due to the ramp-up to full operation of the second potline, increasing the smelter's demand from the current 55 MW[4] to 150 MW. Please note that since the startup of the second potline in June 2018 the smelter has encountered a series of internal challenges such that they have not yet been able to attain full potline operation;
- Increased exports to SONABEL (Burkina) from an average of 60 MW in 2019 to a planned maximum of 150 MW in 2020;
- Increased exports to CEB (Togo/Benin) from an average of 120 MW in 2019 to a planned maximum of 180 MW in 2020;
- Re-operationalisation of the AngloGold Ashanti mine at Obuasi.

3.2.1 Distribution System Demand Forecast Methodology

Distribution network demand typically accounts for approximately 80% of total Ghana demand. The demand forecast for the Distribution System (ie. ECG and NEDCo) was based on the 2020 Budget Statement projection for GDP growth in Ghana[5], as determined by the Ministry of Finance.

Customers of the Distributing Companies have been classified into categories. ECG customers are categorized into Special Load Tariff (SLT) customers and Non – Special Load Tariff (NSLT) customers. The SLT customers include industrial customers who consume a demand of 100 kVA and above whilst the Non SLT customers include both residential and commercial customers who consume a demand less than 100 kVA.

For NEDCo, there are three categories of customers. These are Residential, Non-Residential and SLT customers. NEDCo's operational area covers about 64% of the geographical area of Ghana (including the northern parts of Volta, Ashanti and Western regions) however, the customer density of the operational area is low.

In assertion of the fact that the growth patterns for the different categories of customers, different forecast models were developed for forecasting demand for each customer category for the year 2020 taking into account projections for losses.

3.2.2 Details of 2020 Peak Demand Projections

Table 3.1 shows a detailed breakdown of 2020 Projected Peak Demand showing the individual Load Entity/Distributing Company.

Demand	Customer		2020 – Projected Coincident Peak (MW)
Domestic Peak Demand	ECG		1,874.73
	NEDCo		243.30
	Enclave Power		57.04
	Mines	New Obuasi Obuasi New Tarkwa Prestea Ahafo/Kenyase (Newmont) New Abirim (Newmont)	246.01

[4] VALCO demand as at December 31, 2019
[2] Projected GDP for 2019 of 7.6%: Source: https://www.mofep.gov.gh/sites/default/files/budget-statements/2019-Budget-Highlights.pdf
Accessed 21.10.2019 @ 1.06pm

		Akyempem (Wexford) Perseus (Ayanfuri) Bogosu Akwatia Konongo Adamus Gold Resources Asanko Gold Drill Works	
	Other Bulk Customers	Akosombo Textiles Aluworks Ghana Water Company Ltd Enclave Power Company Diamond Cement Generation Plants Station Service Volta Hotel Savana Cement (Buipe) VRATownships	50.14
Losses +Network Usage			163.94
Total Domestic Peak Demand			2,635.15
Exports	CEB	180	
	CIE	0	
	SONABEL	150	
Total Exports			330.00
VALCO			150.00
Coincident Peak Demand MW			3,115.15

Table 3.1 Summary of 2020 Projected Peak Demand

The Pie-Chart below illustrates the composition of the projected 2020 Peak Demand, showing the percentage share of each customer class. As shown in the Chart, ECG has the highest demand, constituting 60% of the total system peak followed by Exports constituting 10%, followed by NEDCo and the Mines at 8% each. VALCO at two pot-lines constitutes 5%. Other Bulk Consumers constitute 2 % of total peak demand.

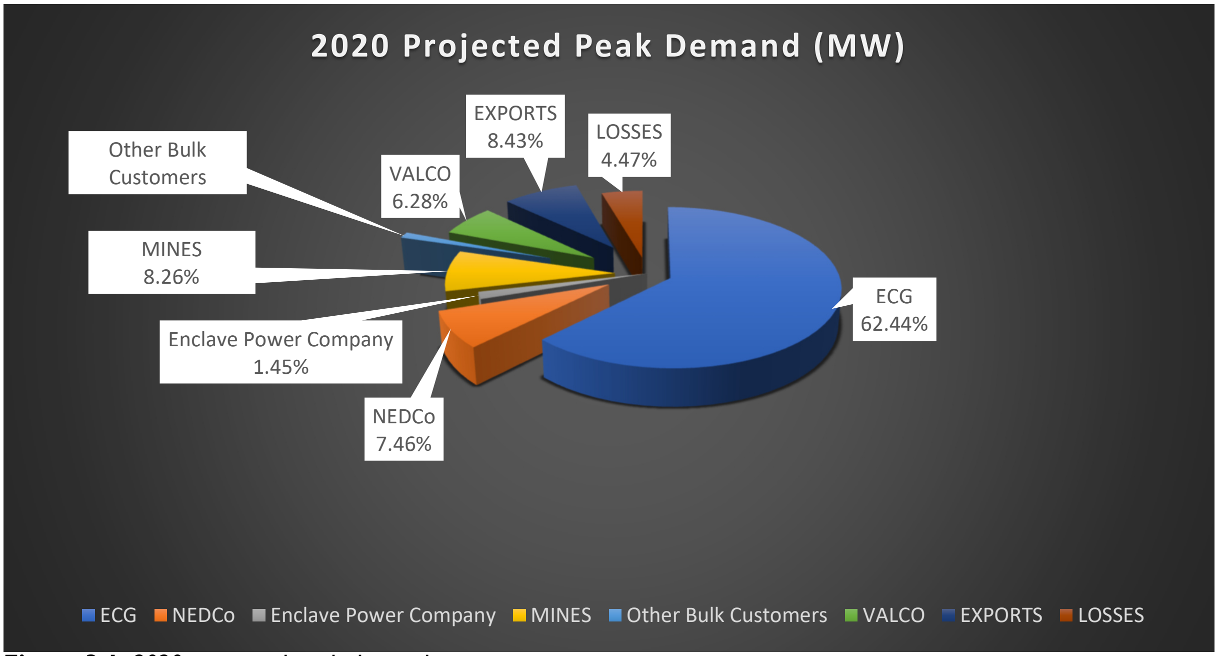


Figure 3.1: 2020 projected peak demand

3.3 2020 Energy Consumption Projections

In 2020, the projected base case energy consumption is 19,594.44 GWh, which includes transmission network losses of 876.22 GWh. The estimated transmission losses, represents a 4.47 % of total projected energy supply. The projected 2020 energy consumption represents an increase of 1,712.44 GWh or in percentage terms, a growth of approximately 9.6 %, over the 2019 consumption of 17,887 GWh.

The summary of 2020 consumption by customer class is presented in Table 3.2.

Energy	Customer	2020 – Projected Consumption (GWh)
Domestic Consumption	ECG	12,234.84
	NEDCo	1,462.70
	Enclave Power Company	283.78
	Mines	1,618.69
	Other Bulk Customers	236.39
	Losses + Network Usage	876.22
Total Domestic		16,712.62
Exports	CEB	902.06
	CIE	0.00
	SONABEL	750.00
VALCO		1,229.76
Total Energy (GWh)		19,594.44.

Table 3.2 Summary of 2020 consumption by customer class

Figure 3.2 below shows a pie-chart representation of the projected consumption of the various customer classes in 2020 and their percentage shares. As shown, ECG's consumption of 12,235 GWh represents 62% of the total projected energy consumption for 2020. It is followed by NEDCo with a projected consumption of 1,463 GWh representing 8% of total consumption.

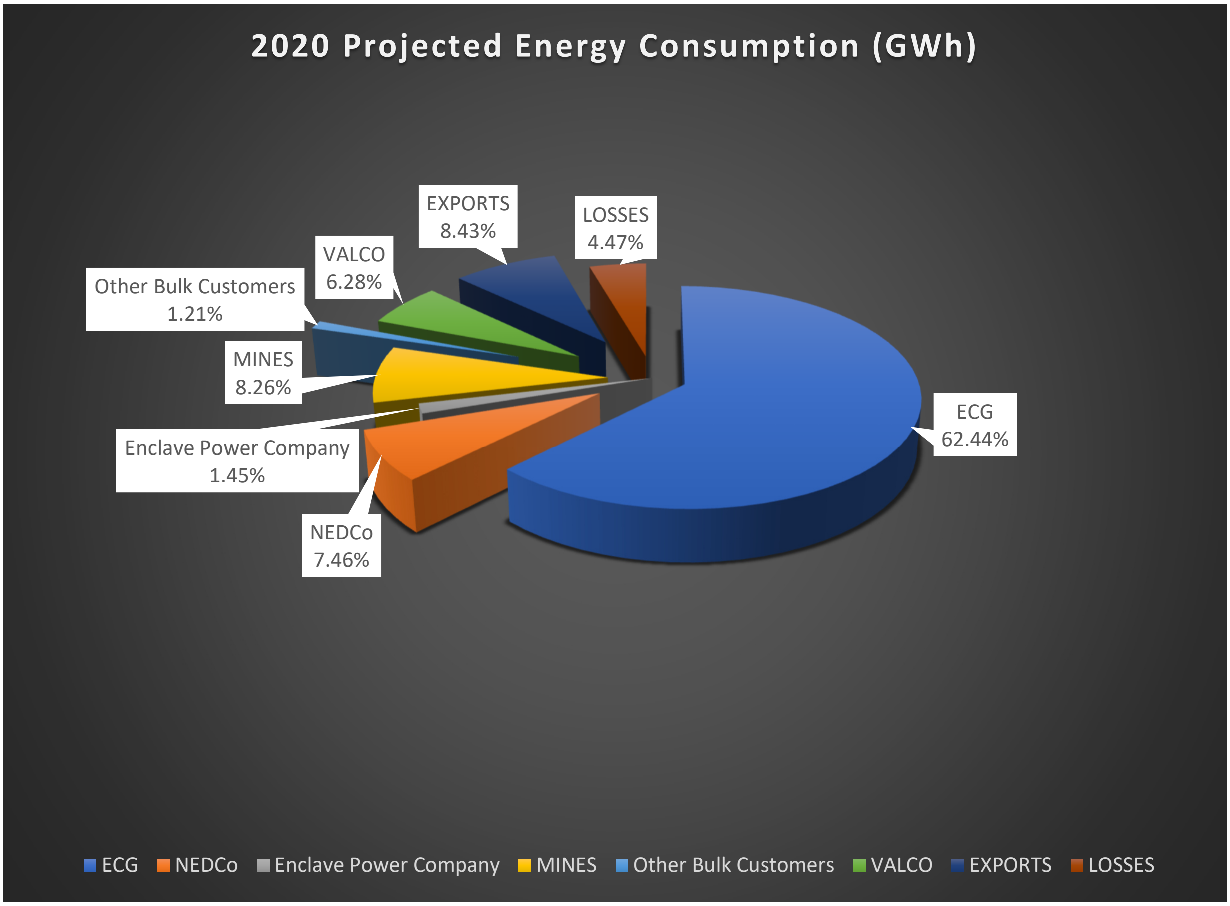


Figure 3.2: 2020 Projected Energy consumption by Customer

3.4 Projected Monthly Peak and Energy Demand for 2020

A summary of monthly energy consumption and the corresponding peak demand for the various customer classes is shown in Tables 3.3 and 3.4.

Energy Forecast (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total GWh
ECG	1045.61	973.37	1071.63	1052.82	1050.29	968.11	957.21	964.99	958.62	1029.90	1054.37	1107.92	12234.84
NEDCo	112.36	114.73	132.86	130.98	131.35	120.84	118.57	114.57	113.94	123.29	129.13	120.08	1,462.70
Enclave Power Company	23.11	22.36	24.58	24.21	25.34	23.77	23.78	24.09	22.75	24.59	24.20	21.02	283.78
MINES	133.44	124.30	134.21	131.74	135.26	131.73	135.72	140.52	136.55	139.35	136.26	139.62	1,618.69
Other Bulk Customers	21.12	20.81	20.78	19.90	19.58	18.74	19.36	18.45	17.95	20.14	18.37	21.19	236.39
VALCO	52.08	83.52	104.16	108.00	111.60	108.00	111.60	111.60	108.00	111.60	108.00	111.60	1,229.76
CEB(Togo/Benin)	104.32	97.00	96.77	69.86	72.19	69.86	61.82	45.46	44.01	63.57	72.19	105.00	902.06
SONABEL(Burkina)	54.00	60.00	63.00	63.00	65.00	62.00	65.00	69.00	68.00	65.00	62.00	54.00	750.00
CIE(Ivory Coast)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EDM(Mali)	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Network Usage	0.80	0.77	0.85	0.83	0.83	0.77	0.77	0.77	0.76	0.81	0.83	0.87	9.65
LOSSES	71.57	69.26	76.29	74.10	74.56	69.58	69.12	68.92	68.05	73.03	74.28	77.80	866.57
Total	1,618.41	1,566.12	1,725.13	1,675.43	1,686.00	1,573.40	1,562.96	1,558.36	1,538.61	1,651.27	1,679.64	1,759.10	19,594.44

Table 3.3: Summary of Projected 2020 Monthly Energy (GWh) Consumption –Base Case Scenario

Coincident Peak Demand (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ECG	1810.69	1810.69	1857.80	1856.34	1836.08	1818.34	1709.64	1720.41	1680.85	1834.70	1835.48	1874.73
NEDCo	216.82	227.20	227.94	247.77	231.11	228.91	219.14	221.35	223.49	235.53	243.30	243.30
Enclave Power Company	53.32	57.04	57.04	57.04	57.04	54.56	54.56	54.56	54.56	57.04	57.04	57.04
MINES	234.16	236.05	237.34	237.35	237.69	238.45	238.01	243.50	244.40	246.62	246.10	246.01
Other Bulk Customers	50.26	48.41	52.80	51.91	51.56	50.29	50.08	48.89	47.74	51.18	50.60	50.14
VALCO	70.00	120.00	140.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00
CEB(Togo/Benin)	170.00	170.00	170.00	170.00	170.00	170.00	170.00	170.00	170.00	170.00	180.00	180.00
SONABEL(Burkina)	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00
CIE(Ivory Coast)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EDM(Mali)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Network Usage	1.63	1.67	1.71	1.73	1.70	1.69	1.62	1.63	1.61	1.71	1.72	1.74
LOSSES	151.42	154.95	158.99	160.50	158.47	157.21	150.66	151.62	149.54	159.11	160.07	162.19
System Peak(Coincident)	2,908.30	2,976.00	3,053.62	3,082.64	3,043.65	3,019.46	2,893.71	2,911.96	2,872.18	3,055.89	3,074.30	3,115.15

Table 3.4: Summary of Projected 2020 Monthly Peak (MW) demand – Base Case Scenario

Chapter 4

2020 SUPPLY OUTLOOK

4 SUPPLY OUTLOOK

4.1 Generation Sources

Every power system is required to have adequate sources of electrical power generation and supply to adequately serve its demand, making provision for operating reserves to provide reliability. In this chapter we take a look at the sources of generation planned to supply electricity demand in Ghana in the year 2020.

4.2 Generation Sources

The sources of generation considered for use on the Ghana power system in 2020 are mainly the existing Hydroelectric, Thermal and Renewable Energy Plants, as well as committed power plant projects already under construction and expected to be commissioned during the year.

4.3 Summary of Generation Sources

Table 4.1 presents a summary of the existing and committed generation sources considered for 2020.

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
Akosombo GS	1020	900	Hydro
Kpong GS	160	105	Hydro
TAPCO (T1)	330	300	LCO/Gas
TICO (T2)	340	320	LCO/Gas
TT1PP	110	100	LCO/Gas
TT2PP	80	70	Gas
KTPP	220	200	Gas/ Diesel
VRA Solar Plant	2.5	0	Solar
TOTAL VRA	2,263	1,995	
Bui GS	404	360	Hydro
CENIT	110	100	LCO/Gas
AMERI	250	230	Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LCO/Gas
KAR Power	470	450	HFO
AKSA	370	350	HFO

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
BXC Solar	20	0	Solar
Meinergy Solar	20	0	Solar
Trojan	44	39.6	Diesel/Gas
Genser	60	60	Gas
CEN Power	360	340	LCO/Gas
Amandi	190	190	LCO/Gas
TOTAL IPP	2,820	2,598	
TOTAL (VRA, Bui & IPPs)	5,083	4,593	

Table 4.1: Existing Generation Sources for 2020

4.4 Hydro Power Generation for 2020

Total projected hydro generation for 2020 is 6,229 GWh . This comprises of 4,646 GWh, 819 GWh and 764 GWh generation at Akosombo, Kpong and Bui Generating Stations respectively.

4.4.1 Akosombo & Kpong Hydro

The generation plan for 2020 assumes Akosombo GS operates on the average four (4) units during off-peak periods and five (5) units during peak periods. This mode of operation will result in a projected minimum elevation of 255 feet at the end of the dry season in 2020.

However, in the first quarter of 2020, due to the WAGP Intelligent Pigging exercise gas supply to Tema will be curtailed, rendering some Thermal Power Plants inoperable. Consequently, all 6 units at Akosombo GS will be put in operation to ensure security of supply.

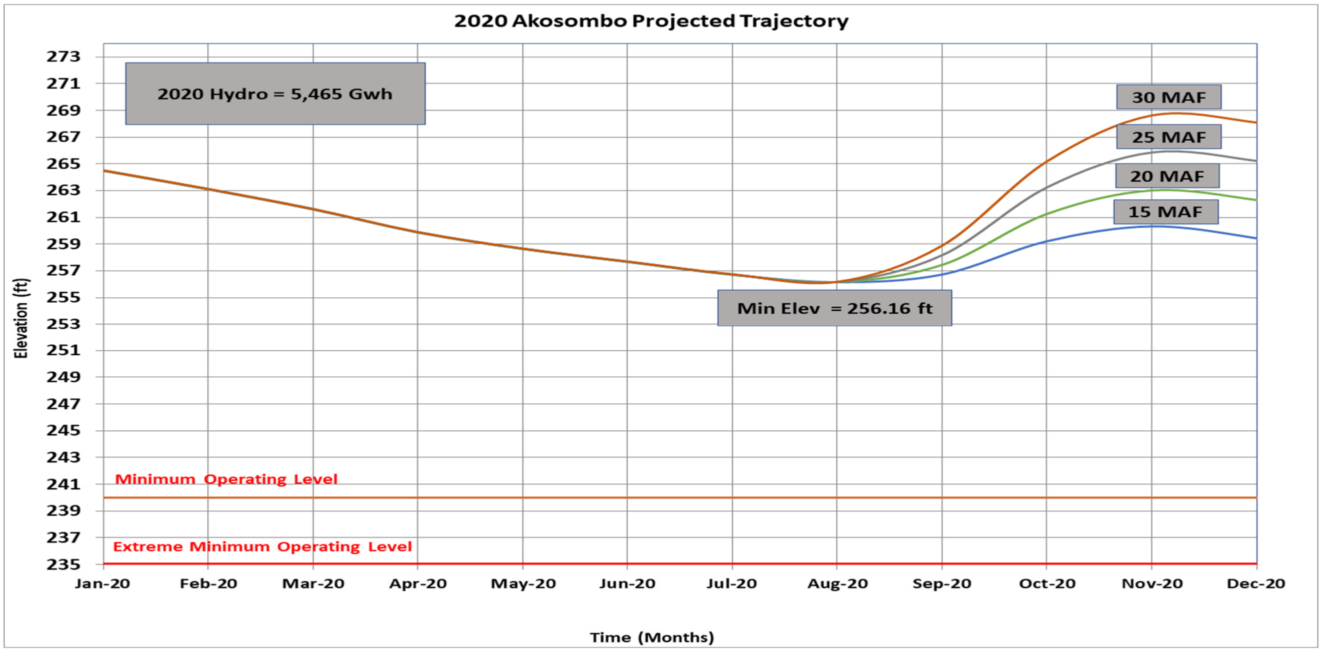


Figure 4.1 2020 Projected Akosombo Reservoir Trajectory

Due to on-going retrofit works, Kpong Generation Station (Kpong GS) will have only three (3) out of the four (4) units available throughout the first quarter 2020. The average capacity that would be available at Kpong GS is 105 MW. The retrofit is expected to be completed by April 2020. Therefore from April 2020 all four units are expected to be available at Kpong GS, increasing the dependable capacity of Kpong GS to 140 MW.

From the above mode of operation, the projected total annual hydro generation from Akosombo and Kpong generating stations is 5,465 GWh.

4.4.2 Bui Hydro

In 2020, Bui Hydro Plant is projected to run on average two (2) units throughout the year. This mode of operation will lead to a projected annual generation of 764 GWh. The plant is assumed to provide an average generation capacity of 220 MW to be dispatched during peak periods and other critical periods as asserted to be of prudence.

It is estimated that, for continuous and sustainable operation of the Bui GS for 2020, the reservoir level at the end of the dry season in 2020 should not drop below 170.00 masl. With a year-start elevation of 180.37 masl in 2020, the estimated total energy generation for the year 2020 is 764 GWh, and the year-end elevation is projected at 177.65 masl.

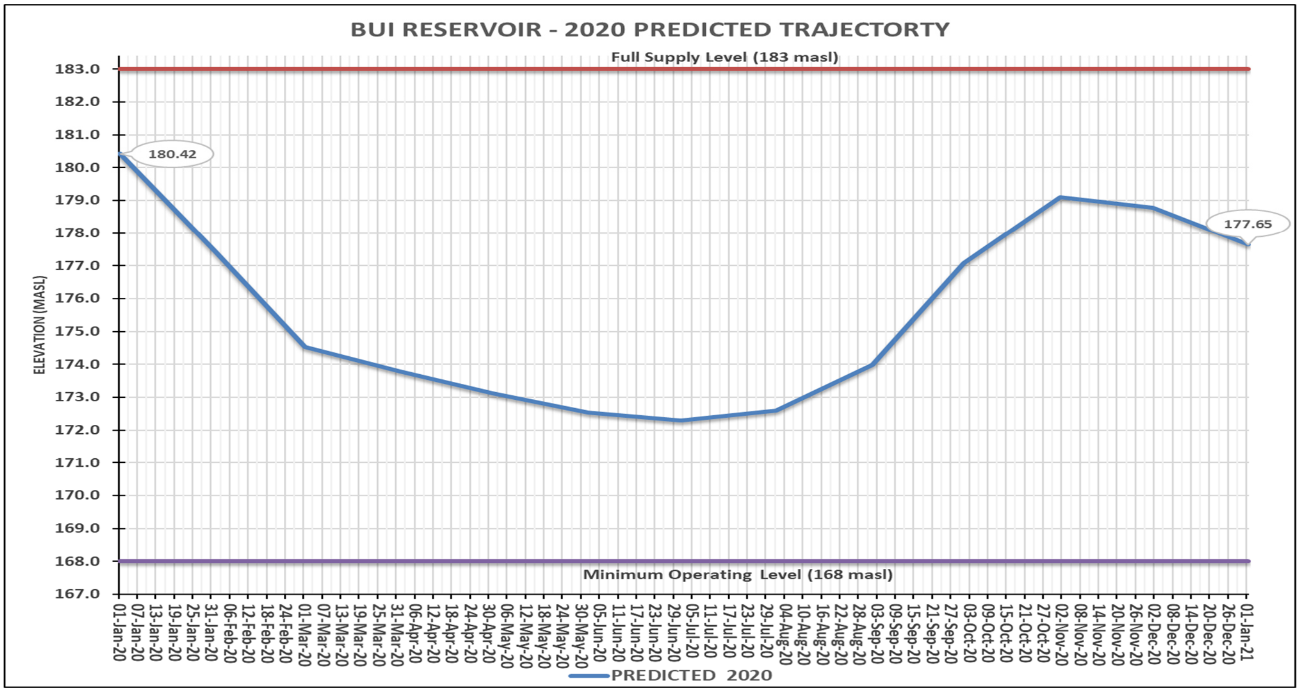


Figure 4.2: 2020 Projected Bui Reservoir Trajectory

4.5 Thermal Power Generation for 2020

The dependable Thermal capacity for 2020 is expected to increase from 3,148 MW (as at January 1, 2020) to 3,292 MW by April 2020 when the Bridgepower Plant is commissioned. The correspondent projected total thermal generation for 2020 is 13,307.96 GWh. The list of existing thermal plants and their projected generation are shown in Table 4.2.

Plant	Installed Capacity (MW)	Dependable Capacity (MW)	Projected Supply (GWh)	Fuel Type
TAPCO	330	300	1,413.72	LCO/Gas
TICO	340	320	1,968.50	LCO/Gas
TT1PP	110	100	97.37	LCO/Gas
KTPP	220	200	237.22	Gas/Diesel
AMERI	250	230	1,292.32	Gas
TT2PP	80	58	5.32	Gas
Total VRA Available Generation	1330	1208	5,014.44	

Plant	Installed Capacity (MW)	Dependable Capacity (MW)	Projected Supply (GWh)	Fuel Type
SAPP 161	200	180	520.22	Gas
SAPP 330	360	350	2,199.68	LCO/Gas
CENIT	110	100	364.12	LCO/Gas
KARPOWERSHIP	470	450	3,174.69	Gas/HFO
AKSA	370	330	157.37	HFO
CENPOWER	360	340	997.13	LCO/Gas
AMANDI	192	190	880.31	LCO/Gas
EARLY POWER	147	144	-	Gas
Total IPP	2209	2084	8,293.52	
Total Supply (GWh)			13,307.96	

Table 4.2: Existing Generation Sources

4.6 New Generation Sources

- ✓ 144 MW Bridgepower Plant located in Tema. The Plant will run on Liquified Petroleum Gas (LPG) or Natural Gas and will be evacuated through the 161kV New Tema Substation.
- ✓ VRA Kaleo and Lawra Solar Power Plants – VRA commenced construction of a 17 MW solar power plant at Kaleo in the Upper West region in September 2019. Commissioning is expected to begin in June 2020 and completed in the First Quarter of 2021.

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
BridgePower	147	144	LCO/Gas
VRA Solar Power	17	0	
TOTAL Committed	164	144	

Table 4.3: Committed Generation Plants for 2020

4.7 Key Assumptions Underpinning the 2020 Demand/Supply Outlook

In developing the 2020 Demand/Supply Outlook, the following key assumptions were made:

4.7.1 Planned Maintenance

The schedule of key generation unit maintenance activities expected to be undertaken in 2020 is shown in Table 4.4.

Plants	Planned Maintenance
Akosombo GS	Unit 1 is scheduled to undergo SCADA Project and annual maintenance from May 15 - June 26, 2020 Unit 2 is scheduled to undergo SCADA Project and annual maintenance from September 28 - November 09, 2020 Unit 3 is scheduled to undergo SCADA Project and annual maintenance from June 28 - August 10, 2020 Unit 4 is scheduled to undergo SCADA Project and annual maintenance from August 12 – September 24, 2020 Unit 5 is scheduled to undergo SCADA Project and annual maintenance from February17 – March 30, 2020 Unit 6 is scheduled to undergo SCADA Project and annual maintenance from April 1 – May 13, 2020
Kpong GS	Unit 1: Quarterly maintenance from Februaruy 03 – 06, June 08 - 11 and October 05 - 08, 2020 Unit 2: Quarterly maintenance from March 9 - 12, July 6 - 9 and November 10 – 13, 2020 Unit 3: Post retrofit inspection for 14 days from April 30 – May 13, 2020 Unit 3: Quarterly maintenance from September 7 – 10, 2020 Unit 4: Major retrofit from January 1 to April 30, 2020
TAPCO	Unit 1: Offline Compressor Water Wash on March 7 – 8, 2020 and June 14 – 15, 2020 Unit 1: Hot Gas Path Inspection from August 2 – 25, 2020 *Unit 2: Bearing replacement and alignment works from January 1 – March 31, 2020. Unit 2: Offline Compressor Water Wash April 29 – 30 and November 29, 2020
TICO	Unit 1: Enhanced Boroscope Inspection on January 18 – 20, 2020 Unit 1: Offline water wash on May 23, August 29 and November 28, 2020 Unit 2: Enhanced Boroscope Inspection on February 15 – 17, 2020 Unit 2: Offline water wash on May 24, August 30 and November 29, 2020 Unit 3: Major inspection on STG from August 15 – September 18, 2020

KTPP	Unit 1: Type B inspection on June 1 – 8, 2020 Unit 2: Type A inspection on February 3 – 7, 2020 Unit 2: Type C inspection on October 1 – 31, 2020
TT1PP	47G1: Offline Compressor Water Wash on March 15, May 21, September 14 and November 17, 2020 47G1: Fuel Nozzles & Boroscope Inspection on May 18 – 21, 2020
CENIT	47G2 is scheduled for Offline water wash on March 15 and December 6, 2020 47G2 is scheduled for Combustion Inspection on August 14 – 21, 2020
TT2PP	Unit 1: Core Engine Swap and main gearbox overhaul July 17 to August 10, 2020 Unit 3: Generator Stator Repair Works January 07 to September 30, 2020 Unit 3: Core Engine Swap and main gearbox overhaul June 24 to July 18, 2020 Unit 5: Type A Maintenance September 03 – 08, 2020 Unit 6: Type A Maintenance September 10 – 15, 2020 Unit 1: Major Plant Inspection (Type A Maintenance) June 14 to 21, 2020
CENPOWER	Unit 1 is scheduled for Combustion Inspection on July 15 - 23, 2020
Bui GS	Unit 1 is scheduled for Quarterly maintenance on January 13 – 17, September 14 – 18, and December 14 – 18, 2020 Unit 1 is scheduled for Level 'A' maintenance from March 2, 2020 to May 30, 2020 Unit 2 is scheduled for Quarterly maintenance on June 15 – 19, August 17 - 21 and November 9 – 13, 2020 Unit 2 is scheduled for Level A maintence on January 1 – 31, 2020 Unit 3 is scheduled for Quarterly maintenance on February 3 – 7, May 4 - 8 and July 20 – 24, 2020 Unit 3 is scheduled for Annual maintenance on October 1 – 30, 2020 Unit 4 is scheduled for Quarterly maintenance on March 9 – 10, May 18 – 19 and October 12 – 13, 2020 Unit 4 is scheduled for Level A maintenance July 1 – 31, 2020 Unit 1 is scheduled for Quarterly maintenance on January 13 – 17, September 14 – 18, and December 14 – 18, 2020 Unit 1 is scheduled for Level 'A' maintenance from March 2, 2020 to May 30, 2020 Unit 2 is scheduled for Quarterly maintenance on June 15 – 19, August 17 - 21 and November 9 – 13, 2020

	Unit 2 is scheduled for Level A maintence on January 1 – 31, 2020 Unit 3 is scheduled for Quarterly maintenance on February 3 – 7, May 4 - 8 and July 20 – 24, 2020
ASOGLI	Unit 2 & 3 scheduled for January 10 – January 23, 2020. (Type C maintenance) Unit 7 & 8 scheduled for March 20 – April 7, 2020 (Type C maintenance) Unit 4 scheduled for July 10 – 23, 2020. (Type C maintenance) Unit 9 & 10 scheduled for October 20 – November 7, 2020. (Type C maintenance) Unit 5 scheduled for November 20 – December 24, 2020. (Type B maintenance) Unit 6 scheduled for December 1 – 14, 2020. (Type C maintenance)
AKSA	Unit 1 is scheduled for ABB Generator L4 maintenance and Engine vibration damper maintenance January 7 – 28, 2020 Unit 2 is scheduled for ABB Generator L4 maintenance and Engine vibration damper maintenance April 7 – 28, 2020 Unit 3 is scheduled for ABB Generator L4 maintenance and Engine vibration damper maintenance May 7 – 28, 2020 Unit 4 is scheduled for ABB Generator L4 maintenance and Engine vibration damper maintenance June 7 – 28, 2020 Unit 5 is scheduled for ABB Generator L4 maintenance and Engine vibration damper maintenance July 7 – 28, 2020 Unit 4 is scheduled for WARTSILA engine 36K mechanical maintenance from February 10 to March 5, 2020

Table 4.4: 2020 Generation Equipment Maintenance Schedule

4.7.2 Natural Gas Supply

In 2020, priority is given to maximise the use of natural gas for generation. Expansion works are ongoing to increase the capacity of the gas infrastructure at Tema from 140 mmscf/day to 235 mmscf/day. This is expected to be completed by April 2020. This will allow up to approximately 120 mmscf/day to be transported from the West to the East.

The expected volumes of gas from the two main Ghana fields are as follows:

- ENI: 180 – 200 mmscf/day;
- Jubilee: 100 – 120 mmsfc/day.

On the basis of these, in 2020 it is expected that a total of about 300 mmscf/day of gas will be supplied by Ghana Gas fields. This could go up to 320 mmscf/day, while a total of about 70 mmscf/day will be supplied by Nigeria. Hence total gas supply from Ghana fields and Nigeria is estimated to be 370 mmscf/day. Gas pipeline pigging works by WAGP is expected to start from January 20, 2020 for a period of up to 60 days. In this Supply Plan it is assumed that the pigging will continue till end of March 2020. During that period there will be no gas supply at Tema, however 70 mmscf/day of gas will be supplied by WAGP at Takoradi.

It is assumed that Reverse Flow from Takoradi to Tema through the WAGP will be 60 mmscf/day up to April 2020 and increase to 120 mmscf/day from May 2020. Natural Gas availability and thermal plant availability in the West could limit the flows to 30 mmscf/day.

In addition, the Tema LNG Project is expected to commence supply by the fourth quarter of 2020. Expected volumes from Tema LNG in 2020 is 75MMscfd. This would add to the diversity of gas sources and significantly improve gas supply reliability.

a. West to East Reverse Flow

The completion of the Takoradi–Tema Interconnection Project (TTIP) has allowed transportation of domestic gas from gas producing fields in the West for use at Thermal Power plants in Tema using the West African Gas Pipeline. So far this has made it possible for Ghana Gas to supply up to about 60 mmscf/day of natural gas to power plants in the Tema Generation Enclave

b. Fuel Price

The following assumptions were made on price of fuel delivered:

- ✓ Ghana Gas –.US$ 6.08/MMBtu
- ✓ Nigeria Gas – US$ 7.01/MMBtu
- ✓ Delivered LCO – US$ 85/barrel
- ✓ Delivered HFO – US$ 119/bbl.

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
OCTP	128	128	128	130	130	130	130	130	130	130	130	130
Jubilee / TEN	87	87	87	125	125	125	125	125	125	125	25	125
N-GAS	80	80	80	30	30	30	30	30	30	30	30	30
LNG	-	-	-	-	-	-	75	75	75	75	75	75
Total	295	295	295	285	285	285	360	360	360	360	360	360

Table 4.5: 2020 Monthly Gas Delivery Profile (MMscfd)

4.8 Demand - Supply Analysis

This sub-section analyses the demand – supply balance for 2020. The assumptions underpinning the demand - supply projections for the year are as outlined in section 4.7 above. Table 4.6 shows the monthly energy generation from all the Generating Plants. The analysis of the monthly energy balance shows supply surplus in 2020. Therefore, security constrained merit order criteria was employed to determine which plants are dispatched on monthly basis.

Customer Category	Energy (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Demand													
Domestic Consumption	16,712.6	1,408	1,326	1,461	1,435	1,437	1,334	1,325	1,332	1,319	1,411	1,437	1,489
VALCO	1,229.8	52	84	104	108	112	108	112	112	108	112	108	112
Export (CEB+SONABEL+CIE)	1,652.1	158	157	160	133	137	132	127	114	112	129	134	159
Projected Energy Consumption	19,594.44	1,618	1,566	1,725	1,675	1,686	1,573	1,563	1,558	1,539	1,651	1,680	1,759
Sources of Supply													
Akosombo	4,646	495	431	393	363	375	363	375	375	363	375	363	375
Kpong GS	819	63	72	80	70	68	65	68	68	65	68	65	68
TAPCO	1,414	91	79	84	81	84	81	167	89	162	167	162	167
TICO	1,968	100	176	156	189	195	189	195	98	91	195	189	195
TT1PP	97	38			32	27	-	-	-	-	-	-	-
KTPP	237	10		38	72	74	43	-	-	-	-	-	-
TT2PP	5	5			-	-	-	-	-	-	-	-	-
VRA Solar	3	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.2	0.3
Imports From Cote d'Ivoire	-	-	-	-	-	-	-	-		-	-	-	-
Total VRA Generation	9,190	803	758	752	807	824	741	805	629	681	805	779	805
Bui GS	764	81	120	110	75	42	38	39	39	41	45	65	67
SAPP 161	520		-	92	52	54	52	37	54	52	54	42	33
SAPP 330	2,200	149	-	147	214	221	214	221	221	214	162	214	221
CENIT	364	46	-	77	74	77	74	-	-	-	-	-	15
AMERI Power Plant	1,292	134	130	139	121	125	121	-	124	75	94	103	125
Karpower Barge	3,175	248	266	85	259	268	259	268	268	259	268	259	268
AKSA	157	93	64		-	-	-	-	-	-	-	-	-
CENPOWER	997	59	224	34	-	-	-	89	120	116	120	116	20
AMANDI	880		-	86	68	71	68	99	99	96	99	96	99
Early Power	-												
BxC Solar		2	2	2	2	2	2	2	2	2	2	2	2
Meinergy	27	2	2	2	2	2	2	2	2	2	2	2	2
Safi Sana	1	0	0	0	0	0	0	0	0	0	0	0	0
Total Supply (GWh)	19,594	1,618	1,566	1,725	1,675	1,686	1,573	1,563	1,558	1,539	1,651	1,680	1,759

Table 4.6: 2020 Demand/Supply Outlook

The above energy supply schedule is illustrated graphically in Figure 4.3 showing the 'percentage share of each generation type' (ie. Hydro, Thermal and Renewable). The Chart indicates that, in 2020, thermal generation will constitute approximately 68.00% of projected total generation whilst hydro generation and renewables (mostly solar PV) would constitute some 31.97% and 0.03% respectively. This indicates the diminishing dominance of hydro in Ghana's overall generation mix.

The high penetration and increasing dominance of thermal generation in the overall generation mix could have serious implications for the sector for the following reasons;

- ✓ Since the tariffs are cedi-denominated and the utilities purchase fuel and other consumables in mostly United States Dollars (USD), any major depreciation of the Ghana Cedi against the major foreign currencies, particularly the USD, would throw the finances of the utilities into disarray.
- ✓ The thermal plants are predominantly gas-based, any disruptions in gas supply would have dire consequences on the power supply situation in the country.

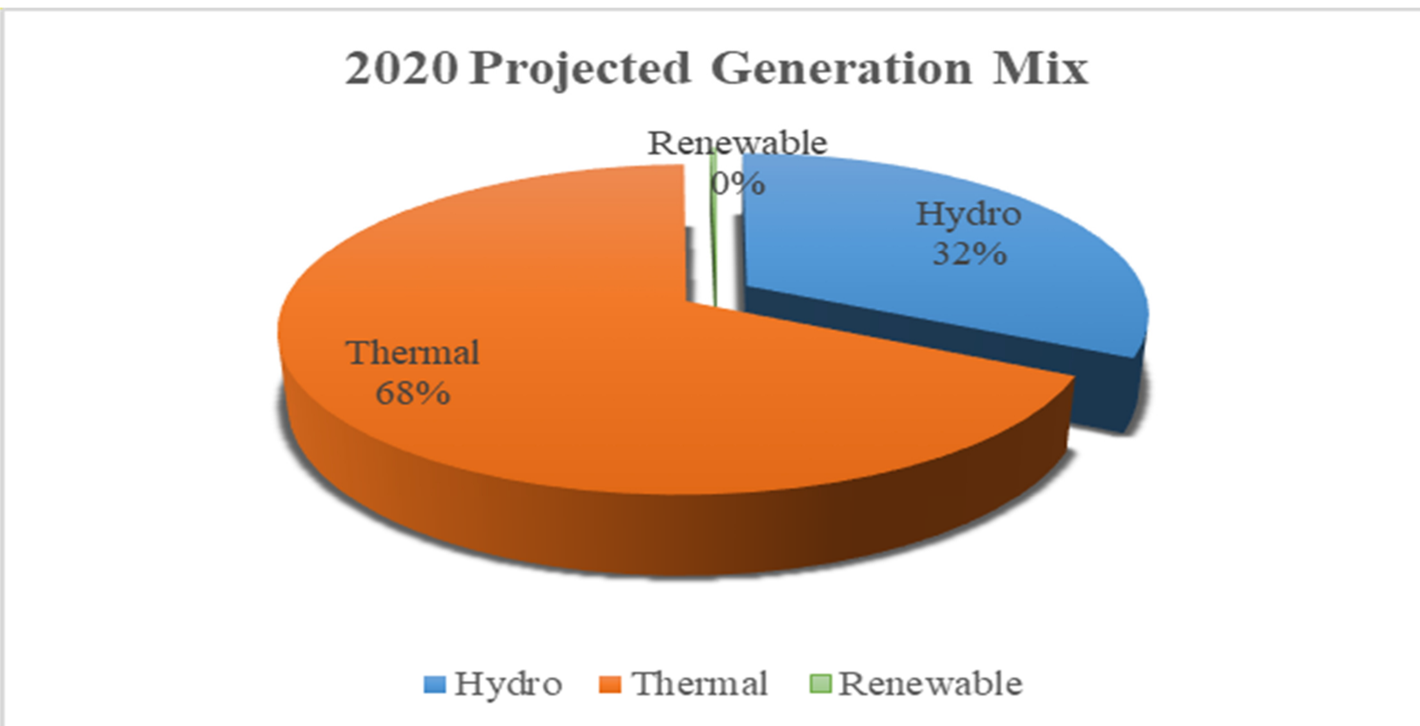


Figure 4.3: Contribution of Supply by Generation Types

4.9 Projected Capacity Situation

The projected monthly Supply capacity levels, taking planned units maintenance and Fuel Supply Systems in to consideration is shown in Table 4.7.

Customer Category	2020 Proj. Peak (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	2635.15	2,519	2,537	2,594	2,613	2,574	2,549	2,424	2,442	2,402	2,586	2,594	2,635
VALCO	150.00	70	120	140	150	150	150	150	150	150	150	150	150
Export (CEB+SONABEL)	330.00	330	330	330	330	330	320	320	320	320	320	330	330
Projected System Demand	3115.15	2,919	2,987	3,064	3,093	3,054	3,019	2,894	2,912	2,872	3,056	3,074	3,115
Generation Sources:	Dependable Gen. Capacity (MW)												
Akosombo	*900*	*900*	*900*	*900*	*750*	*750*	*750*	*750*	*750*	*750*	*750*	*750*	*750*
Kpong GS	*140*	*105*	*105*	*105*	*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*	*140*
TAPCO	*300*	*150*	*150*	*150*	*300*	*300*	*300*	*300*	*150*	*150*	*300*	*300*	*300*
TICO	*320*	*320*	*320*	*320*	*320*	*320*	*320*	*320*	*200*	*200*	*320*	*320*	*320*
TT1PP	*100*	-	-	-	*100*	*0*	*100*	*0*	*100*	*0*	*100*	*0*	*100*
KTPP	*200*	-	-	*100*	*0*	*100*	*0*	*100*	*0*	*100*	*0*	*100*	*0*
TT2PP	*58*			*45*	*45*	*45*	*45*	*45*	*45*	*45*	*45*	*45*	*45*
AMERI Power Plant	*230*	*230*	*230*	*230*	*230*	*230*	*230*	*230*	*230*	*230*	*230*	*230*	*150*
T3	*0*												
VRA Solar	*2.5*												
Imports From Cote d'Ivoire	*0*	-	-	-	-	-	-	-	-	-	-	-	-
Total VRA Available Generation	2,248	1,705	1,705	1,850	1,885	1,885	1,885	1,885	1,615	1,615	1,885	1,885	1,805
Bui GS	*345*	*330*	*330*	*330*	*220*	*220*	*220*	*220*	*220*	*220*	*220*	*220*	*220*
Bui Min Unit	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*
SAPP 161	*180*	*0*	*0*	*180*	*180*	*180*	*180*	*150*	*180*	*180*	*180*	*180*	*180*
SAPP 330	*350*	*0*	*0*	*350*	*350*	*350*	*350*	*350*	*350*	*230*	*230*	*350*	*350*
CENIT	*100*	*0*	*0*	*0*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*
Karpower Barge	*450*	*450*	*450*	*450*	*450*	*450*	*450*	*450*	*450*	*450*	*450*	*450*	*450*
AKSA	*330*	*330*	*330*	*330*	*330*	*330*	*330*	*330*	*330*	*330*	*330*	*330*	*330*
CENPOWER	*340*	*325*	*325*	*325*	*325*	*325*	*325*	*325*	*325*	*325*	*325*	*325*	*325*
Amandi	*192*	*190*	*0*	*0*	*190*	*190*	*190*	*190*	*190*	*190*	*190*	*190*	*190*
Early Power	*144*	*0*	*0*	*0*	*86.4*	*86.4*	*86.4*	*144*	*144*	*144*	*144*	*144*	*144*

Customer Category	2020 Proj. Peak (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trojan	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Genser	*60*	*60*	*60*	*60*	*60*	*60*	*60*	*60*	*60*	*60*	*60*	*60*	*60*
Safi Sana	*0.1*												
Meinergy	*20*												
Solar (Central Region)	*20*												
Total Available Generation (MW)	4,743	3,394	3,204	3,879	4,180	4,180	4,180	4,208	3,968	3,848	4,118	4,238	4,158
Surplus/deficit (MW)	1,628	475	217	815	1,087	1,126	1,161	1,314	1,056	976	1,062	1,164	1,043
Required Reserve (18%)	561	525	538	552	557	550	544	521	524	517	550	553	561
Actual Reserve Margin %		16%	7%	27%	35%	37%	38%	45%	36%	34%	35%	38%	33%

Table 4.7: Projected Monthly Capacity Situation for 2020

The analysis of the above monthly demand and supply situation shows positive monthly generation reserve margins of up to 45% in 2020, as such, there is no need to install additional generation plants. However there could be unforeseen fuel supply challenges that could cause periodic shortages in supply. With such a considerably high reserve capacity, it is anticipated that some existing Power Plants would not be dispatched.

4.10 Fuel Requirement

Currently, the main fuel for thermal power generation is natural gas. However, some generating plants such as AKSA will run on Heavy Fuel Oil (HFO) whiles Bridgepower runs on LPG. Light Crude Oil (LCO) and Diesel (DFO) remain as backup fuel for some plants.

The estimates of quantity and cost of fuel requirement in 2020 is indicated in Table 4.8.

PLANT	LCO (Barrels)	Natural Gas (MMBtu)	HFO (Barrels)
T1		11,569,743	
T2		16,010,601	
TT1PP		1,066,827	
KTPP		2,679,931	
TT2PP		68,655	
AMERI		13,036,789	
TOTAL VRA		52,225,328	
Karpower Barge		25,480,157	
SAPP 161		4,744,538	
SAPP 330		17,063,782	
CENIT		3,968,932	
AMANDI		10,808,570	
CENPOWER	136,147	495,733	
AKSA			212,858
TOTAL IPP	136,147	62,561,712	212,858
TOTAL (VRA&IPP)	136,147	114,787,040	212,858

Table 4.8: Summary of Annual Fuel Requirements

The summary of major fuel requirements for 2020 is as follows:

- ✓ **Natural Gas:** Based on the assumed gas supply from Nigeria and Ghana, the total natural gas consumption is projected to be about 114 million MMBtu. VRA plants will use about 52.2 million MMBtu and IPPs some 59.8 million MMBtu.

- ✓ **HFO:** The AKSA Plant is scheduled to operate on HFO through the year. Therefore, an estimated 1,062,464 barrels would be required by AKSA.
- ✓ **LCO:** There would be no significant requirement for LCO in 2020 due to anticipated high volumes of gas from Sankofa, Jubilee and TEN fields. A total of about 136,147 barrels of LCO will be required.

4.10.1 Monthly Fuel Requirement

The breakdown of Monthly fuel requirements and their associated costs are as shown in Table 4.9 below.

Fuel Required	Fuel Type	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
VRA Thermal Plant															
TAPCO	Gas	MMBtu	743,262	643,255	684,992	662,896	684,992	662,896	1,369,985	725,912	1,325,792	1,369,985	1,325,792	1,369,985	11,569,743
TICO	Gas	MMBtu	815,374	1,433,920	1,270,439	1,536,401	1,587,642	1,536,401	1,587,642	793,821	737,277	1,587,642	1,536,401	1,587,642	16,010,601
TT1PP	Gas	MMBtu	421,389	-	-	345,186	300,252	-	-	-	-	-	-	-	1,066,827
KTPP	Gas	MMBtu	108,569	-	432,217	813,418	840,532	485,196	-	-	-	-	-	-	2,679,931
TT2PP	Gas	MMBtu	68,655	-	-	-	-	-	-	-	-	-	-	-	68,655
AMERI Power Plant	Gas	MMBtu	1,354,806	1,312,962	1,403,511	1,222,413	1,263,160	1,222,413	-	1,249,592	754,344	950,845	1,039,585	1,263,160	13,036,789
IPP															
SAPP 161	Gas	MMBtu	-	-	837,234	472,791	488,551	472,791	334,283	488,551	472,791	488,551	386,113	302,882	4,744,538
SAPP 330	Gas	MMBtu	1,156,396	-	1,139,407	1,661,635	1,717,023	1,661,635	1,717,023	1,717,023	1,661,635	1,253,348	1,661,635	1,717,023	17,063,782
CENIT	Gas	MMBtu	499,656	-	838,733	811,679	838,733	811,679	-	-	-	-	-	168,451	3,968,932
Karpower Barge	Gas	MMBtu	1,989,573	2,136,690	2,284,048	2,080,347	2,149,692	2,080,347	2,149,692	2,149,692	2,080,347	2,149,692	2,080,347	2,149,692	25,480,157
AKSA	HFO	barrels	126,414	86,445	-	-	-	-	-	-	-	-	-	-	212,858
CENPOWER LCO/Gas	LCO	barrels	92,580	350,401	52,751	-	-	-	-	-	-	-	-	-	495,733
	Gas	MMBtu	-	-	-	-	-	-	691,691	932,279	902,205	932,279	902,205	932,279	5,292,938
AMANDI	Gas	MMBtu	-	-	638,228	510,583	527,602	510,583	738,643	738,643	714,816	738,643	714,816	738,643	6,571,200
Early Power	Gas	MMBtu	-	-	-	-	-	-	-	-	-	-	-	-	-

Estimated Fuel Cost														
Total VRA WAGP - Cost @ US$7.01/MMBTU	Gas	MMUS$	4	-	3	8	8	3	-	-	-	-	-	-	27
Total VRA GNGC- Cost @US$6.08/MMBTU	Gas	MMUS$	18	21	20	21	21	21	18	17	17	24	24	26	247
Total VRA Fuel Cost		MMUS$	22	21	23	29	29	24	18	17	17	24	24	26	274
IPP Fuel Cost															
Total IPP LCO - Cost @ US$85/bbl	LCO	MMUS$	8	30	4	-	-	-	-	-	-	-	-	-	42
Total IPP HFO - Cost @ US$119/bbl	HFO	MMUS$	15	10	-	-	-	-	-	-	-	-	-	-	25
Total IPP GNGC- Cost @US$6.08/MMBTU	Gas	MMUS$	15	13	28	24	24	24	24	26	25	26	25	26	280
Total IPP WAGP - Cost @ US$7.01/MMBTU	HFO	MMUS$	8	-	8	12	12	12	12	12	12	9	12	12	120
Total IPP Fuel Cost		MMUS$	46	53	40	35	36	35	36	38	37	35	36	38	467

Table 4.9: Monthly fuel requirements and associated costs

4.11 Estimates of Fuel Cost

The breakdown of the estimated cost of fuel for running all the Thermal Plants in 2020 is presented in the Table 4.10. Based on the assumed unit prices, the total estimated fuel cost for the Thermal Plants is US$ 740.81 Million. This translates into an approximate monthly average of US$ 61.73 Million.

This total cost comprises US$ 273.7 Million or approximately US$ 22.8 Million per month for the VRA.

Type of Fuel	Cost (MillionUS$)
VRA - LCO	0
VRA - GAS	273.70
TOTAL VRA FUEL COST	273.70
IPP - LCO	42.14
IPP - GAS	399.65
IPP - HFO	25.33
TOTAL IPP FUEL COST	467.12
TOTAL VRA & IPP COST	740.81

Table 4.10: **Breakdown of Estimated Fuel Cost for 2020**

Chapter 5

NATIONAL INTERCONNECTED TRANSMISSION SYSTEM

5 NATIONAL INTERCONNECTED TRANSMISSION SYSTEM

5.1 State of the Ghana National Interconnected Transmission System

The National Interconnected Transmission System (NITS) transmits electricity at 69 kV, 161 kV, 225 kV and 330 kV voltage levels. Ghana is interconnected with Côte d'Ivoire and Burkina at 225 kV whiles the interconnections with Togo are at 161 kV and 330 kV. The 330 kV interconnection with Togo was constructed as part of the implementation of the WAPP.

The state of the NITS as at end of year 2019 is as follows:

- The total circuit length is 6,472.23 km;
- The total number of Bulk Supply Points (BSPs) is 65;
- Total number of load transformers at BSPs is 123;
- Total transformation capacity is 8,959.6 MVA;
- Total capacity fixed capacitive compensation devices is 309.8 MVAr;
- Total capacity of reactors is 230 MVAr;
- One 40 MVAr Static Synchronous Compensator (STATCOM[6]) installed at the Tamale substation.

The fixed capacitors, reactors and the STATCOM complement the generating units in providing the reactive power requirements on the NITS in order to maintain voltages within normal levels and minimize overall transmission losses.

The System Control Centre (SCC) in Tema is responsible for the real time dispatch (monitoring, coordination and control) of the Ghana Power System as well as cross-border power exchanges with neighboring countries. SCC is equipped with a Network Manager System (NMS), which is the main tool used to monitor and control dispatch operations on the Ghana Power System.

5.2 Transmission Line, Feeder and Substation Availability

The criteria used for ensuring high transmission Line, Feeder and Substation availability are as presented below:

[6] STATCOM is regulating device used on alternating current electricity transmission networks. It is based on a power elecrtronics voltage source converter and can act as either a source or sink of reactive AC power to an electricity network.

- ✓ All existing transmission lines are expected to be in service in 2020 to ensure transmission of electricity from the generation stations to the Bulk Supply Points across the nation and to enable the execution of power exchanges with neighboring countries.
- ✓ Maintenance work on transmission lines and substations is to be organized in order not to significantly affect power supply to customers except for single transformer substations and consumers served on radial lines.

5.3 Steady State Network Analysis

Network analyses are carried out as part of the process for establishing a Supply Plan in order to determine transmission line loadings, substation bus voltages and network loss levels across the transmission network. In particular, the analyses seek to determine:

- ✓ Transmission line constraints to the evacuation of power from the generating stations to the Bulk Supply Points;
- ✓ The ability of the entire power system to withstand an N-1 contingency (i.e. forced outage of a single network element) e.g. transmission line, generator, transformer, etc;
- ✓ Reactive power demand on the NITS and the level of VAr generation from the generating units;
- ✓ Adequacy of reactive power compensation in the transmission network in achieving acceptable system voltages;
- ✓ Overall stability of the Ghana Power System;
- ✓ Overall transmission system losses during peak and off-peak periods;
- ✓ The impact of locational imbalance in generation resources.

5.3.1 Technical Adequacy Criteria

The following criteria were used to assess the performance of the system under both normal and contingency conditions.

a. Normal Condition

Parameter	Range
Bus Voltages	0.95 pu to 1.05 pu
Transmission Line Power flows	not exceeding 85% of Line Capacity
Transformers	Not exceeding 100% *(nameplate rating)*
Generators	Not exceeding their Capability Curves

Table 5.1: Criteria, normal condition

b. Contingency Conditions

Parameter	Range
Bus Voltages	0.90 pu to 1.10 pu
Transmission Line Power flows	not exceeding 100% of Line Capacity
Transformers	Not exceeding 120% of Nameplate Rating
Generators	Not exceeding their Capability Curve

Table 5.2: Criteria, contingency condition

c. Technical Analysis

Load Flow analyses were carried out to determine the transfer capability and assess the level of reliability of the transmission network to evacuate power from the generation centres to the various Bulk Supply Points.

Loadings on transmission lines and other power equipment are monitored to determine whether there are any limit violations. Also overall transmission system losses are compared to determine the impact of generation and transmission investments on grid performance.

d. Assumptions and Development of a Base Case

The study was carried out on the 2020 network model as highlighted in Section 3 of this report.

e. Generation Additions

The first phase of Early Power Plant consisting of 147 MW located in Tema is expected to be commissioned into service in the first quarter of 2020.

f. Transmission Additions

The following transmission lines under construction are modeled to assess their impact on the grid:

Transmission Lines

- ✓ 330 kV, Anwomaso – Kintampo Transmission line Project.
- ✓ 161 kV, Volta – Accra East – Achimota Transmission line reconstruction

5.3.2 Summary of Results for the Steady State Network Analysis

The following scenarios were studied:

- ✓ Q1 Maximum West Dispatch Scenario - Voltage Analysis
- ✓ Q3 System voltages during periods of low demand
- ✓ Q4 Optimal Dispatch Scenario - Voltage Analysis

a. 2020 Q1 Maximum West Dispatch Scenario

In this section we analyse the expected first quarter 2020 Network conditions, assuming a domestic peak demand of **2,623.1 MW**, one pot line in operation at VALCO (**75MW**). Scheduled exports to neighbouring countries include **140 MW** to CEB and **150 MW** to SONABEL. The Ghana peak demand is **3,070.2 MW.** The load levels for the various BSPs were modelled based on the load forecast for first quarter 2020. The Case also assumes the current status of some major projects would remain the same, i.e. the 330kV Aboadze – Anwomaso – Kintampo – Adubiyili – Nayagnia in service, with the 330 kV Anwomaso-Kintampo section not energized and the 161kV Volta-Achimota-Mallam line project also not completed.

In the first quarter of 2020, the West African Gas Pipeline Company (WAPCo) plans to carry out an Intelligent Pigging exercise on the West African Gas Pipeline. The pigging operation is planned to start on January 20, 2020 and projected to last for a maximum sixty (60) days. In order for the effective execution of the pigging exercise, it is planned to curtail gas supply from the WAGP to Thermal Power Plants located in the Eastern Generation Enclave in Tema. The pigging exercise is therefore going to have a very significant impact on power generation from the enclave such that most Thermal Plants would be inoperable. In view of this, the system operator expects to utilise more generation from the Western Generation Enclave in Aboadze to supply customer loads and to ensure consumption of gas from the WAGP during the period of pigging.

CASE GENERATION	PLANT OUTPUT (MW)
Eastern Enclave (Tema)	
AKOSOMBO GS	722.4
KPONG GS	112.8
Sunon Asogli Power Plant (161kV)	0
Sunon Asogli Power Plant Phase (330kV)	0
Kpone Thermal (KTPP)	0

CASE GENERATION	PLANT OUTPUT (MW)
AKSA Power	300
CENPower	300
CENIT	0
TT1PP	0
TT2PP	0
Total	1,514.7
Western Enclave (Aboadze/Takoradi)	
TAPCo & TICo	470
Karpower (Tema)	450
AMERI	225
Amandi	190
Total	1,335
Northern Generation	
Bui Hydro	300
Total	300
TOTAL SYSTEM GENERATION	3,070.2

Table 5.3: Generation dispatch- 2020 Q1, High West Dispatch

Results of Analysis

Under this dispatch mode, the results show some bus voltage violations at major BSPs on the grid. The stations violating voltage limits include: 161kV Achimota (149.32kV, 0.93 P.U.), Accra East (151.92kV, 0.94 P.U.), Winneba (147.17kV, 0.91 P.U.), Mallam (146.36kV, 0.91 P.U.) and Accra Central (147.27kV 0.91 P.U.). Transmission line loadings on some major lines also exceeded the line loading limit criteria. These include: the 161 kV Volta – Accra East, 161 kV Volta – Achimota and 161kV Tarkwa – New Tarkwa lines recording **110.7%, 90.1%** and **88.2%** respectively. The 161 kV Kumasi – Anwomaso is also observed to be heavily loaded at **80%** of its line capacity. The overall transmission losses registered is **151.1 MW** representing **4.92** % of total generation (**3,070.2MW).**

From the analysis, the maximum evacuation limit for the **Western Generation Enclave (Aboadze)** is **1,350MW** whereas that for the **Eastern Generation Enclave (Tema)** is **1,520 MW.**

Key Observations

1. A high west dispatch scenario shows poor system performance on the basis of transmission losses and voltages. This is primarily due to the nature of the Ghana power system where majority of the load centres are situated in the east.

2. From the analysis, the negative impact on transmission losses is due to the flow of significant levels of reactive power across the 161kV coastal line (Aboadze – Winneba and Aboadze – Cape Coast) corridor and the 161kV Volta – Accra East – Achimota corridor in order to serve the reactive demand of load centres in the east. Due to insufficient reactive energy supply via these lines, voltages at Achimota and Mallam substations deteriorate.
3. From the analysis, the Aboadze – Cape Coast – Winneba and the Volta – Achimota transmission line corridors contribute **11.5MW (7.6%)** and **13MW** (**8.6**%) respectively to the total system losses of **151 MW** observed.
4. The autotransformers at Anwomaso substation that interconnect the 330kV and the 161kV networks are heavily loaded at **89%** of their rating.
5. At the Eastern Enclave, it is observed that transmission lines in the Volta – Achimota corridor record an average loading of **100%** of their rated line capacity. This is highly undesirable hence GRIDCo needs to be adequately resourced to expedite delayed projects to upgrade this very critical transmission line corridor that primarily delivers power to the Capital and its environs.

   Additionally, the Accra 4th Bulk Supply Point (A4BSP) substation at Pokuase sponsored by MIDA and currently under construction will also ease power delivery to the Capital and therefore its completion should not be delayed.

6. Lastly, from the analysis, it is advisable to run all three units of the Bui hydro plant during the peak periods especially during the period of pigging. This is because running less than three units allows for more power to flow from down south towards the northern parts of the grid. In this situation, there is an observed excessive loading (99.4%) of the 161kV Kumasi-Anwomaso line as well as the overload (100.3%) of the 2X200MVA 330/161kV autotransformers at the 330kV Anwomaso substation. These observed voltage deteriorates system voltages up north of the grid.

b. System Voltages during periods of low demand - 3rd Quarter

The rainy season normally occurs in the third quarter of the year. Typically, system demand is low during these periods. In the third quarter of 2019, there were incidences of extremely high system voltages due to low system demand. A study was therefore carried out to assess possible voltage level excursions during the same period in 2020.

The analysis was based on a domestic peak of **1,551.3 MW** and 2 pot lines in operation at **VALCO** (**150MW**). Power exports to **CEB** and **SONABEL** were projected at **140 MW** and **150 MW** respectively for the analyses whereas Ghana system peak was **1,920.4 MW**.

Two scenarios were considered for this analysis namely:

i. **Scenario 1** – Low system demand with majority of the reactors available
ii. **Scenario 2 -** Low system demand with some reactors unavailable.

Scenario 1

The results of this scenario show that if majority of the reactors i.e. Adubiyili- 25 MVAr and 50 MVAr, Nayagnia- 25 MVAr and the Tamale- 40 MVAr SVC are available during low system demand, the system is capable of regulating system voltages to be within the voltage limit criteria. The average recorded voltage is 1.00 P.U. in the northern part of the grid.

Scenario 2

The results of this scenario show that if the above-mentioned reactors i.e. Adubiyili- 25 MVAr and 50 MVAr, Nayagnia- 25 MVAr and the Tamale- 40 MVAr SVC are not available during low system demand, the system is unable to control the system voltage levels to be within the voltage limits. The average recorded voltage is 1.17 P.U. in the northern part of the grid.

There are no observed line loading and system voltage violations. Transmission losses recorded is **69.2 MW**, representing **3.62** % of total system generation of **1,910.2 MW**.

SUBSTATION	kV	PU	kV	PU
	scenario 1		scenario 2	
AKOSOMBO	167.97	1.04	169.1	1.05
VOLTA 161	162.3	1.01	163.08	1.01
ACHIMOTA 161	160.35	1	161.2	1
TAKORADI 161	165.07	1.03	166.34	1.03
PRESTEA 161	163.54	1.02	167.1	1.04
KUMASI 161	163.18	1.01	171	1.06
NKAWKAW 161	163.85	1.02	168.18	1.04
TAFO 161	166.14	1.03	168.72	1.05
ASAWINSO 161	163.11	1.01	173.19	1.08
TAMALE 161	162.61	1.01	190.3	1.18
BUI 161	164.22	1.02	180.97	1.12
VOLTA 330	337.05	1.02	338.76	1.03

PRESTEA 225	229.58	1.02	233.97	1.04
ADUBILIYI 330	332.91	1.01	392.96	1.19
NAYAGNIA 330	331.55	1	389.55	1.18
NAYAGNIA 225	225.99	1	263.88	1.17
NAYAGNIA 161	161.73	1	189.2	1.18
ABOADZE 330	338.65	1.03	341.72	1.04
KINTAMPO 330	335.58	1.02	385.96	1.17
K2BSP 330	337.14	1.02	349.02	1.06

Table 5.4 Substation Voltages for scenario 1 and 2

There are no observed line loading and system voltage violations. Transmission losses recorded is **71.6 MW**, representing **3.73%** of total system generation of **1,920.4 MW**.

c. 2020 Q4 Optimal Dispatch Scenario

Construction work on the Anwomaso – Kintampo section of the 330kV Aboadze – Anwomaso – Kintampo – Adubiyili – Nayagnia transmission line circuit as well as the161kV Volta – Achimota – Mallam line upgrade works are likely to be completed by fourth quarter 2020.

Analyses were carried out to determine the impact these two major projects would have on the performance of the NITS. The analysis was based on a domestic peak of 2,589 MW and 2 pot lines in operation at VALCO (150MW). Power exports to CEB and SONABEL were projected at 140 MW and 150 MW respectively for the analyses whereas Ghana system peak was 3,155 MW. Generation dispatch is simulated optimally to obtain the minimum level transmission losses.

CASE GENERATION	PLANT OUTPUT (MW)
Eastern Enclave (Tema)	
AKOSOMBO GS	777.2
KPONG GS	112.8
Sunon Asogli Power Plant (161kV)	60
Sunon Asogli Power Plant Phase (330kV)	240
Kpone Thermal (KTPP)	0
AKSA Power	300
CENPower	260
CENIT	0
TT1PP	0
TT2PP	0
Total	1,747.2
Western Enclave (Aboadze/Takoradi)	
TAPCo & TICo	420

CASE GENERATION	PLANT OUTPUT (MW)
Karpower	450
AMERI	225
Amandi	100
Total	1,195
Northern Generation	
Bui Hydro	210
Total	210
TOTAL SYSTEM GENERATION	3,155

Table 5.5: Generation dispatch- 2020 Q4

Results of Analysis

Few voltage violations are observed at some nodes such as: the 161kV Winneba (144.92kV, 0.90P.U.), 161kV Achimota (146.72kV, 0.91P.U.), 161kV Accra East (149.38kV, 0.93P.U.), 161kV Mallam (143.76kV, 0.89P.U.) and the 161kV Accra Central (144.66kV, 0.90P.U.). Another issue of concern is the heavy loading observed on the 161 kV Tarkwa – New Tarkwa line recording **83%** of its line capacity. Overall transmission losses of **124.3 MW** is recorded for this scenario, representing **3.94%** of total system generation of **3,155 MW**.

Key Observations

The results above indicate improved performance of the grid though there are few observed operational violations.

However, if the projects mentioned above are not in place by the fourth quarter of 2020, there will be serious overloading and voltage violations in some corridors on the NITS. Table 5.6 and 5.7 provide details of the violations in this scenario.

FROM BUS	TO BUS	MW	% LOADING
VOLTA 161	ACHIMOTA 161	175.9	96.2
VOLTA 161	ACCRA EAST 161	217.9	117.4
TARKWA 161	NEW TARKWA 161	157.9	92.9
KUMASI 161	ANWOMASO 161	336.0	92.3

Table 5.6: Transmission line loadings-2020 Q4

SUBSTATION NAME	VOLTAGE	
	kV	PU
ACHIMOTA 161	146.96	0.91
WINNEBA 161	144.61	0.90
DUNKWA 161	149.12	0.93

SUBSTATION NAME	VOLTAGE	
	kV	PU
KUMASI 161	148.80	0.92
ASAWINSO 161	143.49	0.89
MALLAM 161	143.89	0.89
AYANFURI 161	146.39	0.91
ACCRA EAST 161	149.73	0.93
OBOTAN 161	142.98	0.89
ACGIS 161	144.82	0.90

Table 5.7: Substation voltage violations-2020 Q4

Transmission losses will increase to **177.73 MW** (5.54%) of total system generation of **3,208.9MW.**

This scenario and the previous indicate that as system demand increases, there is a need to utilize more power beyond the predominant 161kV system in the Ghana grid. Steps should rather be taken to utilize power at 330kV to serve loads directly. Also there should be a deliberate effort to reinforce certain key substations in the grid with a 330kV voltage support to improve stability of the system and reduce transmission losses. (e.g. 330/161kV A4BSP- Mallam transmission line link, 330kV Dunkwa 2 substation and 330/161kV Nkawkaw 2-Nkawkaw 1 link).

d. Contingency Analysis (Steady-State)

This section considers single element contingencies using the following cases (i.e. Optimal, High Eastern and High Western generation dispatch scenarios). Simulations were carried out to determine the most critical contingencies on the power system that cause severe transmission line overloads or extreme system voltage violations.

e. 2020 Optimal Dispatch Contingencies

From the simulations, eight (8) contingencies were considered critical. Contingencies that result in line overloads in order of decreasing severity are as listed below:

- Loss of the 330 kV Aboadze – Anwomaso line
- Loss of the 330 kV Anwomaso – Kintampo line
- Loss of the 330 kV Kintampo – Adubiyili line

- Loss of the 330 kV Tamale – Nayagnia line
- Loss of the 161 kV Aboadze – Tarkwa line

Contingencies that result in voltage violations on the grid are as follows:

- Loss of the 161 kV Dunkwa – Ayanfuri line
- Loss of the 161 kV Bui – Sawla line
- Loss of the 161 kV Takoradi Thermal Extension – Cape Coast line

The details of the impact of these single line contingencies are as tabulated in Appendix E.

f. 2020 High Eastern Dispatch Contingencies

Simulations were also done for a High Eastern Dispatch scenario assuming gas supply in the West was curtailed either due to planned work or force majeure. From the simulations, seven (7) contingencies were considered critical.

Contingencies that result in line overloads in order of decreasing severity are listed below:

- Loss of the 330 kV Aboadze – Anwomaso line
- Loss of the 330 kV Anwomaso – Kintampo line
- Loss of the 330 kV Kintampo – Adubiyili line
- Loss of the 161 kV Achimota – Accra Central line
- Loss of the 330 kV Tamale – Nayagnia line

Contingencies that result in voltage violations on the grid are as follows:

- Loss of the 161 kV Dunkwa – Ayanfuri line
- Loss of the 161 kV Bui – Sawla line

The details of the impact of these single line contingencies are as tabulated in Appendix E.

g. 2020 High Western Dispatch Contingencies

Simulations were also done for a high Western Dispatch scenario assuming gas supply in the East was curtailed either due to planned work or force majeure. From the simulations, twelve (12) contingencies were considered critical.

Contingencies that result in line overloads in order of decreasing severity as listed below;

- Loss of the 330 kV Aboadze – Anwomaso line
- Loss of the 330 kV Anwomaso – Kintampo line
- Loss of the 330 kV Aboadze – Volta line
- Loss of the 161 kV Tarkwa – Prestea line
- Loss of the 161 kV Aboadze – Tarkwa line

Contingencies that result in voltage violations on the grid are as follows;

- Loss of the 330 kV Adubiyili – Nayagnia line
- Loss of the 161 kV Takoradi Thermal Extension – Cape Coast line
- Loss of the 161 kV Takoradi Thermal Extension – Winneba line
- Loss of the 161 kV Tamale – Adubiyili line
- Loss of the 161 kV Dunkwa – Ayanfuri line
- Loss of one 161/330kV Autotransformer at Volta

The details of the impact of these single line contingencies are as tabulated in Appendix E.

5.4 Summary of Results for the Steady State Network Analysis

1. In Q1 2020, the average system peak demand is **3,154.7MW.**
2. During this period, the scheduled WAGP maintenance activity will result in the full dispatch of all Power Plants located in the Western Generation Enclave (Aboadze) by the system operator in order to meet the supply and demand requirements for the period.
3. The maximum West dispatch will result in significant increase in transmission system losses from a current of 3.77 % (as at December 2019) to an average high of 5.08% for the 2020 Q1 period.
4. The 161kV Coastal line corridor and the 161kV Volta-Accra East- Achimota corridor are the major contributors to the increase in transmission losses for this period. Together, these corridors contribute about **25 MW** (**15.4**%) of the recorded system losses of **160.3 MW.**
5. A high west dispatch is likely to result in the heavy loading (**91**% of its MVA rating) of the 330/161kV 2x200MVA Autotransformers at the 330kV Anwomaso substation.
6. The analysis indicate that the Bui HEPs must be scheduled to **run all three units** at peak within this period to forestall voltage stability issues.
7. By Q4 2020, the average system peak demand is **3,155 MW**. There is an observed similarity with the peak demand recorded for Q1 2020. This is because in 2020 Q1, the high west dispatch caused significant increase in transmission losses hence, Power Plants had to generate more power to make up for the losses.
8. During this period, there are observed voltage violations at some substations in the Eastern Enclave including, the 161kV Winneba, 161kV Achimota, 161kV Accra East, 161kV Mallam and the 161kV Accra Central substations. This is mainly due to the expected significant increase in system demand. In view of this, there is the need to add-on more compensation devices (capacitor banks) at these substations in the short term.

5.5 Dynamic Simulations

The purpose of the dynamic simulations is to analyse the transient behaviour of the Ghana power system in disturbed situations (short circuit, loss of generation or loss of a critical transmission line, etc). Dynamic simulations were carried out for the power system using a 2020 demand/supply model of the Ghana power system.

The dynamic study seeks to evaluate the Ghana power system's transient response to large system disturbances such as the loss of the biggest production unit.

The main objective of carrying out these simulations is to ascertain that the system complies with the adequacy criteria listed below:

The scope of these simulations involves investigation of the impact of the loss of the biggest Power Plant (i.e. Amandi -190 MW) on the grid.

a. Loss of 190MW Amandi Power Plant

Loss of the 190MW Amandi Power Plant which is the biggest combined cycle generator on the grid is observed to have some effect on system frequency but significantly affects voltage profiles at substations across the grid.

The loss of the Amandi Power Plant results in frequency decay to 49.6 Hz. It is observed from the plot (Figure 5.1) that only primary frequency control is engaged to arrest the frequency to avoid further decay which may lead to load shedding via AFLS action.

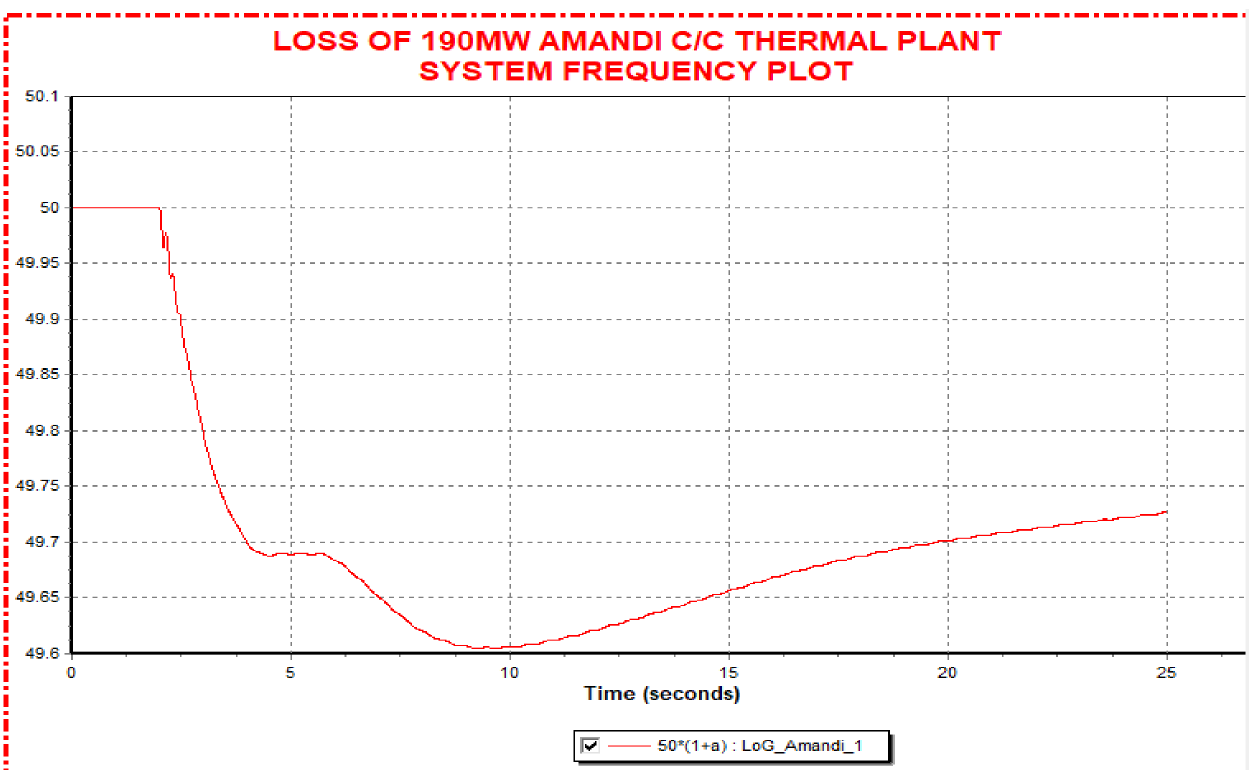


Figure 5.1: ***Loss of 190MW C/C Amandi Power Plant-System Frequency plot***

In Figure 5.1, we observe that the primary frequency response of all connected power plants ramped up their active power outputs sufficient to avoid load shedding.

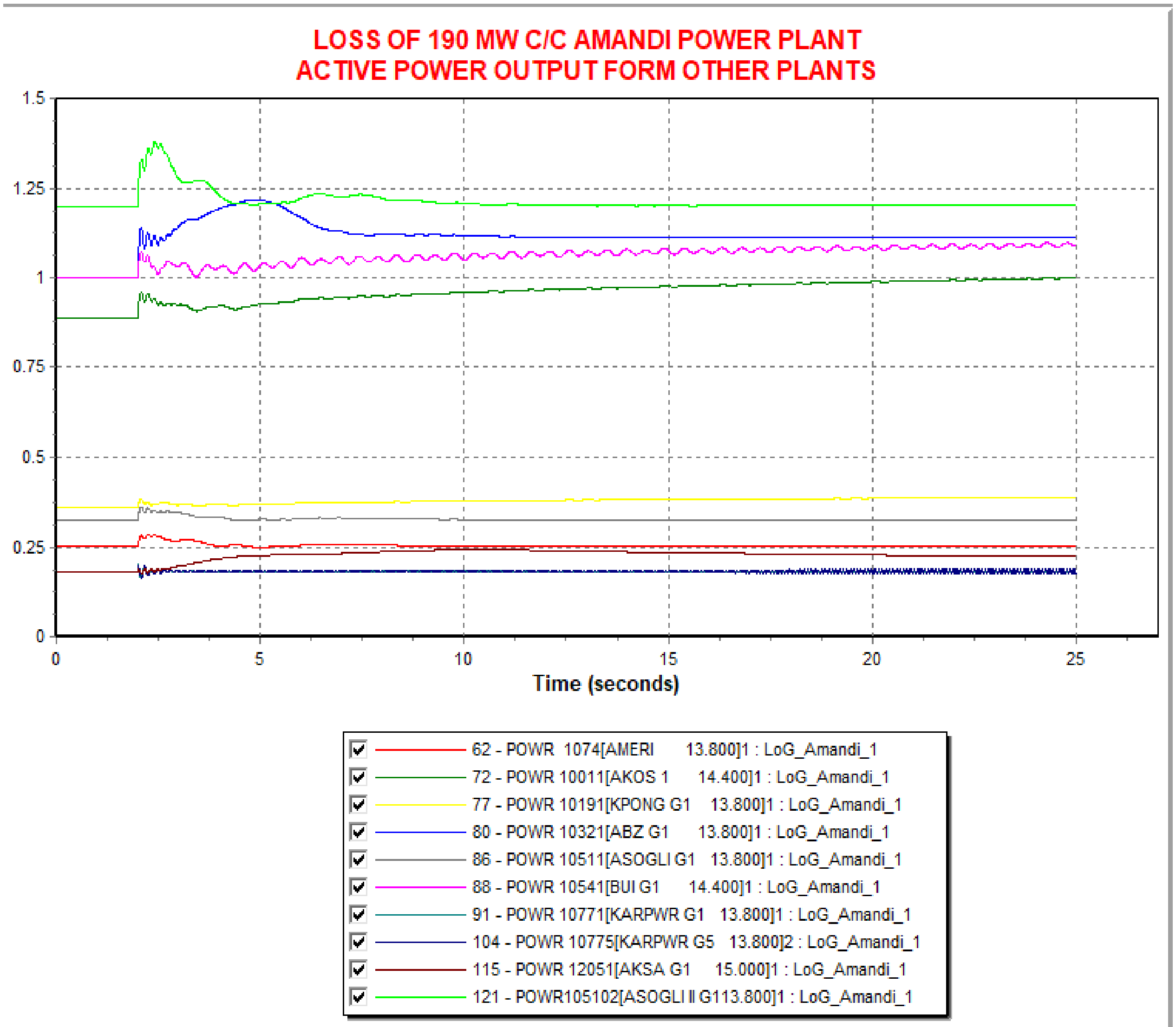


Figure 5.2: *Loss of 190MW C/C Amandi Power Plant-Active power output of other Power Plants*

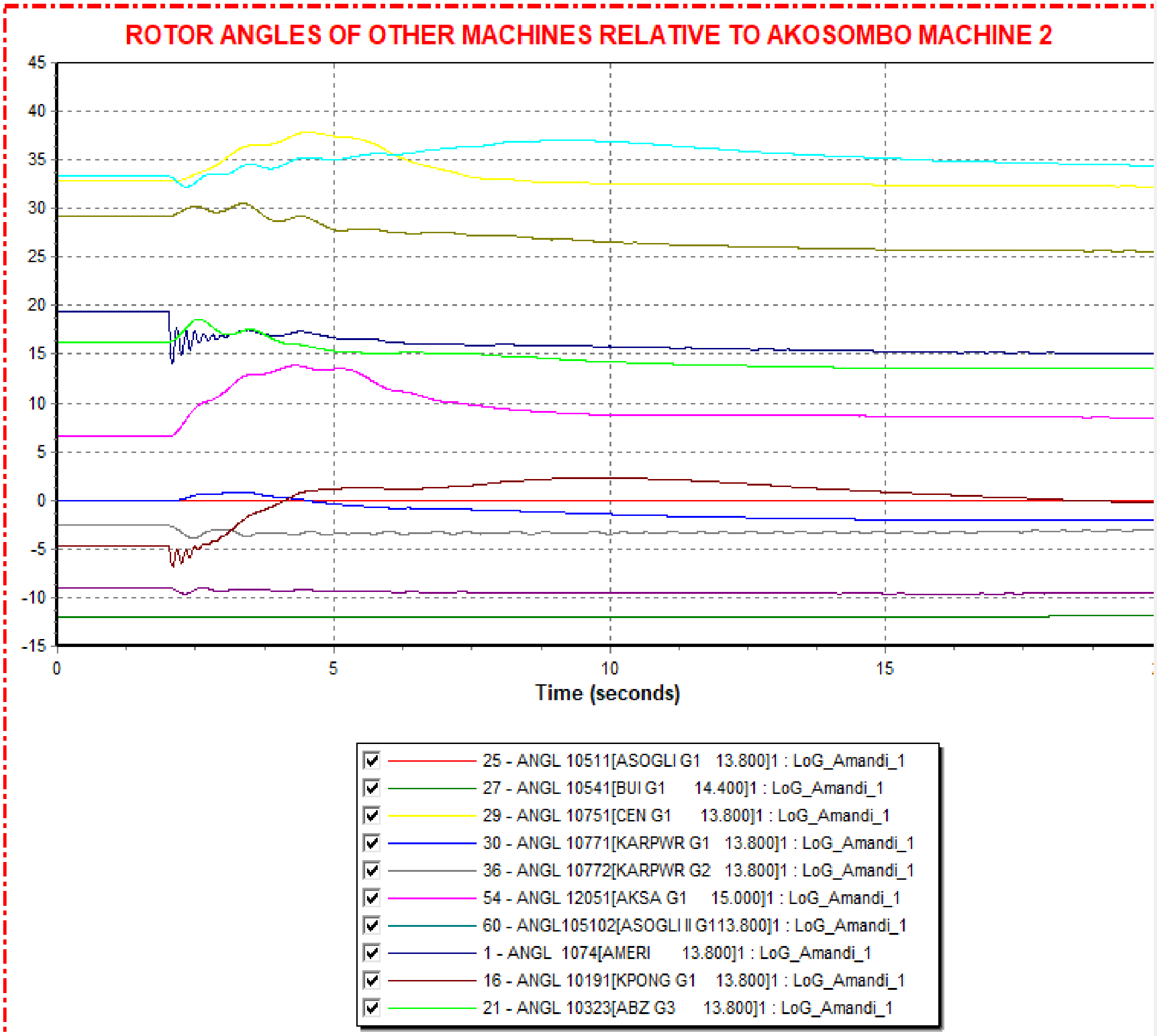


Figure 5.3: *Loss of 190MW C/C Amandi Power Plant-Rotor Angles relative to Akosombo*

Figure 5.3 shows the relative machine angle plots before and after the loss of the 190MW C/C Amandi Power Plant. The results show that though the majority of the power plants were swinging, none of them went out of synchronism.

b. Loss of 330 kV line between Takoradi Thermal and Anwomaso

This contingency is the most critical of all the power flow scenarios simulated. The results show severe overloads and voltage limit violations on the NITS. It also shows that some nearby power plants (e.g. Karpower and Amandi Plants) tend to lose synchronism when the 330kV Takoradi Thermal – Anwomaso line trips. This situation remains the same even at a critical clearing time of four (4) cycles.

From the plot, the impact of the contingency is seen in the oscillations in the rotor angle plot of the Amandi and Karpower power plants. The other Power Plants in service have their oscillations damping out within fifteen (15) seconds.

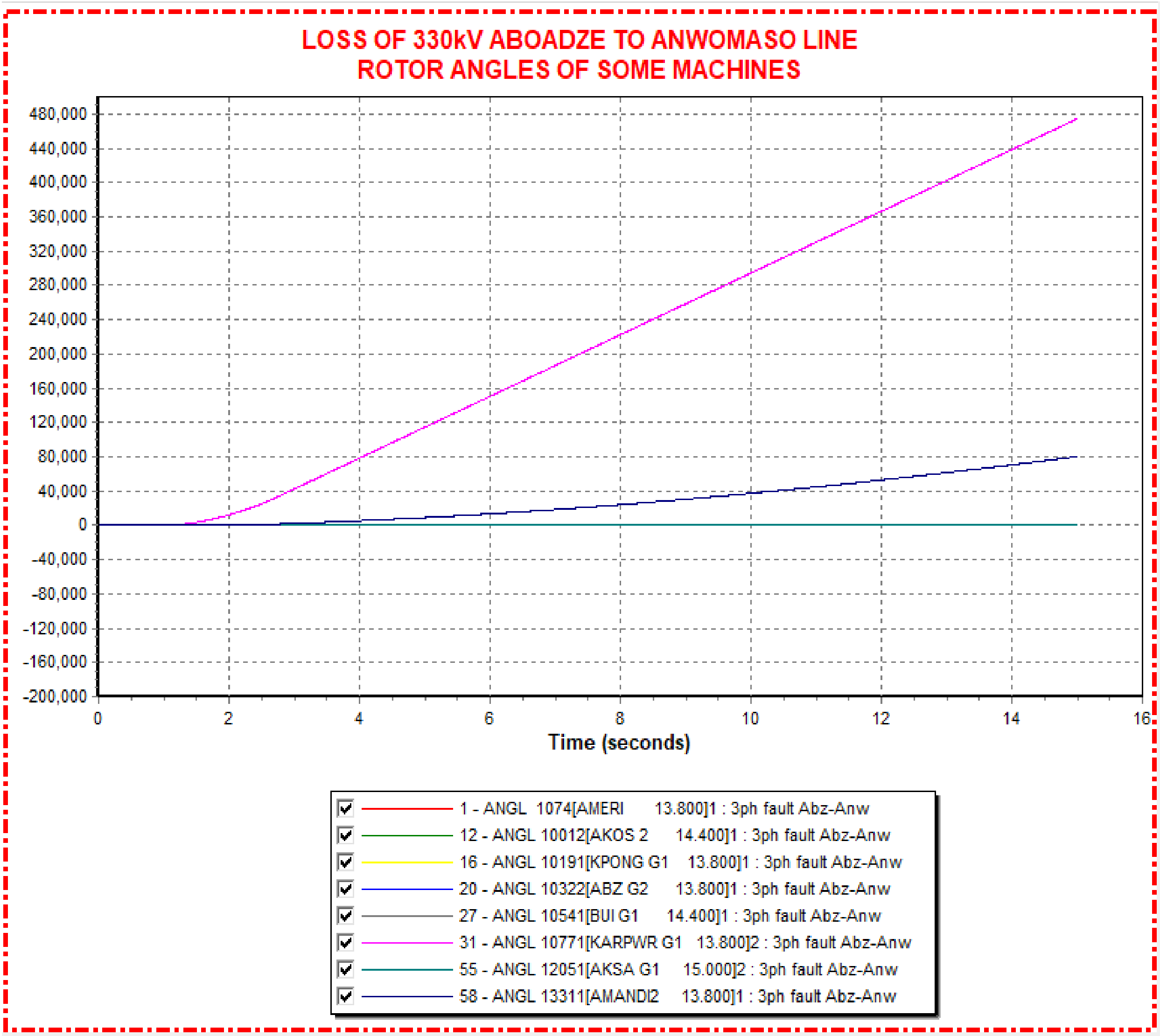


***Figure 5.4**: Loss of 330kV Aboadze-Anwomaso line - Relative Rotor Angles of machines*

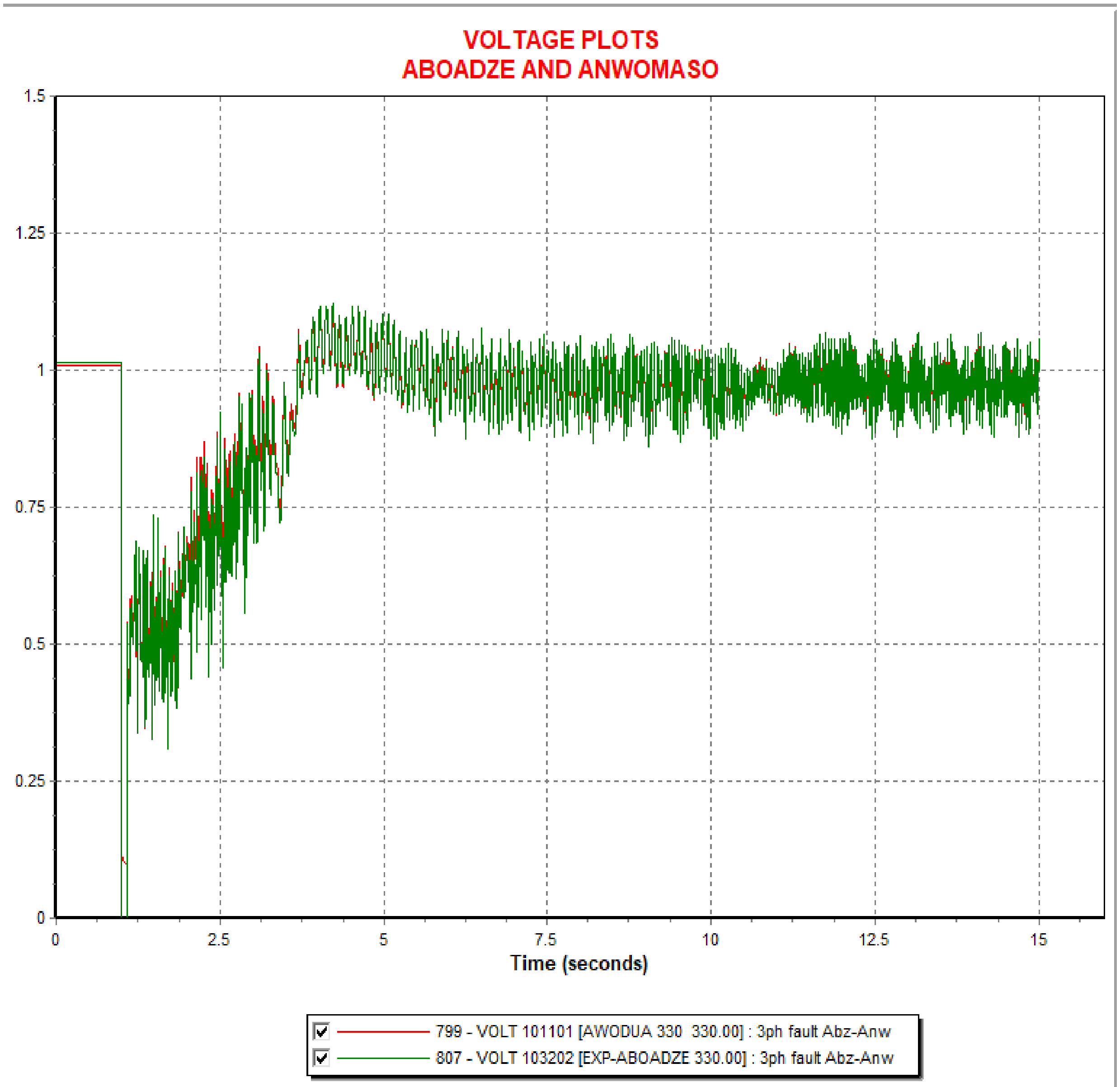


Figure 5.5: *Loss of 330kV Aboadze-Anwomaso line – Voltage Plots (Aboadze and Anwomaso)*

In figure 5.5, it is observed that during the fault on the 330kV line, the voltage dipped but recovered shortly due to reactive power injection by most of the surrounding power plants. Voltage is observed to recover shortly after the fault is cleared after 4 cycles.

Chapter 6

POTENTIAL SUPPLY CHALLENGES IN 2020

6 POTENTIAL SUPPLY CHALLENGES IN 2020

This chapter presents the challenges that may occur during 2020 and its mitigation measures.

6.1 Managing the Hydro Risk

Due to the above-average inflow into the Akosombo and Bui hydro dams in 2019, optimum amount of generation from hydro is expected. This however, requires proper coordination of maintenance activities. The availability and reliability of the thermal units are also very key to maintain the planned hydro draft rate.

6.2 Thermal Fuel Supply Risk

Reliability of Gas supply from WAGP and Ghana Gas Company remains a major risk to electricity supply reliability in Ghana. Although, there is high installed generating capacity, any disruptions in fuel supply, mostly gas, could adversely impact supply reliability.

6.2.1 Gas Supply Interruptions

The planned West African Gas Pipeline pigging exercise scheduled for the period January 20 to March 21, 2020 is expected to result in the curtailment of gas supply to Thermal Power Plants in Tema over the period. Consequently, the Sunon Asogli, TT1PP, Cenit, TT2PP etc are expected to be inoperable over the period. KTPP is expected to run on DFO, AKSA on HFO and Cenpower on LCO to make-up generation in Tema during the pigging.

6.3 Supply Reliability of Customers served on Radial Lines and Single Transformer Stations

6.3.1 Radial lines

Currently, supply reliability to customers served via single circuit radial lines is quite low. This is because an outage on such single circuit radial lines interrupts supply to such customers. The following are some of the single circuit radial lines on the NITS:

- ✓ Tamale – Yendi line;
- ✓ Takoradi – Esiama line;
- ✓ Bogoso – Akyempim line;
- ✓ Bolga - Zebilla line;
- ✓ Zebila – Bawku line
- ✓ Kpando – Kadebi

- ✓ Asiekpe – Sogakope.

Supply reliability to customers served on these lines would improve in future when such lines are upgraded through construction of additional line(s) or by looping them into other adjoining substations.

6.3.2 Single Transformer Stations

Similar to single circuit radial lines, customers supplied by single transformer substations also suffer low level of supply reliability. Consumers facing such challenges are those in Akosombo Township, Yendi, Sogakope and Esiama. Since these townships are supplied via single transformer stations,

Maintenance and/or upgrade works at these stations are often a challenge due to difficulties in securing outages.

6.3.3 Power Evacuation

Due to project financing issues, work on the following projects have delayed;

- ✓ 330kV Anwomaso – Kintampo transmission line
- ✓ 161kV Volta – Achimota – Mallam corridor upgrade

The 330kV Anwoamso – Kintampo line is the remaining section of the 330kV Central Tranmission Backbone infrastructure. This project is to enable the NITS improve system stability whilst exporting at least 100MW power to Burkina. Due to the delays in delivering the project, the 161kV Anwwomaso –Kumasi line is experiencing high loading contributing to system losses. Any contingency on the line will create severe system disturbances which may collapse the power system. It is imperative that GRIDCo gets the necessary support from Government and AfD to complete this section of the line.

The 161kV Volta-Achimota-Mallam Corridor is the most heavily loaded corridor on the Ghana grid supplying power to the Capital and surrounding towns. It is made up of light capacity conductors which are at least 50 years old. In 2018 GRIDCo secured funds to replace all the towers and transmission lines with high capacity conductors. The project has stopped due to project management issues and non-disburement from AfD. As the demand for power increases in 2020, any line contingency on the corridor will mean severe load curtailment to the Capital. It is of utmost importance all efforts be harnessed to complete the project to avoid any laod shedding to the Capital in 2020.

Chapter 7

DISTRIBUTION SYSTEM OUTLOOK FOR 2020

7 DISTRIBUTION OUTLOOK FOR 2020

7.1 Overview of ECG's Distribution Operations

The Electricity Company of Ghana Limited (ECG) is the entity that is mandated to deliver electricity distribution services to consumers located in the Southern Electricity Distribution Zone of Ghana. In 2019, the company focused its activities in the following strategic areas:

- Restructuring electricity distribution business to introduce private sector participation;
- Supporting the Government of Ghana to rationalize the excess generation capacities contracted;
- Expansion of the sub transmission network to improve reliability, minimize system losses, and the extension of the network to new customers and rural communities;
- Customer management and the improvement in work culture and ethics.

Additionally, some key issues with respect to regulation and prudent utility practices were prioritized for discussion and resolution with stakeholders. The company is in the process of carrying out reforms to further unbundle its distribution operations from its customer interface or last mile activities.

7.1.1 ECG's Distribution Network

A reliable and efficient distribution network is essential for the effective operation of the power system in any country. The Electricity Company of Ghana Limited (ECG), being the largest distribution company in Ghana is required to provide a reliable and efficient network for distribution of electricity and associated services to consumers in the Southern Electricity Distribution Zone (SEDZ).

A reliable network should have adequate capacity to transmit power to meet customer demand. Voltages must also be adequate at primary substations to support power transfers from Bulk Supply Points (BSPs) which are the main offtake points of ECG, and the transformers at the primary substations must have adequate capacities to meet peak demand and minimize network losses.

As at September 2019, there were thirty-three (33 no.) Bulk Supply Points (BSPs) where ECG off-took power supply from the Ghana Grid Company Limited (GRIDCo). There were one hundred and eighteen (118 no.) 33/11 kV primary substations and eleven (11 no.) 33 kV switching stations in the entire ECG network for the evacuation of power to load centers. The total 33 kV network length comprised 18,446 km of overhead lines and 1,421 km of underground cables. The total 11 kV network length comprised 9,329.78 km of overhead lines and 1,170.57 km of underground cables.

The major load centers within the ECG network are Accra, Tema, Ashanti and Western regions. These four (4) operational regions account for over 80% of the total demand of ECG.

7.1.2 Network Reliability

The ECG's network reliability assessment has two major focal areas, namely Sub-transmission reliability and the distribution reliability analyses. The Sub-transmission reliability analysis takes a look at the Total Transfer Capabilities (TTC) of the sub-transmission network to deliver power to the primary substations, the transformer loadings and voltage profiles at all primary substations within the ECG network. The Distribution reliability analysis on the other hand focuses on the reliability indices of the Medium and Low Voltage networks of ECG.

As demand grows, the distribution network capacity must keep pace with the growth in consumption. Therefore, projects have been implemented and others are planned to expand/upgrade the network to meet the growing demand of customers and maintain the levels of reliability as demand grows. Table 7.1 below summarizes projects earmarked to boost the capacity and reliability of ECG's network in 2019.

No.	Project Description/ Activities	Rational for Project	Expected Benefits
1	Construction of the Pokuase BSP	This will boost voltage support to Dodowa, Mampong/Aburi, Adenta, Agbogba, Kwabenya, Gimpa/UGMC, Anyaa Ofankor and Nsawam. It will also improve reliability by serving as an alternative/relieveto Achimota ,Mallam , A3BSP and Afienya BSPs.	1. Improve power supply reliability and voltage profiles to Dodowa, Mampong/Aburi, Adenta, Kwabenya, Gimpa,UGMC, Anyaa,Ofankor and Nsawam 2. Reduce technical losses in the Northern portion network of Accra
2	Creation of Switching Points in the 33 kV and 11 kV Primary Distribution Networks	The aim is to provide constant and reliable power supply to customers. (i.e. Improve on system Performance and reduce duration of outages)	1. Improve network reliability 2. Increase operational flexibility of the distribution network

No.	Project Description/ Activities	Rational for Project	Expected Benefits
3	Deployment of Voltage Regulators at Agona ,Nsawam, Chirano & Kasoa Substations	The project aims at improving the voltage profiles of the networks served by these Substations	To improve voltage profiles levels in the networks
4	Construction of a 33 kV Switching Stations in the ECG Network	This is to allow for operational flexibility in the proposed areas which are served by very long primary distribution feeders.	1. Improvement in reliability of the distribution network 2. Increase operational flexibility of the distribution network
5	Deployment of Auto Reclosers and Replacement of faulty Auto Reclosers (11 kV & 33 kV)	To minimize coverage of outages and to improve supply reliability for customers.	To improve power supply reliability to areas where they are deployed
6	Elubo 33kV Switching Station c/w 33kV links	Required to help reduce the levels of technical losses in the 33 kV network in that part of the Western Region operational area, improve voltage levels, improve reliability and increased network capacity	1. Improve power supply reliability to Enchi, Half Assini and surrounding communities 2. Improve voltages in the enclave 3. Reduce technical losses
7	Construction of offloading circuits (33 kV and 11 kV) from these substations in ECG - Daboase, Dwenase, Awaso, Bibiani	Required to improve network capacity and introduce more flexibility.	1. Increase network capacities 2. Improve reliability 3. Improve network flexibility
8	Deployment of Distribution Automation Systems (DAS) on selected 11 kV and 33 kV feeders	To localize outages to improve supply reliability for customers.	To improve power supply reliability to areas where they are deployed

Table 7.1 Projects to improve reliability of ECG's network in 2020

7.1.3 ECG Distribution Loss Reduction

System losses have been one of the major challenges facing ECG. Efforts are in place to continuously reduce it. As at September 2019, system losses were 24.5%. This is made up of 10.5% technical losses and 14% commercial losses. Various strategies have been adopted to minimize system losses. They include the following:

A. <u>Technical Losses</u>

- Low Voltage (LV) network bifurcation and load centering;
- Load balancing of the Low Voltage network;
- Shunt capacitor compensation at substations and on the feeders with poor power factors;
- Deployment of Voltage regulators for voltage profile improvement on 33 kV and 11 kV networks;

- Reconfiguration of 11 kV feeders with high losses;
- Injecting primary and distribution substations to reduce long sub transmission and distribution lines;
- Conversion of long 11 kV distribution feeders to 33 kV; and
- Reconductoring of network sections with bigger sized conductors;

B. Commercial Losses

- Deployment of AMR meters for all 33 kV and 11 kV feeders, power transformers and Distribution transformers for proper energy accounting of the distribution network;
- Platform for easy payment of customer billed energy consumption;
- Strengthening of customer monitoring of prepayment metering systems deployed to ECG's operational areas;
- Audit of billing systems to eliminate errors in billing;
- Strengthening the Loss Control Units (LCUs) to patrol meter installations and regularly check their integrity;
- Strengthening the utility courts to prosecute the theft of power by employees and customers.

Tables 7.2 and 7.3 show some of the specific projects being implemented by the company to improve the distribution system losses in ECG's operations.

No.	Project Description / Activities	Rationale for Project	Expected Benefits
1	Improvement in the reactive power management on selected 11 kV & 33 kV feeders by deploying Shunt Capacitor Banks	This is targeted at technical loss reduction and improvement of power factors of feeders with poor power factors	1. Improve the power factors of the feeders 2. Free up capacity on the feeders and transformers 3. Reduce technical losses
2	Reconfiguration of selected 11 kV feeders with high level of technical losses/Conversion to 33 kV Distribution	The purpose of this project is to reduce the technical loss levels within the distribution network	To reduce technical losses
3	Improvement in the voltage profiles of long 33 kV feeders/networks using Voltage Regulators at Kasoa and Chirano areas.	The main target is to meet regulatory requirement in relation to voltage profiles and reduce technical losses with the distribution network of ECG	1. To improve voltage levels within the distribution networks 2. To reduce technical losses
4	Implementation of Low Voltage Bifurcation works (Distribution transformers) in all operational areas.	Reduction of circuit lengths of low voltage network	1. To reduce technical losses 2. Improve voltage to customers

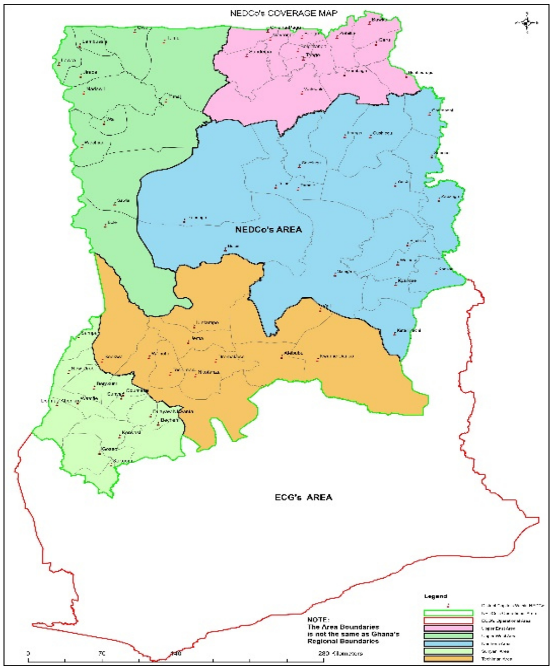
Table 7.2 Projects and activities being undertaken to improve technical losses in ECG

No.	Project/ Activities	Reason	Benefits
1	Re-routing of concealed service tails in Accra East, Central and Tema Regions	This is to reduce the incident of meter by-passing and theft by customers	To reduce commercial losses in the distribution network
2	Smart Prepayment Metering in Accra East, Ashanti SBU and Tema Regions	This is to provide good oversight of meters in the various regions for effective supervision to reduce commercial losses	To reduce losses in the distribution network
3	33 kV & 11 kV feeders and Power transformer metering Project	This is to help in localizing the areas of high losses in the distribution network for loss reduction programmes	To reduce losses in the distribution network
4	Distribution Transformer Metering Project	This is to help in localizing the areas of high losses in the distribution network for loss reduction programmes	To reduce losses in the distribution network
5	Mass faulty meter replacement (Prepayment and Postpaid)	This is to eliminate the incidents of false billing records and consumption charges to customers that contribute to losses in the distribution network	To reduce losses in the distribution network

Table 7.3 Specific Projects and activities being undertaken to improve commercial Losses in ECG

It is expected that the above projects when completed will bring significant improvements to the electricity distribution grid and support the evacuation of power to current and potential customers. Additionally, ECG will explore available opportunities for bilateral power purchase agreement with our neighboring countries and reduce the cost of standby capacities of power plant to ECG.

7.2 Overview of NEDCo's Distribution Operations



NEDCo is a subsidiary of the Volta River Authority (VRA) responsible for electricity distribution in the Northern parts of Ghana. NEDCo's service territory covers 64% of Ghana's land area. This extends to the northern parts of the Ashanti region, parts of Oti, Brong, Western and all the regions in the north.

A large portion of NEDCo's service territory remains rural, characterized by low customer density and relatively low electricity consumption.

NEDCo purchases power solely from VRA to NEDCo's distribution network customers.

7.2.1 NEDCo Distribution Network

At the end of 2019 the NEDCo distribution network comprised of 10 primary substations, 14,237.3 km circuit lengths of MV lines, 18,401.8 km circuit lengths of LV lines, and 6353 no. distribution transformers.

The number of customers increased on average by about 13% per year. At the end of the third quarter of 2019, NEDCo had 930,250 customers. Residential customers accounted for 84% of this customer population and about half of these customers are estimated to be lifeline customers, consuming less than 50 kWh/month. Only 93 of NEDCo's customers were industrial customers as at the end of third quarter of 2019.

The electricity access rate in the NEDCo operational territory is below the national average as shown below:

National = 84.3% (National)

Bono East and Bono Regions = 81.89%

Upper East and North East Regions = 60.62%

Upper West Region = 73.53%

Northern and Savannah Regions = 62.73%

7.2.2 Network Reliability Improvement Projects

The reliability of power supply in NEDCo areas is generally good. However, reliability in some parts of the network have been below expectation due to over-extended and over-ageing feeder lines resulting in high technical losses. Some of these lines were extended as part of the implementation of the Self Help Electrification Project (SHEP). Some interventions have however been made on some of these lines resulting in improved supply reliability.

The following are lines and substations/equipment in NEDCo with challenges affecting supply reliability to customers. Short-Medium term as well as long-term solutions being pursued are also indicated.

7.2.2.1 Yendi-Bimbilla-Kete Krachi 34.5kV Line

This 34.5kV line takes its source from GRIDCo's BSP in Yendi. Bimbilla, Salaga and Kete-Krachi are major communities that are served from this feeder and are about 71km, 147km and 202km respectively away from the Yendi BSP. These communities together with others have a coincident peak demand of 11 MVA as at March 2019. Network studies revealed voltages as low as 29.7kV (86% of rated voltage) and 27kV (about 77% of rated voltage) at Bimbilla and Kete-krachi respectively. NEDCo has initiated actions to installed 3.6MVAr switched potable pole top capacitor banks at Bimbila and Krachi as a short term measure to improve voltage. The Korean EXIM Bank will be assisting NEDCo to construct a 20MVA Booster /switching station at Bimbilla with Switched capacitor bank with the aim of improving voltage quality and reliability. The most technically feasible long term solution is the construction of a 161BSP at Bimbilla.

7.2.2.2 Tamale Installed Capacity Constrain and strategy to resolve challenges

The Tamale Metropolis and its immediate surroundings are currently supplied from GRIDCo's 161 kV 66MVA (2 X 33MVA) BSP at Tamale. As at March 2019, the total non-coincident demand was about 63MVA.

The second GRIDCo substation in Tamale is a 330/161kV substation with no provision yet to directly supply NEDCo. As a short term measure, NEDCo has agreed with GRIDCo to evacuate power from the 10MVA capacity auxiliary transformer at the new Adubiyili substation . NEDCo has initiated steps to construct a 2 X 10 MVA primary substation to evacuate 20 MVA from Adubiyili by mid-2021.

7.2.2.3 Yendi-Gushegu-Gambaga-Bunkprugu 34.5kV Line and strategy to resolve challenges

This 34.5kV line also takes its source from GRIDCo's BSP in Yendi. This line is one of the longest lines with numerous branches due to SHEP. There are no protective/control equipment on the branches for segregation of faults. The effect is that a fault on a branch results in an outage to the entire line, resulting in high frequency and duration outages. NEDCo has awarded a contract for the installation of auto-reclosers, sectionalisers and fuses at different locations of the network. The project is expected to be completed by the first quarter 2020.

7.2.2.4 Tamale-Dalun-Nasia 34.5kV Line

This 34.5kV line takes its source from GRIDCo's BSP in Tamale. This line is one of the longest lines with numerous branches due to SHEP. There are inadequate protective/control equipment on the branches of the line for segregation of faults. The effect is that a fault on a branch results in outage to the entire line, resulting in high frequency and duration of outages.

7.2.2.5 Network Reinforcement and Technical Loss Reduction Strategy to Resolve Challenges

NEDCo intends to undertake a number of projects to be funded by the Korean EXIM Bank. These projects are aimed at reducing losses and improving system reliability. Detailed design and selection of the contractor(s) is expected to commence in 2020. These projects include;

1. Construction of 2 X 10 MVA, 34.5/11kV primary substation at Berekum, Sunyani
2. Construction of 2 X 10 MVA, 34.5/11kV primary substation at Fiapre, Sunyani
3. Construction of 2 X 10 MVA, 34.5/11kV primary substation at Tanoso, Sunyani
4. Construction of 2 X 10 MVA, 34.5/11kV primary substation in Techiman
5. Construction of 2 no. 2 X 10 MVA, 34.5/11kV primary substation in Wa
6. Construction of 20 MVA Voltage Booster/switching station in Bimbila
7. Construction of 20 MVA Voltage switching station in Tumu

7.2.2.6 Wa-Jirapa-Nandom-Hamile 34.5kV Line and strategy to resolve challenges

This 34.5kV line takes its source from NEDCo's primary substation in Wa which also takes its source from the GRIDCo's BSP in Wa. This line serves various districts including Nadowli, Jirapa/Lambusie, Lawra and Nandom. The Wa - Hamile line is about 110 km long and has numerous branches with inadequate protective/control equipment on the branches of the line for segregation of faults. The effect is that a fault on a branch results in an outage to the entire line. Also, there is low voltage at the receiving end of the line due to the length of the line, coupled with increasing load. NEDCo has awarded a contract for the installation of auto-reclosers, sectionalisers and fuses at different locations of the network. The project is expected to be completed by first quarter 2020.

7.2.3 NEDCo Distribution Loss Reduction

A Distribution Loss Study conducted by NEDCo shows that the technical loss on its network is approximately 9.23%. Overall losses for NEDCo, including commercial losses is 27.5%. Efforts are being pursued to bring the losses down. The following are some of the initiatives being made:

a. Technical Loss Reduction Initiatives

- Upgrading portions of distribution network with higher capacity conductors;
- Load balancing on the Low Voltage (LV) networks;
- Deployment of Voltage regulators;
- Construction of new 34.5/11.5 kV substations to reduce long sub transmission and distribution circuits;
- Reactive power compensation projects;
- Shield-wire network upgrade project (Voltage Upgrade)

b. Commercial Loss Reduction Initiatives

- Deployment of AMR meters for all 34.5 kV and 11.5 kV feeders, SLT customers and Feeder T-offs. Additionally, AMR System meters are being installed at BSPs to serve as check meters;
- Setup of a platform for easy payment of customer bills, such as the use of Mobile Money payment system;
- Strengthening the Loss Control Units (LCUs) to patrol meter installations and regularly check their integrity;
- Implement split smart metering for domestic and small scale customers to replace existing meters to minimize meter bypass and tempering.

Chapter 8

OVERVIEW OF MEDIUM-TERM SUPPLY : 2021 - 2025

8 OVERVIEW OF MEDIUM-TERM SUPPLY: 2021 - 2025

A power system must have sufficient generating capacity to reliably supply the electrical energy demand and to meet its peak demand at all times. Typically, it takes at least five years for conventional power plant projects to evolve from conception through arrangements for funding, detailed design, construction to commissioning and commencement of commercial operation.

Medium-term power system planning provides guidance for the development of the power system in the medium-term to meet future electricity demand. Studies are thus performed to evaluate the capability of the existing system to meet operational requirements in the medium term. This is necessary to forecast electricity demand, have a best estimate of inflows into the hydro reservoirs, make projections for fuel supply requirements and various operating factors.

In this chapter, the medium-term (2021 - 2025) peak demand and consumption forecast to serve as a guide for power system investment and planning is presented. This section therefore provides an outlook for generation and transmission system requirements for the next five years (2021 – 2025) to enable adequate and timely measures to be put in place to ensure security of supply in the Ghana Power System over the medium term.

8.1 Demand Outlook

The Projected electricity demand over the period 2021 – 2025 is based on data collated from a load survey exercise. It consists of projected natural growth in domestic demand over the period and some Spot Loads. The expected spot loads for the period are as follows:

- ✓ As part of the development of an Integrated Aluminum Industry in Ghana, VALCO projects to run 2 pot-lines (150 MW) through 2021 to 2022. Demand increases to 300 MW in 2023 and is expected to further increase to 500 MW by 2024. Upon the completion of the final phase of the expansion works by 2027, the maximum demand of VALCO is projected to be 1,150 MW.
- ✓ Mines:
    - Newmont Mines, Ahafo - demand is expected to increase by 10 MW in 2020 and a further increase of 12.5 MW in 2021 at Ahafo-North;
    - Azuma Mines - 18 MW by 2023 at Yagha (50km North West of Wa);

- Anglogold Ashanti – demand is expected to increase to 49 MW by 2025.

✓ Potential Exports:

- Export to Burkina Faso is expected to increase to 206 MW in 2025 from 150 MW in 2021;

- Export to CEB is projected to be 200 MW from 2021;

- Export to Mali is expected to begin by 2025.

Total electricity consumption of Ghana including power exports to Togo, Benin, Burkina Faso and Mali is projected to increase from **20,773** GWh in 2021 to **28,559** GWh by 2025 at a Compound Annual Growth Rate (CAGR) of approximately 8.3 %. The Ghana system peak demand is projected to increase from 3,263 MW in 2021 to 4,403 MW in 2025.
The summary of 2021-2025 projected demand is illustrated in Tables 8.1 and 8.2.

	2021	2022	2023	2024	2025
Domestic	17,564	18,503	19,718	20,750	21,386
VALCO	1,314	2,628	2,628	4,380	4,380
Exports	1,895	1,954	2,017	2,403	2,793
TOTAL	20,773	23,085	24,363	27,533	28,559

Table 8.1: Projected Energy Demand (GWh) (2021- 2025)

	2021	2022	2023	2024	2025
Domestic	2,753	2,895	3,070	3,232	3,397
VALCO	150	300	300	500	500
Exports	361	372	384	445	506
TOTAL	3,263	3,566	3,753	4,177	4,403

Table 8.2: Projected Peak Demand (MW) (2021- 2025)

8.2 Projected Supply Outlook

The power supply outlook was prepared considering the existing and committed capacity additions. The assessment of generation adequacy is based on ensuring that sufficient generation resources are available to meet the forecast demand including the required 18% capacity operating reserve margin.

8.2.1 Existing Generation

The existing generating facilities in Ghana are made up of hydro, thermal and renewable energy sources. The breakdown of projected demand versus expected supply from the existing generation resources is as shown in Table 8.3.

Projected Capacity Demand (MW)		2021	2022	2023	2024	2025
Domestic		2,753	2,895	3,070	3,232	3,397
VALCO		150	300	300	500	500
Exports		361	372	384	445	506
TOTAL		3,263	3,566	3,753	4,177	4,403
Projected Demand + 18% Reserve Margin		3,851	4,208	4,429	4,929	5,196
Existing Generation Capacity MW						
Akosombo	1020	900	900	900	900	900
Kpong GS	160	140	140	140	140	140
Bui GS	400	330	330	330	330	330
TAPCO	330	300	150	150	300	300
TICO	340	320	320	320	320	320
TT1PP	110	100	100	100	100	100
KTPP	220	200	200	200	200	200
TT2PP	70	70	70	70	70	70
AMERI Power Plant	240	230	230	230	230	230
Karpower Barge	450	450	450	450	450	450
Asogli (SAPP(Phase 1))	200	180	180	180	180	180
Asogli (SAPP (Phase 2))	360	350	350	350	350	350
CENIT	110	100	100	100	100	100
AKSA	370	330	330	330	0	0
CENPOWER	360	340	325	325	325	325
Amandi Energy Ltd	204	190	190	190	190	190
VRA Solar	2.5					
Solar (Central Region)	40					
Total Existing Generation	4,986.50	4,530.00	4,365.00	4,365.00	4,185.00	4,185.00
Committed						
VRA T3	132	0	130	130	130	130
Early Power Limited	400	145	190	190	390	390
Pwalugu Hydro	60					60
VRA Kaleo	17					
Total Committed Generation	609.00	145	320	320	520	580
Total Dependable Generation (MW)	5,596	4,675	4,685	4,685	4,705	4,765
Surplus/Deficit		824.16	476.57	256.08	(224.18)	(430.96)
% Excess/Deficit in Generation		25.25%	13.36%	6.82%	-5.37%	-9.79%

Table 8.3: Projected Demand and Supply balance (2021- 2025)

8.2.2 Committed Generation Projects

The following are the committed generation additions expected to come on line in the medium-term:

Projects Under Construction

- ✓ **Early Power:** This is a 400 MW power plant located at Tema. The first phase of the plant (147 MW) is expected to be commissioned in the first quarter of 2020. The final phase making up the 400 MW is planned to be commissioned by 2024.
- ✓ **Pwalugu Hydro and Solar Plant:** This is a 60 MW hydro electric plant in hybrid operation with a 50 MWp Solar PV plant which is expected to be completed and commissioned by 2025. The plant is planned to be located in the Upper East Region.
- ✓ **Kaleo Solar PV Plant**: this is a 17 MW PV plant being constructed by VRA at Kaleo in the northern region. It is planned to be commissioned in 2020.

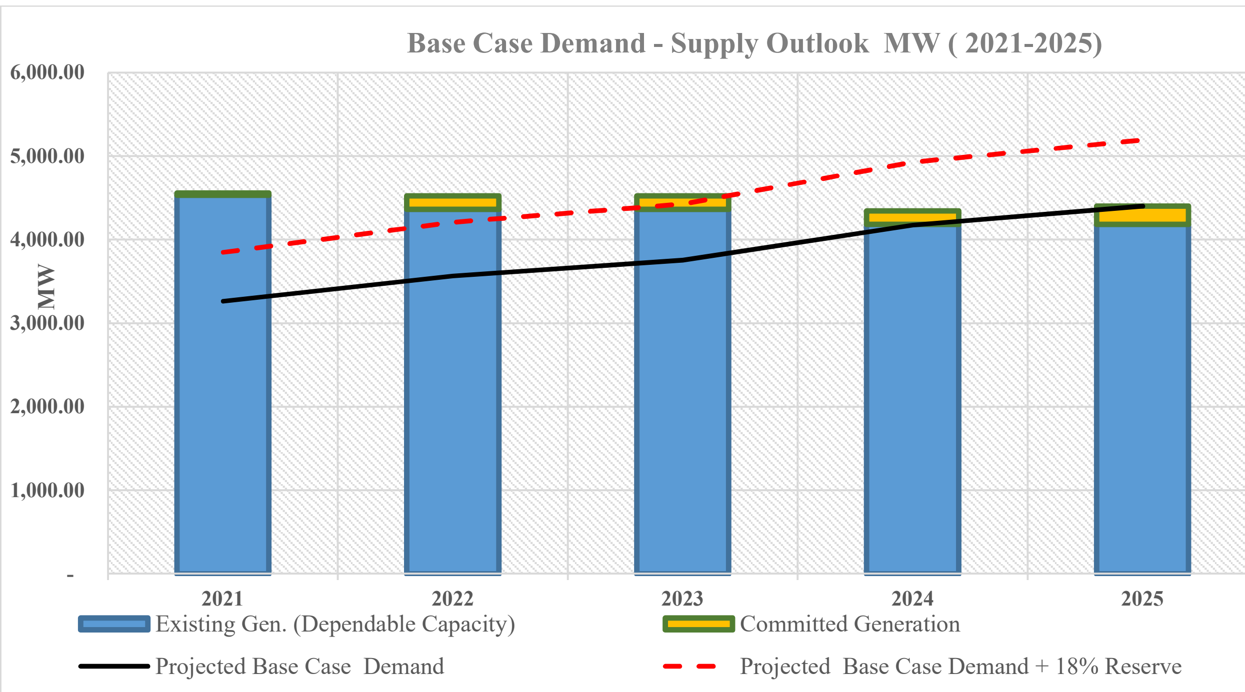


Figure 8.1: Projected Demand Versus Supply balance (2021 - 2025)

8.2.3 Demand and Supply Balance

A comparative analyses of the projected medium term demand and the corresponding projected supply/generating capacity was carried out, as presented in Table 8.3 and Figure 8.1. The sum of the individual plant dependable capacities, including existing and committed/ongoing generation projects was compared with projected reference case peak demand with 18% operating reserve margin. The results of the analyses indicate that existing generating capacity will be adequate to serve projected demand until 2023. The highest generation surplus for the period is 25.25% as projected for 2021 and the lowest is 6.82% for 2023. There is a deficit in supply of 224.18 MW and 430.96 MW for the years 2024 and 2025 respectively, notwithstanding the coming online of currently ongoing generation capacity addition projects.

8.2.4 Additional Generation Requirement

Requirements for additional electricity generation resource acquisition are determined in accordance with the policy to balance supply and demand taking into account the need for the provision of adequate reserve capacity to cater for contingencies.

Deducing from the analysis carried out in section 8.2.4 above, projected dependable capacity for the years 2024 and 2025 would not be adequate to serve projected demand including the 18% operating reserve margin required for reliability.

Therefore, additional generation capacities of 225 MW and 210 MW would repectively be required to be procured and commissioned into service by January, 2024 and 2025.

It is important to note that these additions are required to meet the mandatory reserve margin of 18%.

8.3 Medium Term Transmission Network Expansion/Upgrade Requirements

The results of the extensive system network analyses carried out using the projected demand and supply scenario in the Tables above, indicate that there would be the need for the following transmission line and equipment additions in the medium term to meet the required supply reliability indices, and this is in addition to the investment identified under Section 5. The following are the critical transmission additions required:

- ✓ 161kV Aboadze-Takoradi-Tarkwa-Prestea
- ✓ 2nd Circuit 330 kV Prestea – Dunkwa – Kumasi line
- ✓ 330/161 kV Dunkwa substation
- ✓ 161kV Pokuase – Mallam line
- ✓ 161kV Aboadze – Mallam line Upgrade
- ✓ 161Kv Bogosu – Dunkwa – New Obuasi upgrade
- ✓ 161 kV Dunkwa – Asawinso upgrade

- ✓ 2nd Circuit 330 kV Aboadze – Pokuase
- ✓ Accra (Pokuase) – Kumasi (Anwomaso) 330 kV line
- ✓ Eastern Transmission Corridor Projects:
  - 161kV Kpando – Juale Line
  - 161kV Juale – Yendi Line
- ✓ Kumasi third Bulk Supply Point
- ✓ Transformers and Compensation devices
- ✓ SCADA upgrade project
- ✓ Replacement of interconnection transformers with phase shifting transformers (Prestea and Nayagnia)

8.4 Creation of new Generation Enclaves

Currently apart from Akosombo GS and Bui GS, there are two other generation enclaves in Ghana, namely the Tema and the Takoradi thermal generation enclaves.

Power system network analyses carried out show that establishing new generation enclave near Kumasi and Winneba result in considerable improvement in the stability of the NITS and significantly reduces transmission system losses. It also improves the quality of supply to end users through improved network voltage control via generators.

8.4.1 360 MW Plant sited at Kumasi

Results for an analysis carried out on a 2022 network model which assumes a total system generation of 3,543.2 MW. For the base case scenario, total system losses were 132.5 MW representing 3.74 % of total generation.

Power flow and analyses indicate that siting a 360 MW combine cycle thermal plant at Kumasi results in a the significant reduction in transmission losses to 107.6 MW representing 3.1 % of total generation. A reduction in total system losses of 24.9 MW is thus achieved.

Table 8.4 shows the load flow results.

	No generation at Kumasi	360 MW generation at Kumasi
Losses (MW)	132.5 MW	107.6 MW

Table 8.4: Comparison of system losses (MW) - Siting Generation at Kumasi

The results again show significant reduction in some transmission line loadings (congestion) within the South West to Ashanti corridor as shown in Table 8.5:

	Percentage Line Loading	
	No Generation	360 MW Generation at Kumasi
New Tarkwa – Tarkwa	76%	56%
Takoradi - Tarkwa	56%	41%
Dunkwa -Ayanfuri	93%	87%
Dunkwa - New Obuasi	86%	107%

Table 8.5: Comparison of line loadings (% line thermal capacity) - Siting Generation at Kumasi

It also shows bus voltage improvements as shown in Table 8.6.

Bus Voltage (kV)	No generation at Kumasi	360 MW generation at Kumasi
Dunkwa	150.7	162.9
Ayanfuri	148.7	159.8
New Obuasi	153.7	160.9
Kumasi	156.4	159.1

Table 8.6: Comparison of bus Voltages (kV) - Siting Generation at Kumasi

8.4.2 360 MW Plant sited between Winneba and Kasoa

Power flow analyses indicate that siting a 360 MW generation facility in the western part of Accra (between Winneba and Kasoa) also results in significant improvements in the transmission network voltage profile. It also reduces congestion on the 161 kV Aboadze – Mallam and Volta – Mallam transmission corridors. Additionally, total transmission system losses of 135.2 MW (3.8 %) is reduced to 115.1 MW (3.2%).

Tables 8.7 to 8.8 show the load flow results.

	No generation at Winneba	360 MW generation at Winneba
Losses (MW)	135.2 MW	115.1 MW

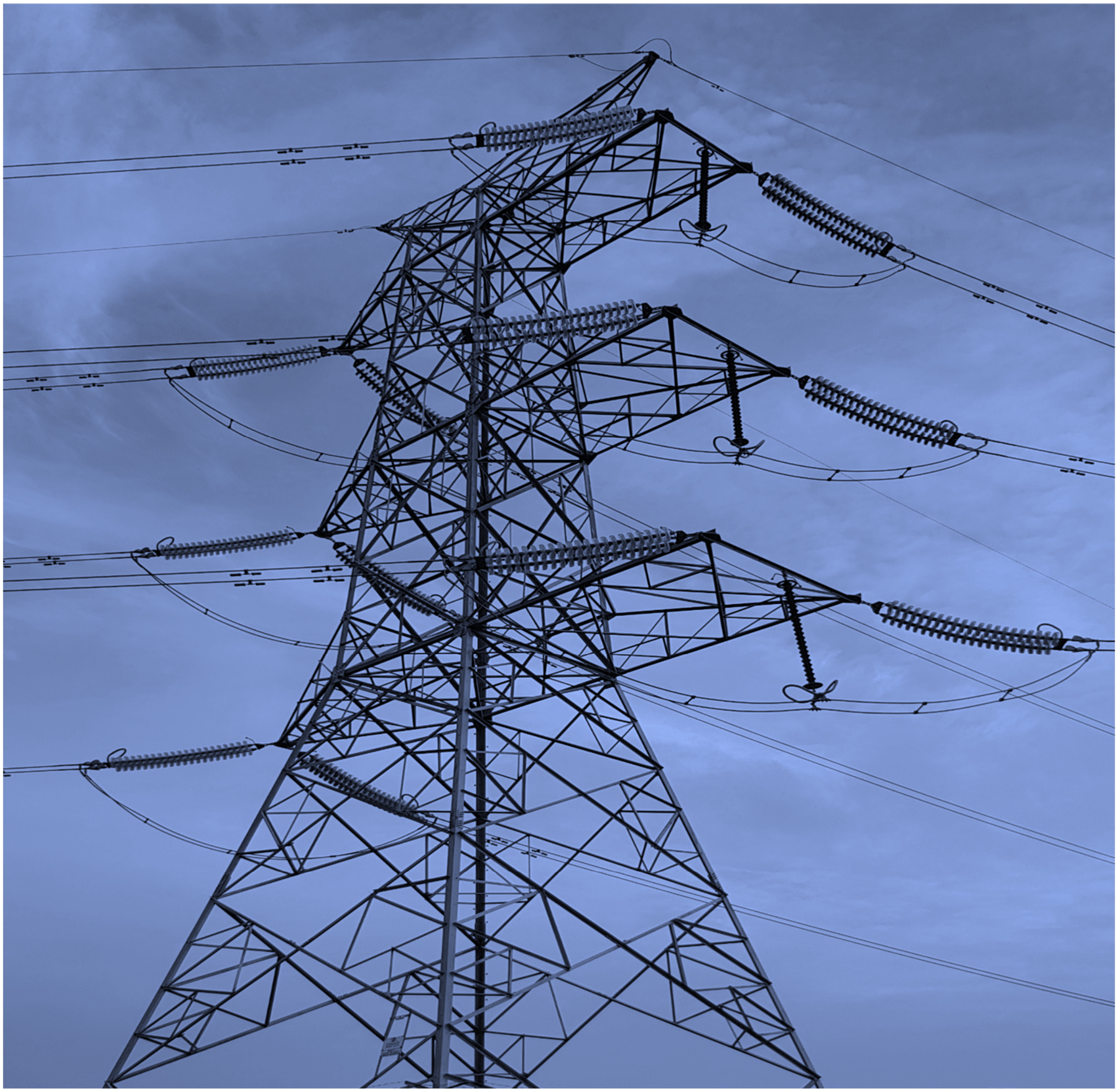
Table 8.7: Comparison of system losses (MW) - Siting Generation at Kumasi

It also shows bus voltage improvements in Accra, Winneba and Kasoa as shown in Table 8.8.

Bus Voltage (kV)	No generation at Winneba	360 MW generation at Winneba
Mallam	152.5	156.4
Achimota	155.3	157.9
Winneba	149.7	161.3
Accra Central	152.7	156.1
Kasoa	150.5	158

Table 8.8: Comparison of bus Voltages (MW) - Siting generation at Winneba

Furthermore, in the event of an outage to the 330kV Aboadze – Volta line, the remaining Coastal lines get highly loaded (about 86% of line thermal capacity). With generation in Winneba the flow on the line reduces to 29% of the line's thermal capacity under same contingency (with the 330kV Aboadze - Volta line still out of service).



Chapter 9

CONCLUSION

9 CONCLUSIONS

The following conclusions are drawn in respect of the electricity supply and demand plan for 2020 and for the medium term (2021 – 2025):

9.1 Demand and Supply Outlook

j) The 2020 total system demand is projected to be 3,115 MW (base case), representing a 11.1 % growth over the 2019 peak demand of 2,804 MW. The corresponding projected energy consumption for 2020 is 19,594.44 GWh of which:
   - ✓ Hydro supply will be 6,228.74 GWh representing 32% of the total energy supply;
   - ✓ Thermal supply will be 13,307.96 GWh representing 67.3% of total energy supply; and

k) Renewables supply will be 57.7 GWh representing 0.3% of total energy supply

l) Total projected energy exports are 1,652.1 GWh for 2020.

m) VALCO is expected to operate on two pot lines with projected total consumption of 1,229.8 GWh.

n) There is the need to dispatch Akosombo and Bui Hydro Plants conservatively throughout 2020 to ensure that the two reservoirs are not drawn down below their minimum operating levels to guarantee sustainable operations in the coming years

o) In terms of fuel, the following quantities of the various fuel types are required;
   - ✓ Natural Gas - 114,784,040 MMBtu
   - ✓ HFO - 212,858 barrels
   - ✓ LCO 136,147

p) In terms of fuel cost, an annual total of approximately **740.81** Million USD is required, averaging a monthly total of some US$ **61.7** Million.

q) In 2020, Tema industrial zone will be the largest generation enclave in Ghana with an installed capacity of 1,978.5 MW

r) Under maximum west generation scenario with KarPower in the West, the autotransformers at Volta will become overloaded leading to low voltages in the East (Accra/Tema Area).

9.2 Requirements for Grid Reinforcement

a) The transmission system has inadequate available transfer capacity to meet the demand requirements of the major load centres (of Accra, Kumasi, Tarkwa, etc.) particularly at peak. This situation would result in low voltages, overloading of lines and increased overall transmission system losses.

b) For radial lines and single transformer stations, significant percentage of network loads could be islanded in the event of outage of such lines and transformers.

c) In normal operation, there would be congestion on the Volta –Accra East – Achimota - Mallam transmission corridor especially when there is high generation in the east.

d) Severe low voltages would be experienced at Kumasi, Accra and surrounding areas in the event of loss of the 330 kV Aboadze – Kumasi and the 330 kV Aboadze – Tema transmission line respectively.

e) A fair East-West balance in generation provide better system stability and minimal overall transmission system losses.

f) In the first quarter of 2020, there is would be high generation from the western generation enclave due to planned maintenance work by WAGPCo on their gas pipeline. The high West dispatch will result in a significant increase in transmission system losses from a current of 3.77 % (as at December 2019) to an average high of 5.08% in the period.

g) A high west dispatch is likely to result in the heavy loading (**91%** of its MVA rating) of the 330/161kV 2x200MVA Autotransformers at the 330kV Anwomaso substation and a congestion on the 161 kV Aboadze – Accra transmission corridor, this would result in voltage violations in major substations in the Eastern portion of the grid as follows:

- ✓ the 161kV Winneba,
- ✓ 161kV Achimota,
- ✓ 161kV Accra East,
- ✓ 161kV Mallam and
- ✓ the 161kV Accra Central.

A minimum thermal generation would be required in east to compliment three Akosombo units to raise the bus voltages to acceptable levels during this period.

9.3 Distribution Systems

a) The commissioning of the Accra Central BSP has increased the level of reliability and distribution capacity to meet the growing demand within the ECG network in Accra. This has resolved the loading constraints on selected 33 kV feeders and reduce technical losses within the ECG Accra network.

b) In a bid to improve voltages in Nsawam and Mampong/Aburi, ECG has installed a number of Voltage Regulators to improve on reliability and quality of supply. Furthermore, a number upgrade projects have either been commissioned into service or under construction. This is to increase distribution capacity and reliability of supply customers.

c) Power supply reliability in NEDCo Areas is generally good. However, reliability in some areas of the network has been lower than expected due to over extension and over-ageing resulting in high technical losses. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them.

9.4 Medium Term Supply

a) Total electricity consumption of Ghana including power exports to Togo, Benin, Burkina Faso and Mali is projected to increase from **20,773** GWh in 2021 to **28,559** GWh by 2025 at a Compound Annual Growth Rate (CAGR) of approximately 8.3 %. The Ghana system peak demand is projected to increase from 3,263 MW in 2021 to 4,403 MW in 2025.

b) It is expected that with the deployment of the committed generation capacity, there would be adequate dependable generation capacity to meet projected demand including a reserve capacity of 18% for the period 2021 - 2023 with a highest surplus of 25.25% for 2021 and lowest of 6.82% for 2023.

There would be a deficit in supply of 224.18 MW and 430.96 MW for the years 2024 and 2025 respectively, notwithstanding the coming online of currently ongoing generation capacity addition projects. Therefore, additional generation capacities of 225 MW and 210 MW would repectively be required to be procured and commissioned into service by January, 2024 and 2025.

Chapter 10

RECOMMENDATIONS

10 RECOMMENDATIONS

Based on the above conclusions, the following recommendations are made:

a) The ongoing transmission expansion projects should be expedited and completed in 2020 to ensure that the peak demand can be supplied. These are:
   - ✓ Volta – Achimota – Mallam Transmission Line Upgrade Project
   - ✓ Kumasi – kintampo 330 kV transmission line Project

b) A well-coordinated maintenance programme should be pursued by both GRIDCo and the Generating Companies (GENCOs).

c) Fuel supply security and adequacy remains the single most important risk to power supply reliability in Ghana. In this vein, it is strongly recommended that all the relevant sector agencies stakeholders work conscientiously together to ensure that fuel supply is adequate and secure at all times.

d) For the medium term, the reserve margin for the 2024 and 2025 falls short of the required reserve margin of 18% (for reliability of supply). Therefore, additional generation capacity would need to be procured in time for commissioning by the beginning of 2024 and 2025. The recommendation of the medium to long-term system plan should be followed through to ensures that adequate resources provision would be made available to meet future electricity demands.

e) In order to meet the transmission reliability indices, the following are the critical transmissions additions and upgrades are required:
   - ✓ Upgrade of 161kV Aboadze-Takoradi-Tarkwa-Prestea
   - ✓ Construction of a second 330 kV Prestea - Dunkwa – Kumasi line
   - ✓ Upgrade of 161kV Aboadze-Mallam transmission lines
   - ✓ 161 kV Mallam – A4BSP transmission line link
   - ✓ Construction of a second 330 kV Aboadze – A4 BSP circuit
   - ✓ Construction of a double circuit 330 kV line from A4BSP to Kumasi
   - ✓ Construction of a 330 kV substation at Dunkwa with a link to the existing 161 kV substation

11 APPENDICES

Appendix A –Forecast: Peak and Energy Demand

A1: Base Case - Peak Demand Forecast (MW): 2020 - 2029

A2: Base Case - Energy Demand Forecast (GWh) -2020 – 2029

Appendix B – List of NEDCo Projects aimed at reducing network losses

Appendix C – Glossary

Appendix D– Grid Map

Appendix E – Summary of NITS Load Flow analyses (Contingency Cases)

APPENDIX A - FORECAST PEAK DEMAND AND ENERGY CONSUMPTION

A1: Base Case - Peak Demand Forecast (MW): 2020 – 2029

Load forecast: Peak demand (MW)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
ECG	1,875	1,958	2,054	2,161	2,278	2,425	2,581	2,748	2,925	3,113
NEDCo	243	256	265	274	281	291	300	310	320	331
ENCLAVE POWER COMPANY	57	71	74	77	82	85	91	94	99	103
MINES	246	266	284	318	324	325	329	328	327	325
Other Bulk Customers	50	58	58	59	59	59	59	59	59	59
VALCO	150	150	300	300	500	500	825	1,150	1,150	1,150
CEB(Togo/Benin)	180	200	200	200	200	200	200	200	200	200
SONABEL(Burkina)	150	161	172	184	195	206	219	232	246	261
CIE(Ivory Coast)	0	0	0	0	0	0	0	0	0	0
EDM(Mali)	0	0	0	0	50	100	100	100	100	100
Network Usage	2	2	2	2	2	2	3	3	3	3
LOSSES	162	142	158	179	206	210	249	287	304	327
Total	3,115.15	3,263	3,566	3,753	4,177	4,403	4,956	5,511	5,733	5,973

A2: Base Case -Projected Energy Demand (GWh) -2020-2029

Load forecast: Energy (GWh)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
ECG	12,234.84	12,780.53	13,403.75	14,106.05	14,867.06	15,825.57	16,845.88	17,931.97	19,088.09	20,318.74
NEDCo	1,462.70	1,510.70	1,562.50	1,615.40	1,659.30	1,715.70	1,771.20	1,829.20	1,889.40	1,951.75
ENCLAVE POWER COMPANY	283.78	352.44	366.17	384.48	407.36	421.09	448.56	466.86	494.33	512.64
MINES	1,618.69	1,851.68	1,993.84	2,250.17	2,294.96	2,310.18	2,338.64	2,332.53	2,320.60	2,310.85
DIRECT	236.39	265.10	279.02	346.86	346.86	346.86	346.86	347.86	347.86	347.86
VALCO	1,229.76	1,314.00	2,628.00	2,628.00	4,380.00	4,380.00	7,227.00	10,074.00	10,074.00	10,074.00
CEB(Togo/Benin)	902.06	1,051.20	1,051.20	1,051.20	1,051.20	1,051.20	1,051.20	1,051.20	1,051.20	1,051.20
SONABEL(Burkina)	750.00	843.59	902.64	965.82	1,023.77	1,085.20	1,150.31	1,219.33	1,292.49	1,370.04
CIE(Ivory Coast)	-	-	-	-	-	-	-	-	-	-
EDM(Mali)	-	-	-	-	328.50	657.00	657.00	657.00	657.00	657.00
Network Usage	9.65	10.46	11.62	12.22	13.80	14.55	16.67	18.80	19.49	20.21
LOSSES	866.57	793.13	886.02	1,002.62	1,160.51	751.93	842.92	933.34	994.67	1,083.37
Total	19,594.44	20,772.81	23,084.75	24,362.83	27,533.32	28,559.29	32,696.24	36,862.10	38,229.12	39,697.66

APPENDIX B: List of NEDCo Projects aimed at reducing network losses

No.	Project Description/ Activities	Rational for Project	Expected Benefits
1	DNMS (Distribution Network Management System)	Improvement of reliability throughout the NEDCo network	Improved reliability through ease of detection of faults and reduction in response times to faults.
2	34.5kV switching station at Tumu	This will improve reliability by providing switching flexibility	Improve power supply to Tumu township and its environs.
3	Supply and Installation of Portable Capacitor bank for Bimbilla Feeder	Compensation for voltage drop on lines	Improved power quality on the Bimbilla feeder for its environs
4	34.5kV switching station at Bimbilla	This will improve reliability by providing switching flexibility	Improve power supply at Bimbilla, Kpassa, Salaga Kete-krachi and surrounding communities
	34.5kV Tumu switching station	This will improve reliability by providing switching flexibility	Improve power supply at Tumu, Gwllu, , Kpassa, Salaga Kete-krachi and surrounding communities
6	Construction of Lamashegu 34.5/11kV substation and sub transmission lines	Improve power supply quality and reliability	This will allow access to power for new customers and more reliable electricity supply to existing customers
7	Re-energization of Pwalugu substation	Improve power supply quality and reliability	This will allow access to power for new customers and more reliable electricity supply to existing customers

APPENDIX C: GLOSSARY OF ELECTRICAL UTILITY TERMS

1000 Watt-hours	=	1 Kilo Watt-hour (kWh)
1000 Kilo Watt-hour	=	1 Mega Watt-hour (MWh)
1000 Mega Watt-hour	=	1 Giga Watt-hour (GWh)
1000 Giga Watt-hour	=	1 Tera Watt-hour (TWh)

Average Day Load

The average system demand is indicative of the system's load during most part of the day that is from 7: am – 5: pm apart from the peak load.

Capability

The maximum load a generator, piece of equipment, substation, or system can carry under specified (standardized) conditions for a given time interval without exceeding approved limits.

Capacitor

1) In a power system, installed to supply reactive power.

2) A device to store an electrical charge (usually made of two or more conductors separated by a non-conductor such as glass, paper, air, oil, or mica) that will not pass direct current and whose impedance for alternating current frequencies is inversely proportional to frequency. 3) In a power system, capacitors consist of metal-foil plates separated by paper or plastic insulation in oil or other suitable insulating fluid and sealed in metal tanks.

Capacitor bank

A grouping of capacitors used to maintain or increase voltages in power lines and to improve system efficiency by reducing inductive losses.

Capacity

The rated continuous load-carrying ability, expressed in megawatts (MW) or megavolt-amperes (MVA) of generation, transmission, or other electrical equipment.

Installed Capacity

The total of the capacities shown by the name plate ratings of similar kinds of apparatus, such as generators, transformers, or other equipment in a station or system.

Combined Cycle

An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. Such designs increase the efficiency of the electric generating unit.

Conductor

A substance or body that allows an electric current to pas continuously along it.

Contingency

In a power system, the possibility of a fault or equipment failure. First contingency disturbances (outages) involve only one system element, such as a transmission line fault or a transformer failure. A second contingency disturbance would have one system element out of service and subject the system to a fault and loss of a second element.

Demand

The rate at which electric energy is delivered to or by the System or part of the System and is the sum of both Active and Reactive Power, unless otherwise stated.

Demand, Peak:

The highest electric requirement occurring in a given period (e.g., an hour, a day, month, season, or year). For an electric system, it is equal to the sum of the metered net outputs of all generators within a system and the metered line flows into the system, less the metered line flows out of the system.

Dispatch

The operating control of an integrated electric system to: (1) assign specific generating units and other sources of supply to meet the relevant area Demand taken as load rises or falls; (2) control operations and maintenance of high voltage lines, substations and equipment, including administration of safety procedures; (3) operate interconnections; (4) manage energy transactions with other interconnected Control Areas; and (5) curtail Demand.

Disturbance

An unplanned event that produces an abnormal system condition. Any occurrence that adversely affects normal power flow in a system

Fault

An event occurring on an electric system such as a short circuit, a broken wire, or an intermittent connection.

Generation (Electricity)

The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

Giga (G)

A prefix indicating a billion (1,000,000,000); 109 in scientific notation. Hence Gigawatt (GW) and Gigawatt-hour (GWh).

Grid

The transmission network (or "highway") over which electricity moves from suppliers to customers.

Grid Operator

An entity that oversees the delivery of electricity over the grid to the customer, ensuring reliability and safety.

High voltage:

Descriptive of transmission lines and electrical equipment with voltage levels from 100 kV through 287 kV.

Independent Power Producer (IPP):

A private entity that operates a generation facility and sells power to electric utilities for resale to retail customers.

Insulator:

The porcelain support used to insulate electric service wires from the pole. All electric lines require an insulator to attach the wires to the pole or to a residence.

Interconnected System

A system consisting of two or more individual electric systems that normally operate in synchronism (matching frequency, voltage, phase angles, etc) and have connecting tie lines.

Kilowatt (kW)

One thousand watts of electricity (See Watt).

Kilo watthour (kWh):

One thousand watthours.

Load

The amount of power carried by a utility system or subsystem, or amount of power consumed by an electric device at a specified time. May also be referred to as demand. A connection point or defined set of connection points at which electrical power is delivered to a person or to another network or the amount of electrical power delivered at a defined instant at a connection point, or aggregated over a defined set of connection points.

Load Centers

A geographical area where large amounts of power are drawn by end-users.

Losses

Electric energy losses in the electric system which occur principally as energy transformation from kilowatt-hours (kWh) to waste heat in electrical conductors and apparatus.

Maximum Demand:

The highest amount of electrical power delivered, or forecast to be delivered, over a defined period (day, week, month, season or year) at a defined.

Megawatt (MW)

One million watts of electricity (See Watt).

masl

Metres above sea level

Overload

Operation of equipment in excess of its normal, full load rating or operation of a conductor in excess of ampacity, and if continued for a sufficient length of time, would cause damage or overheating.

System Planning

The process by which the performance of the electric system is evaluated and future changes and additions to the bulk electric systems are determined.

Power System

The electricity power system of the national grid including associated generation and transmission and distribution networks for the supply of electricity, operated as an integrated arrangement.

Reactive Power

Means the product of voltage and current and the sine of the phase angle between them measured in units of volt-amperes reactive and standard multiples thereof. Reactive power is a necessary component of alternating current electricity which is separate from active power and is predominantly consumed in the creation of magnetic fields in motors and transformers and produced by plant such as: (a) alternating current generators (b) capacitors, including the capacitive effect of parallel transmission wires;(c) synchronous condensers.

Reliability

The degree of performance of the elements of the bulk electric system that results in electricity being delivered to customers within accepted standards and in the amount desired. It is a measure of the ability of a power system to provide uninterrupted service, even while that system is under stress. Reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply. Electric system reliability has two components -- adequacy and security.

Adequacy is the ability of the electric system to supply the 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 is the ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system facilities.

Single Contingency

The sudden, unexpected failure or outage of a system facility(s) or element(s) (generating unit, transmission line, transformer, etc.). Elements removed from service as part of the operation of a remedial action scheme are considered part of a single contingency.

Stability

The ability of an electric system to maintain a state of equilibrium during normal and abnormal system conditions or disturbances.

Supervisory Control and Data Acquisition (SCADA)

A computer system that allows an electric system operator to remotely monitor and control elements of an electric system.

Switching Station

An installation of equipment where several transmission lines are interconnected. Does not include equipment for transforming voltage levels.

Power System

An interconnected combination of generation, transmission, and distribution components comprising an electric utility, an electric utility and independent power producer(s) (IPP), or group of utilities and IPP(s).

Right of Way (ROW)

A corridor of land on which electric lines may be located. The Transmission Owner may own the land in fee, own an easement, or have certain franchise, prescription, or license rights to construct and maintain lines.

Thermal Limit

The maximum amount of electrical current that a transmission line or electrical facility can conduct over a specified time period before it sustains permanent damage by overheating or before it violates public safety requirements.

Transfer Capability

The amount of power, usually the maximum amount, that can be transmitted between one system and another; power flow and stability studies determine transfer capability under various outage, system loading, and system operating conditions.

Transformer

A device for transferring electrical energy from one circuit to another by magnetic induction, usually between circuits of different voltages. Consists of a magnetic core on which there are two or more windings. In power systems, most frequently used for changing voltage levels.

Transmission System (Electric)

An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

Utility

A public or private organization created for the purpose of selling or supplying for general public use water, electric energy, telephone service, or other items or services.

Voltage

The electronic force or electric potential between two points that gives rise to the flow of electricity.

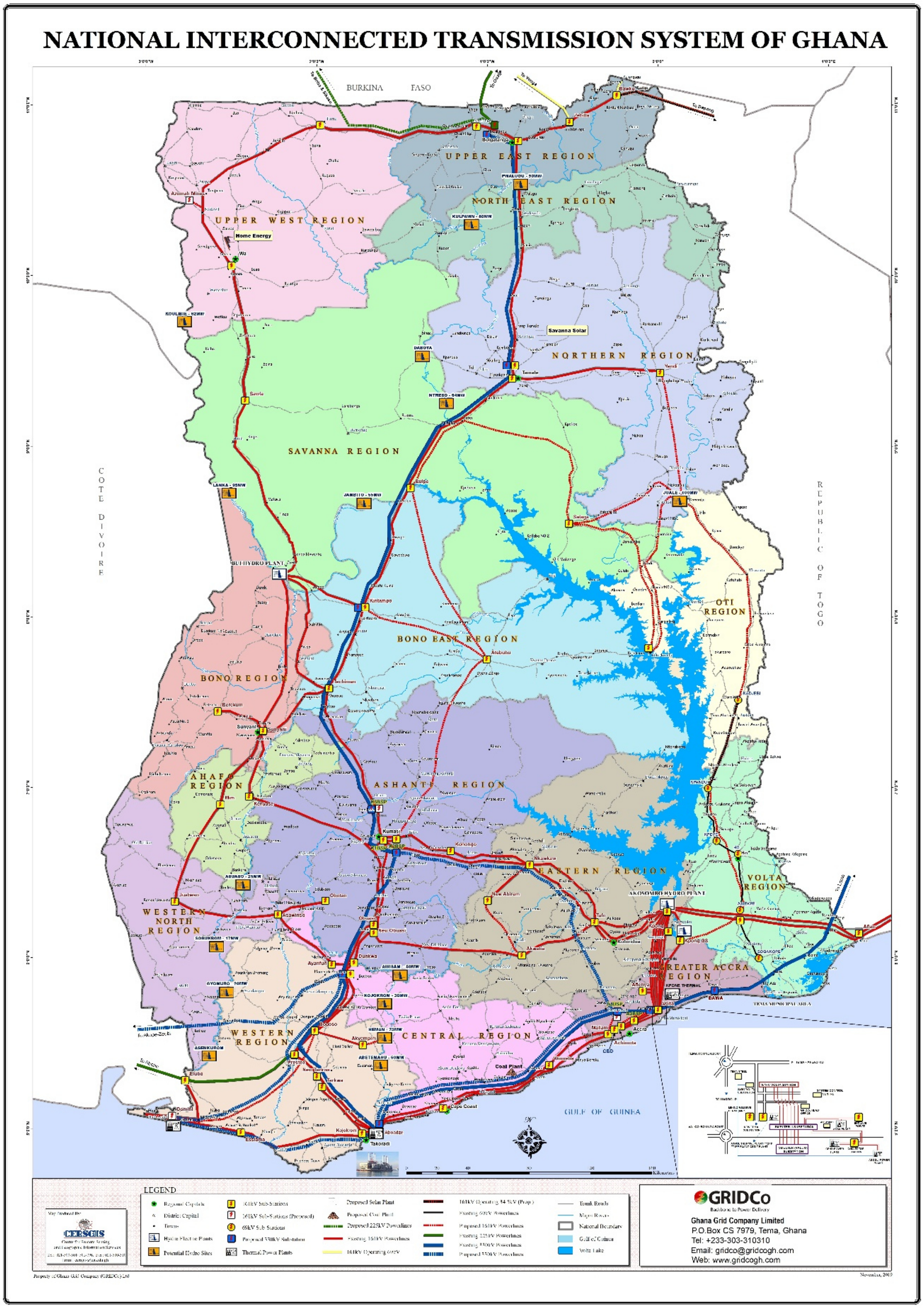
Voltage Stability

The condition of an electric system in which the sustained voltage level is controllable and within predetermined limits.

Wheeling

The use of the facilities of one transmission system to transmit power and energy from one power system to another.

APPENDIX D – GRID MAP



APPENDIX E: Summary of NITS Load Flow analyses (Contingency Cases)

Table 11.1: 2020 Optimal Dispatch Contingencies

Transmission Line overload causing contingencies			
Line	Line Loading violation	Remarks	Recommended solution
330 kV Aboadze– Anwomaso	N/A	The load flow does not converge due to the high quantum of power (approx. 350MW) flowing on the 330kV new lines from Aboadze prior to the line contingency.	• Due to the high quantum of power flown on these lines, rerouting onto the 161kV system will not augur well for the system. • Reduce power export levels to SONABEL. • Embark on effective load management (load shedding) within the vicinity of these lines.
330 kV Anwomaso– Kintampo	N/A	The load flow does not converge. From Anwomaso, about 200MW of power flows to Kintampo prior to the line contingency.	
330 kV Kintampo – Tamale	N/A	The load flow does not converge. Also from Kintampo, about 207MW of power flows to Tamale prior to the line contingency.	
330 kV Tamale – Bolgatanga	N/A	The load flow does not converge. Also from Kintampo, about 165MW of power flows to Bolgatanga prior to the line contingency.	
161 kV Aboadze – Tarkwa	161 kV Aboadze – Takoradi (91.0%). 161 kV Takoradi – Tarkwa (127%).	The load flow converges. Adjacent small capacity lines become overloaded as indicated.	• Embark on effective load management (load shedding) between Tarkwa and Prestea to curtail further system disturbance. • Short term measure is to upgrade the 161kV Western lines from Aboadze to Prestea
System Voltage violation causing contingencies			
Line	Voltage violation	Remarks	
161 kV Dunkwa – Ayanfuri	Observed bus voltage violations on some buses on the following buses: Ayanfuri (137.68 kV, 0.86 PU), Obotan (140.46 kV, 0.87PU), Asawinso (142.92 kV, 0.88PU), Juabeso (144.91 kV, 0.90PU), Mim (151.20 kV, 0.94PU).	The load flow converges.	• Embark on effective load management (load shedding) within the vicinity of the lines to curtail voltage collapse.
161 kV Bui – Sawla	Observed bus voltage violations on some buses on the following buses:	The load flow converges.	

Transmission Line overload causing contingencies			
Line	Line Loading violation	Remarks	Recommended solution
161 kV Aboadze T3–Cape Coast	Sawla (142.78 kV, 0.89 PU), Wa (143.69 kV, 0.89PU). Observed bus voltage violations on some buses on the following buses: Cape Coast (141.80 kV, 0.88 PU), Winneba (152.11 kV, 0.94PU), Mallam (151.92, 0.94PU).	The load flow converges.	

Table 11.2: *2020 High East Dispatch Contingencies*

Line	Line Loading violation	Remarks	Recommended solution
	Transmission Line overload causing contingencies		
330 kV Aboadze – Anwomaso	N/A	The load flow does not converge. This is primarily due to the high quantum of power (approx. 320MW) flowing on the 330kV new lines from Aboadze prior to the line contingency.	• Due to the high quantum of power flown on these lines, rerouting onto the 161kV system will not augur well for the system. • Reduce power export levels to SONABEL. Embark on effective load management (load shedding) within the vicinity of these lines.
330 kV Anwomaso – Kintampo	N/A	The load flow does not converge. From Anwomaso, about 190MW of power flows to Kintampo prior to the line contingency.	
330 kV Kintampo – Tamale	N/A	The load flow does not converge. Also from Kintampo, about 200MW of power flows to Tamale prior to the line contingency.	
330 kV Tamale – Bolgatanga	N/A	The load flow does not converge. Also from Kintampo, about 160MW of power flows to Bolgatanga prior to the line contingency.	
161 kV Achimota – Accra Central line	161 kV Achimota -Mallam (197%).	Line initially flow in excess of 170 MW. Upon contingency, adjacent small capacity lines become overloaded.	• Embark on effective load management (load shedding) in the Achimota-Accra Central load centres, possibly load shifting to other surrounding load centres in the vicinity to curtail further system disturbance.
		System Voltage violation causing contingencies	
Line	*Voltage violation*	*Remarks*	
161 kV Dunkwa – Ayanfuri	Observed bus voltage violations on some buses on the following buses: Ayanfuri (138.43 kV, 0.86 PU), Obotan (141.20 kV, 0.88PU), Asawinso (141.65 kV, 0.88PU), Juabeso (145.54 kV, 0.90PU), Mim (151.69 kV, 0.94PU).	The load flow converges.	• Embark on effective load management (load shedding) within the vicinity of this line. • Short-medium term measure is to upgrade the small capacity 161kV Dunkwa-Ayanfuri-Asawinso line into bigger capacity line.
161 kV Bui – Sawla	Observed bus voltage violations on some buses on the following buses:	The load flow converges.	• Bring in Bui condenser to support voltages up north

Transmission Line overload causing contingencies			
Line	Line Loading violation	Remarks	Recommended solution
	Sawla (142.49 kV, 0.89 PU), Wa (143.41 kV, 0.89PU).		• Last resort, embark on effective load management (load shedding) within the vicinity of this line.

Table 11.3: 2020 High West Dispatch Contingencies

Transmission Line overload causing contingencies			
Line	Line Loading violation	Remarks	Recommended solution
330 kV Aboadze – Anwomaso	N/A	The load flow does not converge due to the high quantum of power (approx. 420MW) flowing on the 330kV new lines from Aboadze prior to the line contingency.	• Due to the high quantum of power flown on these lines, rerouting onto the 161kV system will not augur well for the system. • Reduce power export levels to SONABEL.
330 kV Anwomaso – Kintampo	N/A	The load flow does not converge. From Anwomaso, about 200MW of power flows to Kintampo prior to the line contingency.	• Embark on effective load management (load shedding) within the vicinity of these lines.
330 kV Aboadze – Volta	N/A	The load flow does not converge. Also from Aboadze, about 270MW of power flows to Tema prior to the line contingency.	• Short term measure is to integrate the A4BSP substation. • Medium to long term measure is to upgrade the 161kV Coastal lines to higher capacity 488MVA
161 kV Tarkwa – Prestea	• 161 kV New Tarkwa – Prestea (151%). • 161 kV Tarkwa – New Tarkwa (159%).	The load flow converges. Adjacent small capacity lines become overloaded.	• Embark on effective load management (load shedding) within the vicinity of the line. • Short term measure is to upgrade the 161kV Western lines
161 kV Aboadze – Tarkwa	• 161 kV Aboadze – Takoradi (110%). • 161 kV Takoradi – Tarkwa (163%).	The load flow converges. Adjacent small capacity lines become overloaded.	• Embark on effective load management (load shedding) within the Tarkwa to Prestea vicinity. • Short term measure is to upgrade the 161kV Western lines from Aboadze to Prestea.
System Voltage violation causing contingencies			
Line	Voltage violation	Remarks	Recommended solution
330 kV Adubiyili – Nayagnia	N/A	The load flow does not converge due to voltage support issues in that vicinity.	• Reduce power export levels to SONABEL. • Embark on effective load management (load shedding) within the vicinity of line.
161 kV Takoradi Extension – Cape Coast – Winneba	N/A	The load flow does not converge due to voltage support issues in that vicinity.	• Embark on effective load management (load shedding) within the vicinity of line.

Transmission Line overload causing contingencies			
Line	Line Loading violation	Remarks	Recommended solution
161 kV Dunkwa – Ayanfuri	Ayanfuri (129.79 kV, 0.81 PU), Obotan (132.76 kV, 0.82PU), Asawinso (133.39 kV, 0.83PU), Juabeso (138.73 kV, 0.86PU), Mim (147.03 kV, 0.91PU)	The load flow converges. Surrounding substations recorded severe low voltages.	• Medium to long term measure is to upgrade the 161kV Coastal lines to higher capacity 488MVA • Embark on effective load management (load shedding) within the vicinity of this line. Short-medium term measure is to upgrade the small capacity 161kV Dunkwa-Ayanfuri-Asawinso line into bigger capacity line.
161/330kV Autotransformer at Volta	N/A	The load flow does not converge. This is due to the high quantum of power flown on the 330kV Aboadze-Volta line and through the Autotransformers. A contingency reroutes power onto the 161kV Coastal lines which will not augur well for the system	Install the third Autotransformer between Asogli and Collector.