REPUBLIC OF GHANA

2017

Electricity Supply Plan

for the Ghana Power System

A 2017 Power Supply Outlook with Medium Term projections

2017 ELECTRICITY SUPPLY PLAN FOR GHANA

An Outlook of the Power Supply Situation for 2017 and Highlights of Medium Term Power Requirements

ACKNOWLEDGEMENT

We hereby wish to express our deepest appreciation to the supply plan committee which is made up of experts from Energy Commission, GRIDCo, VRA, BPA, ECG and NEDCo as follows:

- Frank Otchere – Ghana Grid Company Limited *(Chairman)*
- Benjamin Ntsin – Ghana Grid Company Limited
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EXECUTIVE SUMMARY

In line with the requirement of the Ghana Grid Code, we present in this document the Electricity Supply Plan for the year 2017.

The report was prepared by the Supply Plan Committee. It presents an outlook of power demand and supply for 2017 taking into consideration all the firm additional new projects and existing generation sources. It assesses the available hydro generation taking into consideration low reservoir elevations at Akosombo and provides the likely power supply situation for 2017. It gives an idea of fuel requirements and associated cost and evaluates the power evacuation requirements for reliable power supply. It highlights the anticipated challenges and makes recommendations on the best course of action to ensure reliable power supply for 2017. The report further provides an outlook of the electricity demand and supply requirements for the next five years.

Review of 2016 Performance

Peak Demand

In 2016, the power system recorded a coincident system peak load of 2,087 MW on November 29, 2016 which represents an increase of 154 MW (8%) over the 2015 coincident system peak of 1,933 MW.

Energy Consumption

The total energy consumed (including losses) for the period was 13,700 GWh. This compared to the 2015 value of 11,692 GWh represents a 17.2% growth in energy consumption.

Energy Supply

The total energy supplied (including imports from Cote d'Ivoire) over the period was 13,707 GWh. This comprises 5,561 GWh hydro generation, 7,381 GWh thermal generation and 765 GWh Imports.

Transmission Lines and Feeder Availability

The average feeder availability on the NITS in 2016 was 97.07 % and the System Average Availability (SAA) for the transmission grid was 99.37 %.

2017 Demand Outlook

The projected system peak demand for 2017 is 2,386 MW which represents a 14.2 % growth over the system peak demand for 2016 of 2,087 MW. The projected annual consumption for 2017 is 15,614 GWh which represents 13.8% (in absolute terms, an increase of 1,914 GWh) growth over the 2016 actual annual consumption of 13,700 GWh.

2017 Supply Outlook

Hydro Power Generation for 2017

The projected total hydro generation for 2017 is 5,244 GWh, this would be made up of 3,681 GWh, 723 GWh and 840 GWh from Akosombo, Kpong and Bui Generation Station respectively.

Akosombo Hydro Elevation

The Akosombo Lake elevation at January 1, 2017 was 250.5 feet and is expected to bottom up at 240.5 feet in 2017.

Bui Hydro Elevation

The Bui elevation at January 1, 2017 was 175.87 m and is expected to bottom up at 170.52 m in 2017.

Thermal Power Generation for 2017

The projected total thermal generation for 2017 is 9,937.48 GWh. The generation would be made up of generation from the following plants:

Projected Thermal Supply	Energy (GWh)
VRA Existing Thermal & Solar Generation	
T1	1,258
T2	1,983
TT1PP	177
TT2PP + TT2PP-X	0
MRPP	0
KTPP	62
Solar	4
Total VRA Thermal Generation	**3,484**
Existing IPP Thermal Generation	

Projected Thermal Supply	Energy (GWh)
SAPP (includes new plant)	1,477
CENIT	154
AMERI	1,619
Karpower Barge	1,802
AKSA	1,174
Trojan	19
Central Solar	**32**
Total IPP Thermal Generation	**6,277**
Total VRA Supply	**7,884**
Total Non-VRA Supply	**7,118**
Import	615
Total Supply	**15,615**

Fuel Cost

Based on the projected thermal generation of 9,937.48 GWh for 2017, an estimated US$989.9 Million will be required to purchase LCO, Natural Gas, HFO and diesel to run the thermal plants. About US$ 540.53 million will be required by VRA and about US$ 674.9 million will be required by the IPPs.

TYPE OF FUEL	COST (Million USD)
VRA – LCO	147
VRA – GAS	130
VRA – DFO	18
TOTAL VRA FUEL COST	**296**
IPP – GAS	181
IPP – LCO	114
IPP – HFO	357
IPP – DFO	5
TOTAL IPP FUEL COST	**656**
TOTAL VRA & IPP COST	**951**

Import from Ivory Coast

A total of 615 GWh of energy and a maximum of 200 MW of power is expected to be imported from Ivory Coast from January to May 2017.

Solar Power Plant

The VRA 2.5 MWp solar power and BXC 20 MWp plant which are all connected onto the medium Voltage distribution system are expected to produce a total of 36 GWh of energy.

2017 Distribution Outlook

A number of concerns were identified in the distribution network.

ECG Network

A reliability study carried out on the four major load centers: Accra, Kumasi, Tema and Takoradi identified distribution line congestion, poor voltages and overloads on transformers. It should be noted however that these constraints are not widespread. ECG has embarked on a number projects to address the constraints.

NEDCo Network

There are some capacity and voltage constraints within some sections (Wa, Bawku, Navrongo, Atebubu, Ejura, etc.) of NEDCo's sub-transmission network which require to be addressed to guarantee the reliability and quality of supply to consumers. There are also a number of obsolete switchgear identified in Bawku and Navrongo primary substations. NEDCo has embarked on a number projects to address the constraints.

Medium Term

Demand and Supply Projections

The medium term (2018-2022) demand and supply table below shows that whereas in 2018 there is excessive supply surplus of 1019 MW it reduces drastically to only 20 MW by 2022.

Year	**2018**	**2019**	**2020**	**2021**	**2022**
Projected System Demand (MW)	**2,646**	**3,128**	**3,462**	**3,712**	**3,828**
Total Supply Required (Demand +Reserve)	**3,308**	**3,910**	**4,327**	**4,640**	**4,784**
Total Existing Hydro Capacity (MW)	**1,120**	**1,120**	**1,120**	**1,120**	**1,120**
Total Existing Thermal Capacity (MW)	**2,362**	**2,462**	**2,462**	**2,462**	**2,462**
Total Existing Renewables (MW)	**22.5**	**22.5**	**22.5**	**22.5**	**22.5**
Committed Generation Projects					
Karpower Phase II	220	220	220	220	220
CENPOWER	360	360	360	360	360
Early Power	142	300	400	400	400
GPGC	100	100	100	100	100
VRA T3	0	120	120	120	120
Total Committed Generation (MW)	**822**	**1,100**	**1,200**	**1,200**	**1,200**

Expected Total Generation (MW)	**4,326.5**	**4,704.5**	**4,804.5**	**4,804.5**	**4,804.5**
Surplus (MW)	**1,019**	**794**	**477**	**165**	**20**

Taking into consideration the fact that the average lead time of four (4) years for development of major generation projects**,** it is recommended for urgent steps to be taken to attract investment in additional generation to ensure adequate supply capacity with reserve margin for 2022 and beyond.

Strategic Medium Term NITS Requirements

System network analyses carried out indicate congestion, especially in the southern parts of the NITS. It further indicates that in the medium term the addition of the following transmission infrastructure will improve the reliability of Power Supply;

- Construction of a second Prestea - Dunkwa – Kumasi 330 kV line;
- Construction of a second 330 kV Aboadze – A4 BSP line;
- Construction of a double 330 kV A4BSP to Kumasi line;
- Eastern Transmission Corridor Projects (Kpando – Juale, Juale – Yendi)
- Construction of 330 kV substation at Dunkwa with a link to the existing 161 kV station;
- Construction of a third Bulk Supply Point in Kumasi at 330kV level.

New Generation Enclave on immediate West of Accra

Analyses carried out show that developing a new generation enclave of up to 200 MW on the immediate West of Accra (i.e. between Kasoa and Winneba) improves power evacuation in the South as follows:

- System losses reduce tremendously to **95.1 MW 3.96%** *(from 106 MW or 4.4 % of generation);*
- Congestion/overloading on the Volta-Accra, East-Achimota-Mallam corridor is reduced thereby delaying the need for future reinforcement of the corridor;
- Voltages in Accra and surrounding locations improve significantly;
- System reliability is improved;
- System stability is consequentially improved.

Impact of Siting Generation in Kumasi

Medium term analysis reveals that siting up to 200 MW generation resources in Kumasi addresses low bus voltages at the station. This confirms the Transmission Master Plan proposal to site a 300 MW combine cycle plant in Kumasi or Dunkwa to address the reactive power challenges.

Recommendation

a. Due to expected supply challenges during the 1st quarter, Akosombo Generating Station should run up to 6 Units to meet the expected system demand. The dispatch strategy for the rest of the year should be to run 3 units during off-peak and 4 units during peak periods. This mode of operation is expected to keep reservoir elevation at 240.55 ft. before the onset of the inflow season;

Fuel Type	Quantity	Total Annual Cost (USM)
LCO	4,355,129 barrels	261
Gas	34,804,321 mmbtu	311
DFO	136,013 barrels	23
HFO	4,951,644	357

b. The planned 2017 grid expansion programmes especially those connected with transmission upgrades should be expedited and completed on schedule;

- The termination of Akosombo – Achimota transmission line at Volta,
- Prestea-Kumasi 330 kV line,
- Aboadze – Prestea double circuit 330kV line,
- Kpando - Kedjebi line,
- Volta - A3BS – Achimota - Mallam line upgrade,
- The construction of A4BSP.

c. All load entities should invest in reactive power compensation facilities to ensure that their customer-end power factors comply with the Grid Code (Article 9.33) requirement of 0.9 pu lagging;

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

e. Towards ensuring that there is adequate supply including reserve margin for reliability at all times in the medium term to serve ever-increasing demand, immediate steps should be taken to install additional as required. **NOTE: a**

typical thermal generation project takes averagely four (4) years to implement;

f. Initiate steps to develop a new generation enclave to the immediate West of Accra (between Kasoa and Winneba) to reduce losses, reduce congestion and delay the need for future investment on the Volta-Mallam corridor;

g. Initiate steps to install non-intermittent generation facilities *(such as waste-to-energy, etc.)* totalling up to 200 MW in Kumasi in the medium term. This would help to improve voltages in Kumasi and its surroundings. This is in accordance with the Transmission Master Plan proposal to site a 300 MW combine cycle plant either in Kumasi or Dunkwa to address the reactive power challenges;

h. The following substation projects should be expedited;

- The completion of the Afienya BSP,
- Expansion of the transformer capacity at the Sogakope BSP,
- Construction of the Pokuase BSP to improve voltage supply in the Ofankor – Nsawam environs.

i. The interventions detailed in Appendix C1 to address constraints on the ECG network in Accra, Kumasi, Tema and Takoradi should be expeditiously implemented to ensure that they are completed on schedule;

j. Put in necessary and timely financial arrangements to ensure the supply of the required quantities of fuel for running thermal plants at all times.

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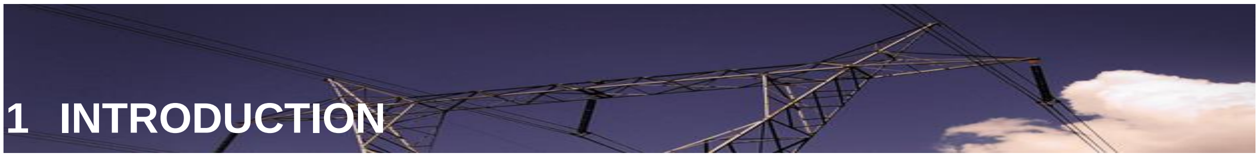


1 INTRODUCTION

This Supply Plan details projections for electricity demand and supply in 2017, based on available information and assumptions for load forecasting as well as the expected generation for the year. It presents the strategy for delivering electricity generation, transmission and distribution services on the Ghana power system in 2017 for the information of stakeholders and the general public.

It assesses the capacity for hydroelectric power production, taking into consideration the current reservoir elevations at Akosombo and Bui, thereby making recommendations for hydro power generation based on projections for the draft on the reservoirs in 2017. It further estimates the amounts of thermal generation required, together with the corresponding fuel requirements and associated costs. It goes on to evaluate the grid requirements for meeting the demand for 2017, highlights the anticipated challenges and makes recommendations on interventions necessary to ensure reliable power supply in Ghana in 2017.

The report was prepared by a team of experts from the Energy Commission, GRIDCo, ECG, NEDCo, BPA and VRA. The team consulted with all the power producers in the sector and other key stakeholders to firm up maintenance programmes, potential new projects and other information required to develop the Supply Plan. The team first conducted a comprehensive review of the power system performance in 2016 based on which demand and supply projections were made for 2017.

The report further makes projections for the medium term (2018 - 2022) electricity demand and supply outlook.

1.1 ORGANISATION OF THE REPORT

Chapter 1 of the report provides the Introduction, whiles chapter 2 presents a review of the 2016 performance of the power system. Chapter 3 presents the electricity demand outlook for 2017, whiles Chapter 4 focuses on the 2017 Generation Outlook together with the associated fuel requirements and costs. Chapter 5 takes a look at evacuation issues on the Transmission System whiles Chapter 6 highlights the anticipated challenges. Chapter 7 presents an outlook of electricity distribution on the ECG and NEDCo systems. Chapter 8 provides a medium term outlook for 2018 - 2022. Chapter 9 draws conclusions on the report and Chapter 10 presents recommendations to ensure the security and reliability of supply on the power system.

2 SYSTEM PERFORMANCE REVIEW FOR 2016

This chapter presents a review of the 2016 performance of the Ghana Power System. The review includes among others comparisons of the actual peak demand, energy generation and consumption against the projections for the review period. It also assesses the performance of the power system with respect to voltages, system frequency and transmission system losses.

2.1 Peak Demand and Energy Consumption

In 2016, the power system recorded a coincident system peak load of 2,087 MW on November 29, 2016 which represents an increase of 154 MW (8%) over the 2015 coincident system peak of 1,933 MW. The 2016 peak demand was however 390 MW (15.7 %) below the peak demand of 2,477 MW forecast for the 2016 Supply Plan.

A summary of the monthly actual peak demands against what was projected over the period is shown in the table below:

Table 1: System Peak Demand and Projection for the Year 2016

Month	*Actual Demand (MW)*	*Projected Demand (MW)*	**Actual – Projected** *(MW)*
January	**1999**	**2331**	**-332**
February	**1987.2**	**2308**	**-320.8**
March	**1982.2**	**2326**	**-343.8**
April	**2039.4**	**2362**	**-322.6**
May	**2053**	**2365**	**-312**
June	**1918**	**2349**	**-431**
July	**1812**	**2283**	**-471**
August	**1868**	**2278**	**-410**
September	**1914**	**2358**	**-444**
October	**1990**	**2336**	**-346**
November	**2078**	**2402**	**-324**
December	**2087**	**2477**	**-390**

The Table above shows that actual monthly system peak demand was below the projected throughout the year. The factors that could have contributed to the low demand realised are as follows:

- **Tariff** – There was a 59.2 % increase in electricity tariff in December, 2015. Several consumer groups raised concern over the new tariff, and preliminary investigations indicate that many have consequently adjusted their energy consumption patterns and adopted strategies to keep within the lower tariff class. This has resulted in a significant reduction in system demand;
- **Prolonged Energy Crisis** - The recent energy crisis has been the longest lasting compared with previous ones, spanning the last quarter of 2011 to mid-2016. The prolonged energy crisis significantly affected economic growth in Ghana and thereby distorting the electricity growth pattern;
- **Discontinued/Suspended Customer Operations** – Some bulk customers discontinued or suspended all or part of their operations within the year 2016 due to a number of challenges, thereby leading to a reduction of their average demand. Examples are:
  - ✓ **AngloGold Ashanti** who suspended operations in June 2016. The demand at the mine has reduced from an average of 56 MW to 13 MW. They are seeking strategic partnership to revive operations at their mine in Obuasi. Currently mining of gold is ***suspended*** and the only demand from the facility comes from its auxiliaries;
  - ✓ **Goldstar Resources, Bogosu Ltd** shut down their Sulphide Plant (Biox) in the last quarter of 2015 due to shortage of Sulphide Ore. This resulted in a reduction in the average demand from an average of 30 MW to 7MW.
- **Embedded/Distributed Generation** – Investments in embedded and distributed generation have increased recently. The following are some of the embedded generation projects:
  - ✓ Some IPPs like **Trojan (25 MW** in Tema), **BXC (20 MW** solar in Winneba), SAFISANA biomass (1.6MW) etc. are connected directly on the distribution system, serving load that would otherwise have been served from the NITS;

- ✓ **Roof top solar installations** such as those sponsored and managed by PURC, the EC (571 units totalling 334 kWp so far installed as of December 21, 2016) and other private individuals. These units directly serve customer facilities where they are connected;

- ✓ **Private generating sets** - Due to the long duration of the recent Energy Crisis in Ghana, some residential, commercial and industrial consumers have invested in small to medium size generating sets to supplement supply from the grid.

  Also, some customers deliberately run their generating sets as substitute for grid supply in order to avoid entering a high tariff class.

2.2 Energy Generation

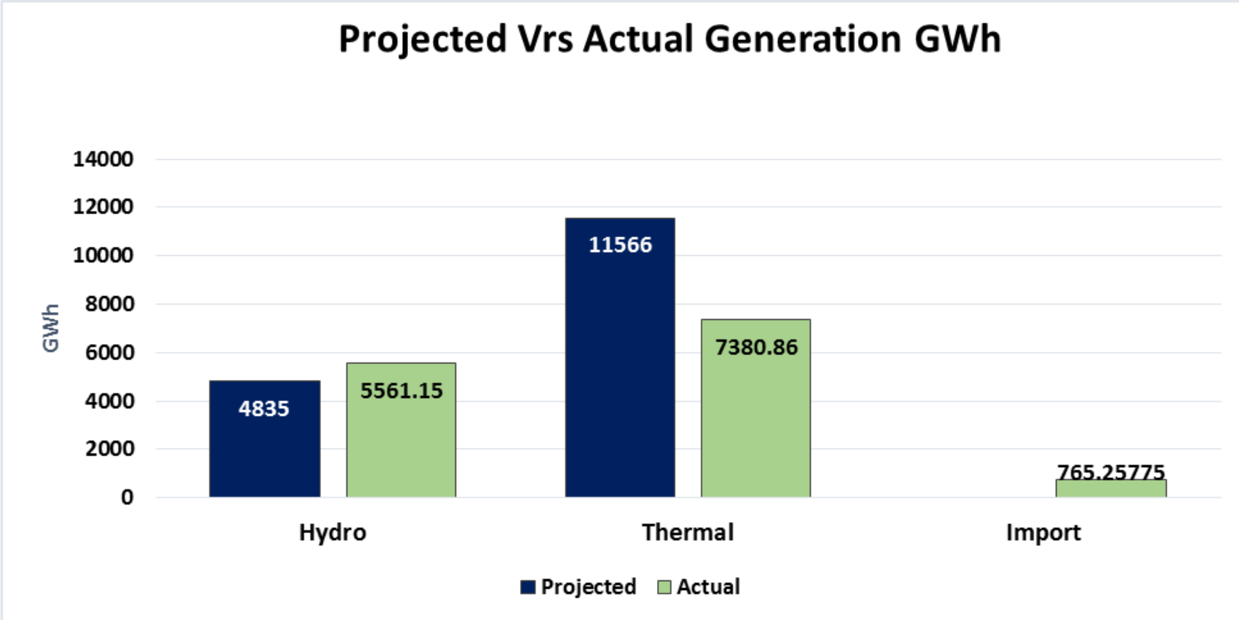
Actual monthly energy generation as against the projected are illustrated in the Table below:

Table 2: Projected versus Actual Energy Generation in 2016

Months	Hydro		Thermal		Import		System Total	
	Actual	Projected	Actual	Projected	Actual	Projected	Actual	Projected
Jan	425	402	716	691	36	0	1177	1093
Feb	446	377	672	882	22	0	1141	1259
Mar	591	402	570	1043	32	0	1194	1445
Apr	641	389	491	1012	40	0	1172	1401
May	486	402	634	1033	64	0	1184	1435
Jun	368	389	626	966	76	0	1076	1355
Jul	339	417	587	955	111	0	1037	1372
Aug	312	417	691	947	81	0	1084	1364
Sep	367	403	587	949	121	0	1076	1352
Oct	467	417	580	1016	100	0	1147	1433
Nov	613	403	539	1015	25	0	1178	1418
Dec	505	417	685	1057	37	0	1227	1474
Total	**5560**	**4835**	**7378**	**11566**	**745**	**0**	**13693**	**16401**

The Table above is presented graphically in the Chart below:

Chart 1: Projected versus Actual Energy Generation in 2016



The total energy generated including imports from Cote d'Ivoire over the period was 13,693 GWh. This comprises 5,560 GWh hydro generation, 7,378 GWh thermal generation and 745 GWh Imports. The generation mix at the end of the period was therefore 40.6% hydro, 53.9% thermal and 5.4% import.

Energy generated from thermal sources was less than the projected by 4,188 GWh (36.18%) over the period and this is attributed to inadequate gas supply from the WAGP and Ghana Gas. There were also some financial challenges which made it difficult for VRA to purchase adequate and timely quantities of LCO and DFO to run the thermal plants.

2.3 Energy Consumption

For the period under review, the total energy consumption (including losses) was 13,692 GWh in comparison to the projected value of 16,798 GWh. Compared to the 2015 value of 11,692 GWh, the 2016 figure represents an increase of 2008 GWh (17.2%) over that of 2015. This unusually high increase in 2016 consumption over that of 2015 could be attributed to the severe load shedding carried out in 2015 due to insufficient generation. A summary of actual and projected energy consumption for 2016 is presented in the Table 4 below:

Table 3: Summary of Energy Consumption for 2016, actual vs. projection

Customer	*Projection (GWh) 2016*	*Actual (GWh) 2016*	*Actual (GWh) 2015*	*% Growth*
ECG	10778	9267.11	7544	22.8%
NED	1285	1139.46	1012.56	12.5%
Mines	1813	1250.32	1231.18	1.6%
VALCO	620	616.78	572.89	7.7%
Export	1081	465.69	581.35	-19.9%
Direct Customers	582	345.31	300	15.1%
Losses	615	607.38	442.64	37.2%
Total Energy	**16790**	**13700**	**11684.98**	**17.2%**

The details of the peak demand and energy consumption per Bulk Supply Points are included in Appendix B.

2.4 Energy Exchanges (Export and Import)

410.46 GWh of energy was transmitted to CEB, comprising 186.52 GWh power exports from VRA and 223.94 GWh which was wheeled from CIE.

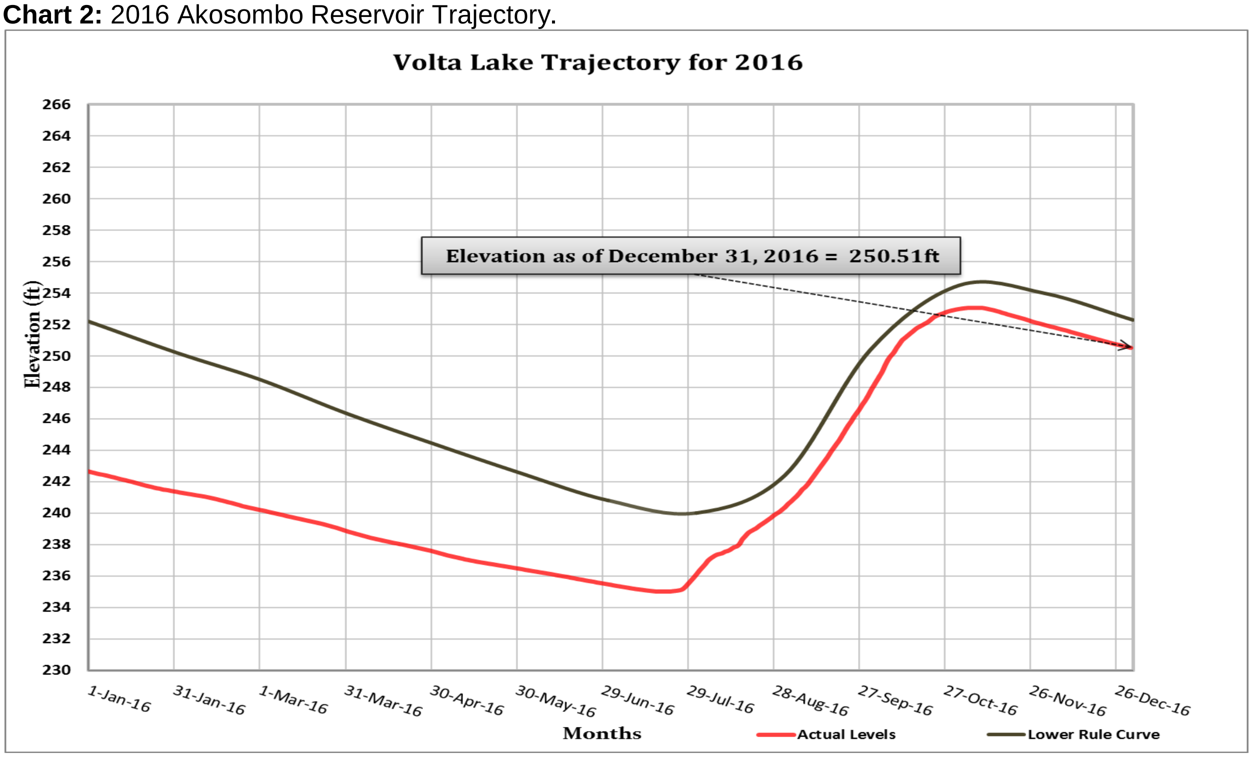
The net interchange between Ghana and Cote d'Ivoire on the tie line was 511.37 GWh. This was made up of 511.22 GWh of import and 0.15 GWh of exports to CIE.

2.5 Hydro Reservoir Operation

2.5.1 Akosombo Reservoir

The Volta Lake year start elevation for 2016 was 242.65 feet. Due to this low reservoir level, it was recommended not to operate more than 3 units throughout the year in order to ensure system stability and to also not draw down the lake to below 235 feet. However, the aforementioned fuel supply challenges for thermal generation made it difficult to adhere to the recommended plan. Between January and February, the Akosombo plant was operated mostly with 3 units off-peak and 4 units at peak. From March, the plant operated with 4 units off-peak and 6 units at peak. That notwithstanding, the reservoir elevation dropped to a minimum of 235.01 feet which was just 0.01 feet above the Extreme Minimum Operating level. This was mainly as a result of higher discharge from the Bui Hydroelectric dam. Hence, the year-end drop in elevation was 7.6 feet. The recorded Lake elevation at the end of the inflow season was 253.05 feet a rise of 18.04 feet above the recorded minimum. The corresponding total net inflow was 32.74 MAF which is 2.74 MAF above the long-term average of 30 MAF. Chart 2 below shows the Akosombo reservoir trajectory for 2016.

Chart 2: 2016 Akosombo Reservoir Trajectory.



2.5.2 Bui Reservoir

The year-start elevation of the Bui reservoir in 2016 was 178.59 masl. Due to challenges with thermal generation, there were supply constraints on the Ghana Power System which obliged generating more from the Bui dam than the projected.

The minimum reservoir level at the end of the dry season on May 18, 2016 was 168.31 masl. This was 3.78 masl below the projected minimum of 172.09 masl for the year. At the end of the inflow season the reservoir level rose to a maximum level of 178.91 masl on October 24 2016. The year-end elevation on December 31, 2016 was 175.87 masl.

The reservoir trajectory in 2016 is shown in the chart below.

Figure 4: Bui actual trajectory

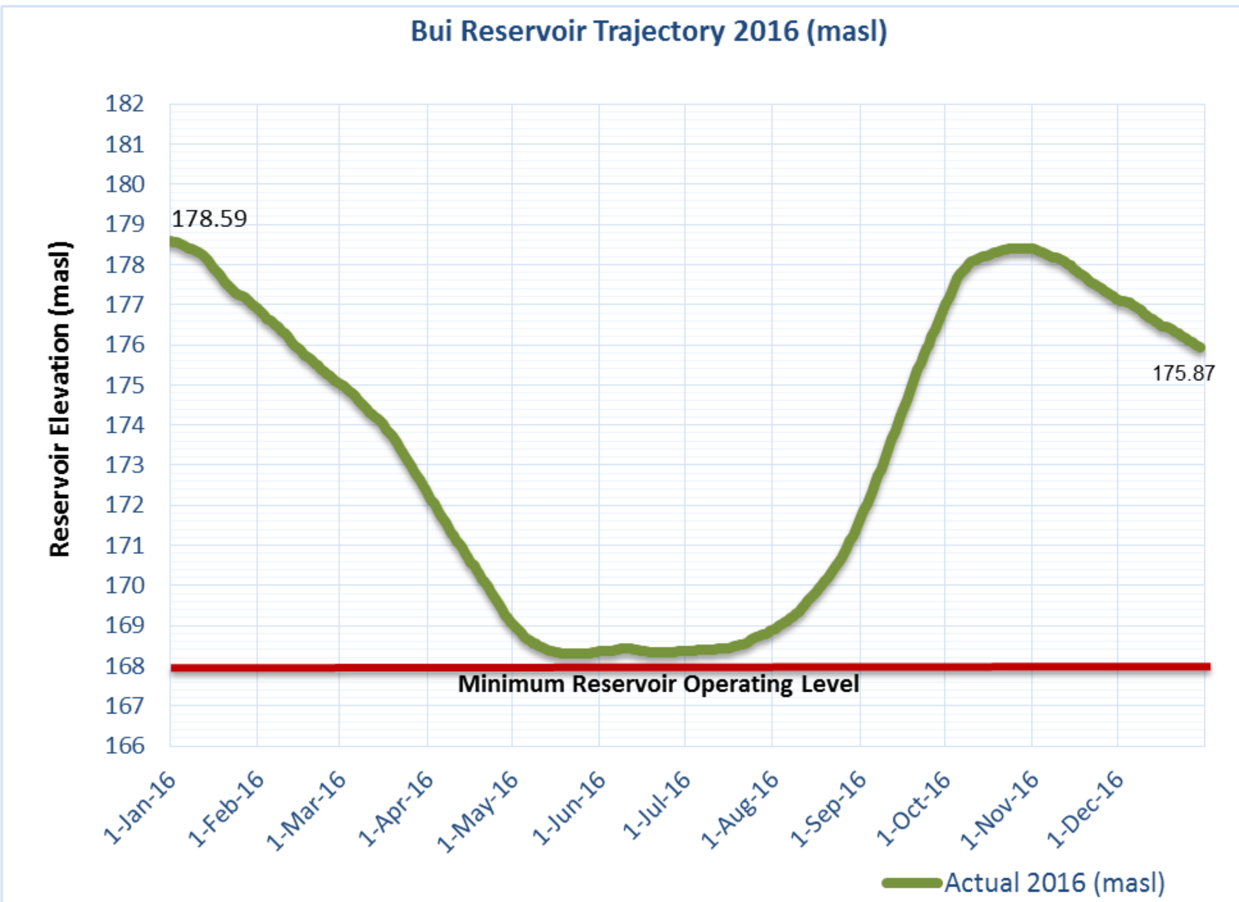


Chart 3: Bui Reservoir Trajectory (Actual).

2.6 Generating Plant Availabilities for 2016

The following table presents the actual generating plant availabilities as against the forecast for the period.

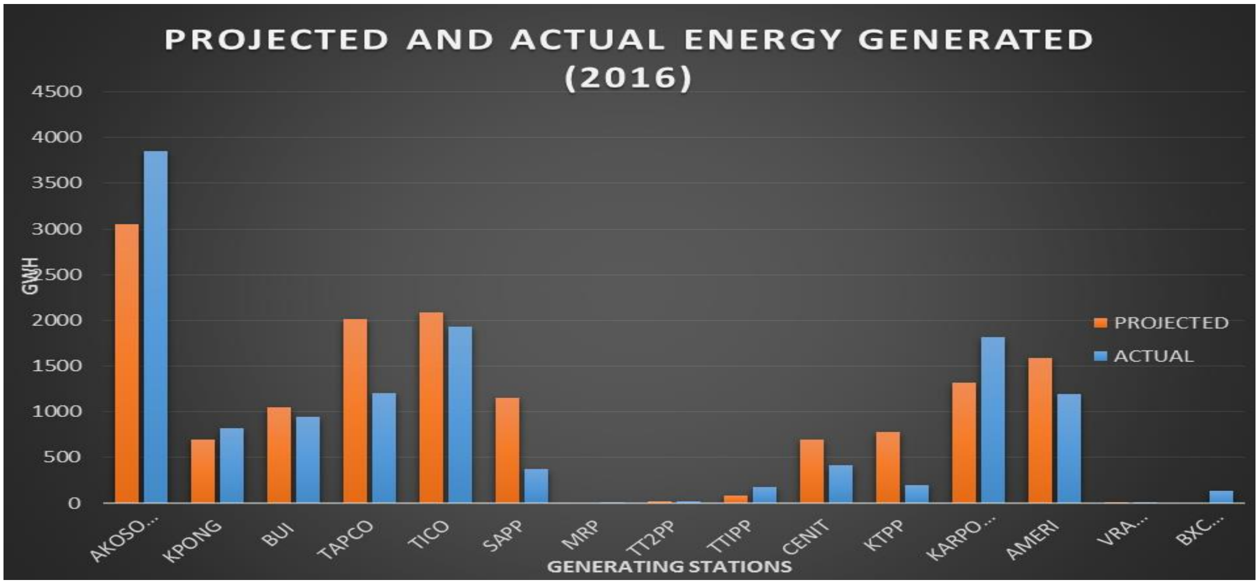
Table 4: Generating Plants' actual and estimated availability for the year 2016

Plant	*Forecast (%) Availability*	*Actual (%) Availability*
Akosombo Hydroelectric Plant	85	95.84
Kpong Hydroelectric Plant	72	76.55
Takoradi Thermal Power Plant (TAPCo)	85	73.83
Takoradi Thermal Power Plant (TICo)	85	90.78
Tema Thermal Power Plant (TT1PP)	88	64.59
CENIT	92	70.36
Karpower	92	97.27
Tema Thermal Power Plant (TT2PP)	85	52.75
Sunon Asogli Power Plant (SAPP)	92	57.91
Ameri	-	95.61
Bui	85	91.22
MRP	80	33.33
Kpone Thermal Power Plant (KTPP)	85	70.74

It should be noted that the plant availability factors were determined based on the total plant dependable capacities.

The Karpower and Akosombo hydro plants recorded the high unit availabilities of 97.27 % and 85.84% respectively compared to the respective forecast figures of 92 % and 85 %. TT2PP and MRP on the other hand registered the low availabilities of 52.72% and 33.33 % respectively compared to the respective projections of 85% and 80%. The Chart below shows the actual monthly energy generation against the projected.

Chart 4: Generating Plant projected & actual energy generation for the year of 2016



2.7 Fuel Supply Issues

In 2016, there were major fuel supply (gas, LCO and DFO) challenges. Most thermal plants in Tema and Takoradi were inoperable for long periods because of the lack of adequate stocks of LCO. Gas supply from Nigeria was inadequate for running gas-fired units in Tema.

The fuel supply challenges could be attributed to the following reasons:

- **Ghana Gas** – Ghana gas supply to run gas-fired units in Aboadze was often interrupted due to fault on the FPSO. Damage to the Turret on the FPSO also led to reduced volumes of gas production form FPSO.
- **WAGP** – Gas supply from the West African Gas Pipeline was intermittent and at other times completely cut off due to non-fulfilment of financial obligations as well as some technical challenges in Nigeria;
- **LCO / DFO** – There were prolonged periods when there were inadequate stocks of LCO at the thermal plants in Tema and Takoradi, largely due to inability to finance purchases. This often necessitated frequent undesirable switching between firing on LCO and Natural Gas. This often led to ‘coking’ on the units thereby reducing their output.

2.8 Generation Deficiency and Load Shedding

2.8.1 Load management program

Due to the cessation of gas supply from WAPCO and fault on some thermal generating units, there was supply inadequacy on the Ghana power system between April and August of 2016 leading to incidences of load shedding in the Ghana.

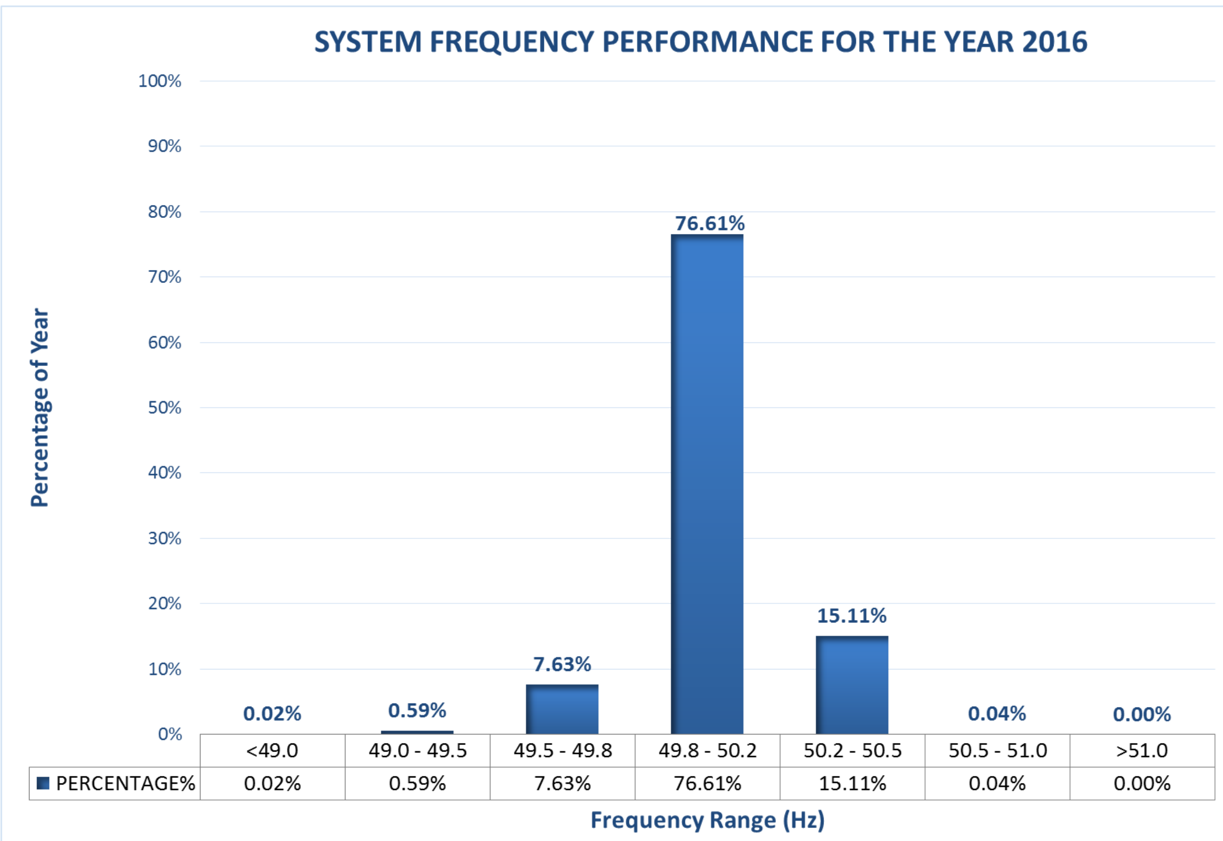
2.8.2 Automatic Frequency Load shedding (AFLS)

The period under review registered 24 (no.) automatic frequency load shedding relay (AFLS) operations which cumulatively lasted 320 hours and 27 minutes. This represents a significant improvement on the 2015 performance where there were 116 operations lasting 868 hrs and 44 mins.

2.9 Quality of Supply

2.9.1 System Frequency

The chart below shows system frequency performance during the year 2016.



It was in emergency state for 0.65% of the year: 0.59% within 49.0Hz – 49.5Hz, 0.04% within 50.5Hz – 51.0Hz, 0.02% below 49.0Hz and 0.0% above 51.0Hz.

2.9.2 System Voltages

An analysis of voltages at selected Bulk Supply Points (BSP) at peak time indicates that voltages across the NITS have largely been within normal limits, except Kumasi.

STATION	NUMBER OF DAYS OF THE YEAR			PERCENTAGE OF THE YEAR		
	Normal	Below Normal	Above Normal	Normal	Below Normal	Above Normal
Achimota	**272**	94	0	**74.32%**	25.68%	0 %
Mallam	**293**	73	0	**80.05%**	19.95%	0%
New Tema	**362**	3	1	**98.91%**	0.82%	0.27%
Kumasi	**147**	211	0	**41.06%**	58.94%	0%
Takoradi	**360**	6	0	**98.36%**	1.64%	0%
Tamale	**365**	0	1	**99.73%**	0.00%	0.27 %

Kumasi voltages were below limits 211 days (out of 365) in 2016. The low voltages are largely due to poor customer (ECG) load power factors and the relatively long circuit distance from generating plants.

2.10 Transmission Network Performance

2.10.1 Feeder Availability

The average feeder availability on the NITS in 2016 was 97.07 %.

2.10.2 Transmission Lines

The System Average Availability (SAA) for the transmission grid was 99.37 % in 2016.

Table 5: The percentage transmission line availability for the year 2016.

Voltage Class	*Availability %*
69kV	99.70%
161kV	99.36%
225kV	98.58%
330kV	99.05%
System Average Availability %	99.37%

2.10.3 Transformer Capacity

Over the period under review, transformer capacity on the NITS increased from 4,498.5 MVA to 4,722.2 MVA, an increase of 223.7 MVA.

The Table below shows typical transformer peak loadings in some major substations.

Table 6: Substation Transformer peak loadings in September 2016

Substation	Transformer Code	Rating (MVA)	Peak Loading (MVA)	% of Rating
Achimota	5T1	66	73.3	111.0
	5T2	66	61.0	92.5
	5T3	66	0.0	0.1
	5T4	66	64.4	97.6
	5T5	66	70.3	106.6
	5T6	66	55.4	84.0
Mallam	37T1	66	45.2	68.5
	37T2	66	48.4	73.3
	37T3	66	52.6	79.8
	37T4	66	46.4	70.3
New Tema	4T1	66	53.7	81.4
	4T2	33	33.2	100.6
	4T3	66	60.3	91.4
	4T4	20	0.1	0.4
	4T5	66	65.4	99.0
	4T6	20	0.0	0.1
Kumasi	13T1	66	46.0	69.7
	13T2	66	50.0	75.8
	13T3	66	50.0	75.8
	13T4	66	50.0	75.8
Takoradi	8T1	33	0.0	0.0
	8T2	33	29.9	90.7
	8T3	33	30.2	91.6

2.10.4 New installations in 2016

Table 8 below shows the projects that were commissioned in the year under review.

Table 7: Commissioned Projects

EQUIPMENT	PROJECTS
GENERATING PLANTS	1. 250MW Ameri plant
	2. 360 MW Sunon Asogli phase II
	3. 220 MW Kpone thermal plant
TRANSMISSION LINES	1. 330kV Asogli- Volta
	2. 161kV Bolgatanga- Tumu
	3. 161kV Bolgatanga- Navrongo
SUBSTATION/ TRANSFORMERS	1. Bolgatanga substation was expanded and commissioned.
	2. A 66 MVA transformer was installed at Achimota substation.
	3. A 9 MVA transformer was upgraded to 13 MVA at the Ho substation.

	4. A 13.3 MVA transformer was upgraded to 33 MVA transformer.
	5. A 33 MVA transformer was commissioned at the Cape Coast substation.
	6. A 33 MVA transformer was commissioned at the New Tema substation.
	7. A 66 MVA transformer was commissioned at the Smelter II substation.

3 DEMAND OUTLOOK FOR 2017

3.1 Peak Demand

The 2017 demand forecast is based on an econometric projection of a population growth of 2.6% and a GDP growth of 7.7% in 2017 with one pot line in operation at VALCO. The projected coincident system peak demand for 2017 is 2,386 MW, an increase of 299 MW, representing a 14.2 % growth over the 2016 recorded peak of 2,087 MW.

The factors that are expected to contribute to growth in demand include:

a. Expected increase in spot loads, including:
   - 30 MW demand increment from Enclave Power Authority;
   - “Drillworx”, a new mining company in Konongo: 5 MW ;

b. On-going distribution network expansion works intended to extend coverage and improve service quality to ECG and NEDCo customers;

c. Also, various rural electrification projects within the ECG and NEDCo distribution zones earmarked for commissioning in 2017.

The details of the projected coincident peak demand by customer is shown below:

Table 8: Summary of 2017 Projected Demand

Customer			2017 – Projected Coincident Peak (MW)
Domestic Peak Demand	**ECG**		1,572
	NEDCo		185
	Mines	ASHGOLD (New Obuasi)	204
		ASHGOLD (Obuasi)	
		GGL (New Tarkwa)	
		Prestea	
		Newmont (Ahafo/Kenyase)	
		Newmont (New Abirim)	
		Akyempem (Wexford)	
		Perseus Gold(Ayamfuri)	
		Bogosu	
		Akwatia	
		Konongo	

		Adamus Gold Resources	
		Asanko Gold	
		Drill Works	
	Other Bulk Customers	Akosombo Textiles	75
		Aluworks	
		Ghana Water Company Ltd	
		Enclave Power Company	
		Diamond Cement	
		Generation Plants Station Service	
		Volta Hotel	
		Savana Cement (Buipe)	
		VRA Townships	
	Network Usage		1
	Losses		101
Total Domestic Peak Demand			**2,138**
Exports	**CEB**		120
	CIE(inadvertent exchange)		3
	SONABEL		50
Total Exports			**173**
VALCO			**75**
Coincident Peak Demand MW			**2,386**

The above coincident customer peak demand projections are illustrated graphically in the chart below:

Chart 5: System Peak Demand for 2017 by Customer

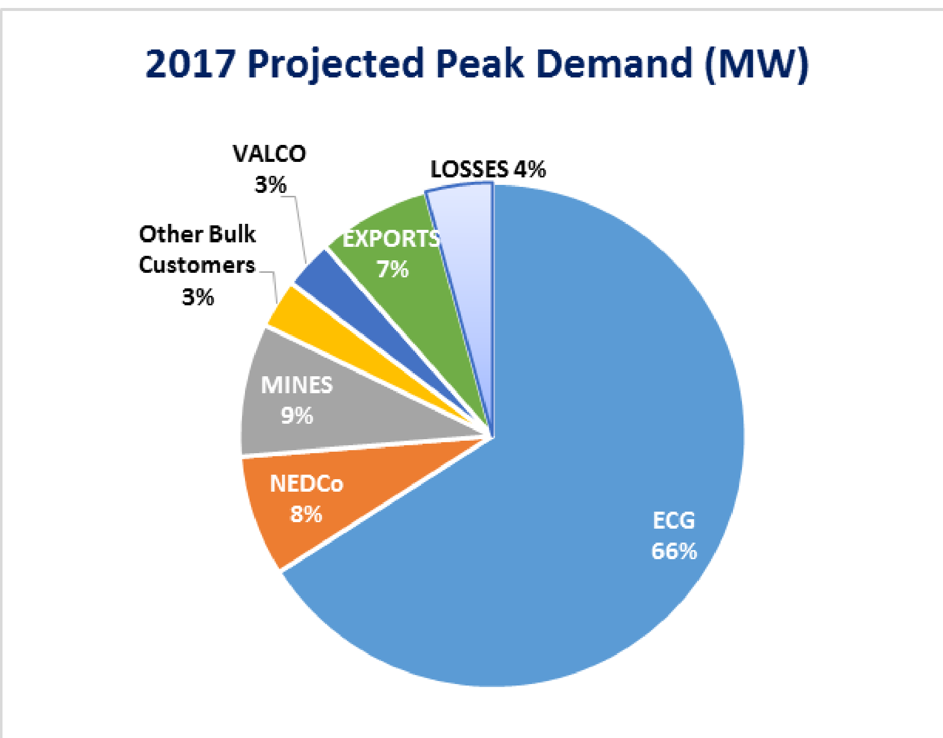


Chart 6 shows coincident system peak demand for 2017 by customer class. ECG's demand constitutes 66% of the total system peak followed by the Mines with 9%. At plotline, VALCO's demand of 75 MW constitutes 3%, NEDCO 8%, other bulk consumers 3%. Exports to CEB and SONABEL account for 7% of the total system demand.

3.2 Outlook of Energy Consumption

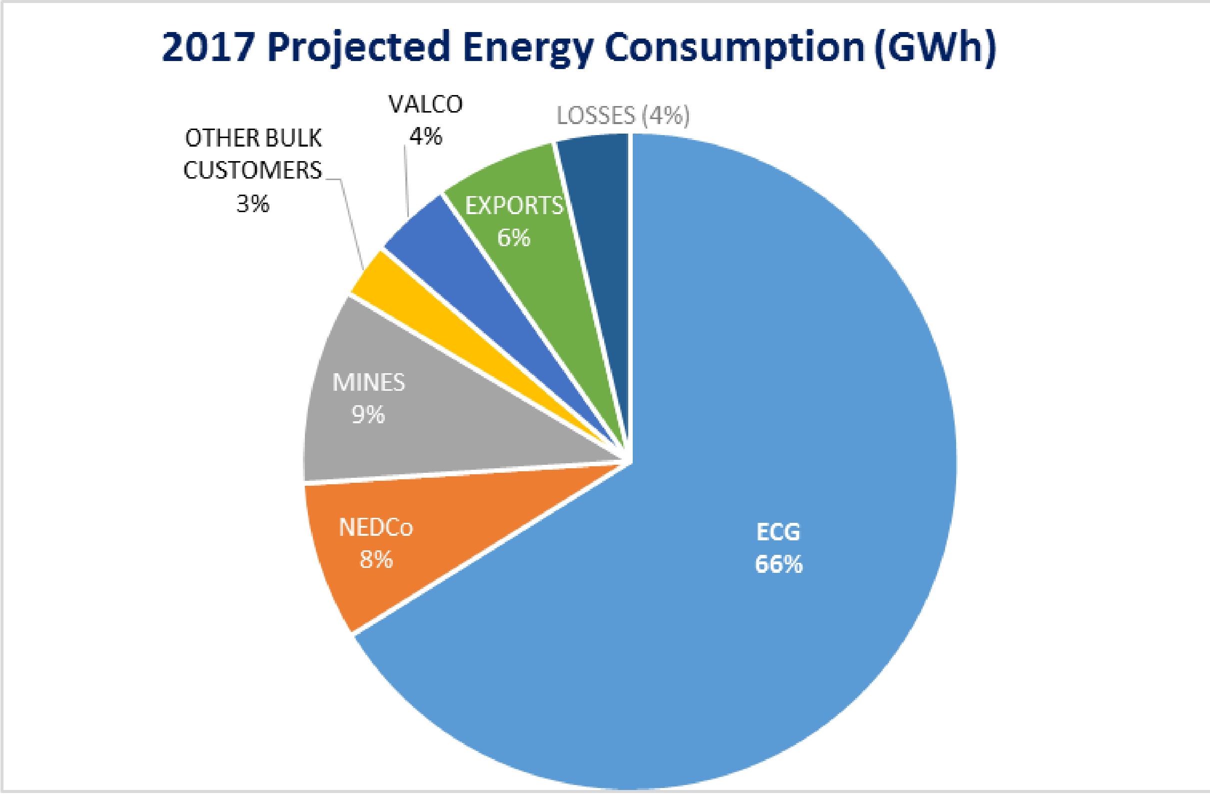
The total projected energy consumption for 2017 is 15,615 GWh. This includes estimated transmission losses of 585 GWh, representing 3.7 % of total energy consumption. The projected 2017 energy consumption represents a growth of approximately 14 %, over the 2016 actual consumption of 13,693 GWh, an increase of 1,907 GWh.

The summary of estimated customer energy consumption in 2017 is in Table 11 below:

Table 9: Summary of projected 2017 Energy Consumption

Customer		2017 – Projected Consumption (GWh)
Domestic Consumption	ECG	10,326
	NEDCo	1,213
	Mines	1,498
	Other Bulk Customers	425
	Network Usage	8
	Losses	585
Total Domestic		14,055
Exports	CEB	750
	CIE	18
	SONABEL	172
VALCO		620
Total Energy (GWh)		15,615

Chart 6: 2017 projected Energy consumption by customer



As shown in Chart 9 above, ECG is the highest consumer among all the load entities in Ghana, accounting for approximately 66% of the total projected energy consumption for the year 2017, followed by the mines who are projected to consume 1,498 GWh (9%).

3.3 Projected Monthly Consumption

A summary of the monthly energy consumption is indicated in Table 3 below. A total of 14,055 GWh is projected for domestic consumption, 620 GWh for VALCO and 940 GWh for exports to CEB and SONABEL.

Table 10: Summary of Expected 2017 Monthly Energy Consumption (GWh)

Customer	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Domestic	1,197	1,113	1,218	1,186	1,208	1,123	1,122	1,114	1,117	1,197	1,192	1,268	14,055
VALCO	48	53	51	53	51	53	53	51	53	51	53	53	620
Export (CEB+ SONABEL)	80	72	80	77	80	77	80	80	77	80	77	80	940
Projected Demand	1,324	1,238	1,349	1,316	1,339	1,252	1,255	1,244	1,247	1,327	1,322	1,401	15,615

The highest monthly energy consumption is projected to be experienced in the month of December, where consumption is expected to be 1401 GWh.

4 OUTLOOK: SOURCES OF GENERATION

4.1 Akosombo & Kpong Hydro

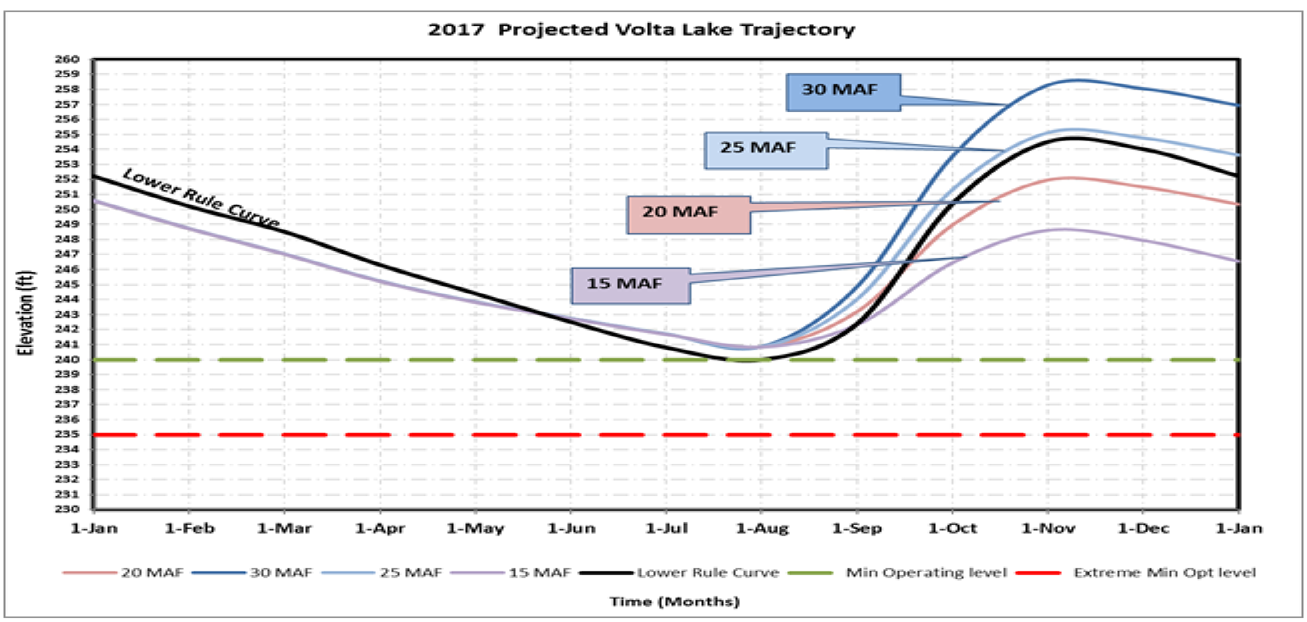
The 2017 year start elevation for the Akosombo reservoir was 250.47 feet. This is 10.47 feet above the Minimum Operating level of 240 feet. Based on an analysis conducted, we recommend to run 3 units off peak and 5 units at peak in 2017 at Akosombo GS in order to maintain the reservoir elevation above 240 feet before the onset of the inflow season.

However, current challenges with Gas supply and on-going maintenance activities on thermal units at the Aboadze enclave will necessitate the running of 6 units during peak periods in the first quarter of 2017. The station shall revert to 3 unit operation during off-peak and a maximum of 5 units at peak for the rest of the year.

Kpong GS which is currently undergoing retrofit will have 3 units out of the total 4 units available. Hence, the total average capacity at Kpong GS will be 105 MW. As a result, total projected annual hydro generation from Kpong and Akosombo generating stations will be 4,400 GWh.

The projected elevations for the Akosombo reservoir in 2017 based on the above recommended hydro generation are shown in Chart 7 below. For an average inflow of 25 MAF, the projected minimum elevation at the end of the dry season in July 2017 will be 240.55 feet.

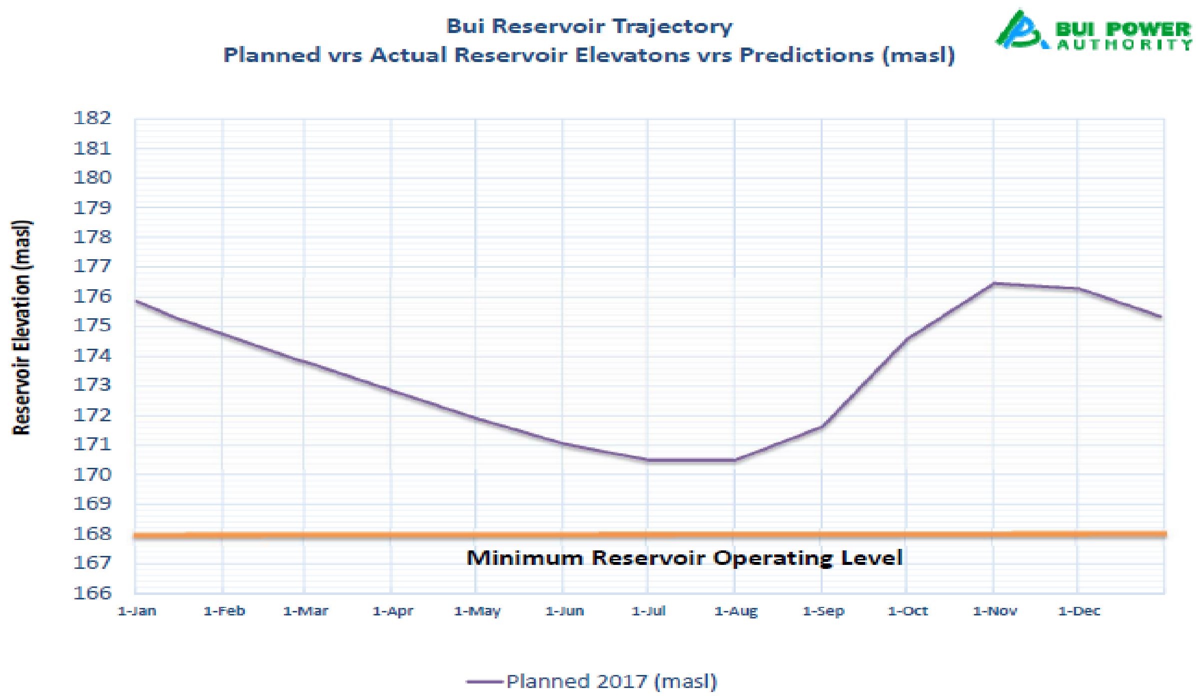
Chart 7: 2017 Projected Akosombo Trajectory



4.2 Bui Hydro

In 2017, Bui GS will operate up to three (3) units based on system demand in the first quarter and then reduced to two (2) units at peak for the rest of the year. This mode of operation will lead to a projected annual production of 841 GWh.

Chart 8: 2017 Projected Bui Reservoir Trajectory



4.3 Thermal Generation

The total existing installed thermal generating capacity is 2,351.5 MW of which dependable capacity is 2,155 MW. However, as of January 2017 the available thermal generating capacity was 1,800 MW. This is mainly because the TAPCO plant at Aboadze (dependable capacity of 300 MW) has been shut down for maintenance. In addition, currently the TT2PP and MRP plants are unavailable due to faults on some units and lack sufficient natural gas supply from Nigeria for running them.

The installed, dependable and available capacities of existing generation sources assumed for the 2017 energy supply plan are shown in Table 10. From Table 10, the total installed capacity of the existing generation sources is 3,954 MW of which 3,663 MW is dependable.

Table 11: Existing Generation Sources

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type	Availability Factor (%)
Akosombo GS	1020	1000	Water	90%
Kpong GS	160	148	Water	72%

TAPCO (T1)	330	300	Gas/LCO	65%
TICO (T2)	340	320	Gas/LCO	85%
TT1PP	126	100	Gas/LCO	88%
TT2PP	49.5	45	Gas	85%
MRP	80	70	Gas	80%
KTPP	220	200	Gas/Diesel	85%
VRA Solar Plant	2.5	0	Sunlight	18%
TOTAL VRA	**2,328**	**2,183**		
AMERI	250	240	Gas	90%
SAPP	200	180	Gas	92%
SAPP 2	360	340	Gas/LCO	85%
CENIT	126	100	Gas/LCO	92%
Bui GS	400	360	Water	85%
KAR Power	225	220	HFO	90%
Central Solar	20	0	Sunlight	15%
Trojan	25	22	Diesel/Gas	75%
Genser	20	18	Coal	80%
TOTAL (VRA&IPP)	**3,954**	**3,663**		

4.4 Supply Outlook

The main sources of generation considered are existing plants and committed additional generation projects earmarked for commissioning in 2017.

4.4.1 Additional Generation Resources

In 2017, installation of additional generation resources totaling 801 MW is expected to be completed and commissioned into operation. 743 MW of this is expected to be dependable. The details of installed and dependable capacities of on-going additional generation projects and their expected timelines are shown in Table 12 below. It is assumed that the construction of Cenpower plant will be completed by the end of 2017 and reach COD in 2018.

Table 12: Expected Additional Generation Sources in 2017

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type	Availability Factor (%)	Remarks
SAPP (2)	180	170	Gas	85%	Awaiting Gas for commissioning
AKSA	370	340	HFO	90%	240 MW from June 2017, full capacity by September, 2017
Karpower Barge 2	225	200	HFO	90%	450MW to replace existing 225 MW. Hence, additional capacity

					of 225 MW from July, 2017
TT2PP-X	36	33	Gas	85%	Awaiting Gas for Commissioning
TOTAL	**801**	**743**			

4.5 Key Assumptions

In developing the 2017 Supply Outlook, the following assumptions were made;

4.5.1 Planned Maintenance

The schedule of key maintenance activities planned to be undertaken in 2017 on generating units at the various power plants is shown in Table 14 below.

Table 13: 2017 Planned Maintenance

Plants	Planned Maintenance
Akosombo GS	• Each of the 6 units will undergo maintenance for separate months in the year Therefore, supply from Akosombo will not be affected since 3 to 5 units is expected to be dispatched
Kpong GS	• Kpong major retrofit is ongoing. Semi Annual inspection for 1 week will be carried out on 1 unit at a time in March, April and October 2017. In addition, there will be a post retrofit inspection on unit 2 in the month of August.
TAPCO (T1)	• ***Unit 1:*** Generator Rotor Repairs from March 20 – April 26, 2017. Hot Gas Path Inspection in the Month of October. • ***Unit 2:*** Major Inspection from January 8 to July 31, 2017. Major Inspection • ***Unit 3:*** Minor Inspection on steam turbine and generator from April 17 – May 18, 2017.
TICO (T2)	• ***Unit 2:*** Hot Gas Path Inspection and hardware upgrade from January 25 – March 25, 2017. • ***Unit 3:*** Major Inspection from January 25 to March 2, 2017.
TT1PP	• Unit scheduled for 3 days' outage. Maintenance will therefore not impact on supply.
TT2PP	• Unit 1: Engine Swap; main gearbox overhaul, June 1 – June 21, 2017; • Unit 2: Engine Swap and main gearbox overhaul, June 24 – June 30, 2017; • Unit 3: Engine Swap and main gearbox overhaul, July 17 – August 9, 2017
MRP	• Each of the 3 units will undergo maintenance for 4 days for 4 separate months in the year
VRA Solar Plant	• Maintenance will not impact on supply
SAPP	• No major maintenance activity is planned
CENIT	• No major maintenance activity is planned
Bui GS	• Maintenance will not impact on supply

The calendar of generating unit maintenance activities is also attached in **Appendix D.**

4.5.2 Gas Supply Projections

Two main sources of natural gas supply are expected as follows:

- **Nigeria Gas** – Average supply of 30 mmscf/day from January – December 2017,
- **Ghana Gas** – Average supply varies between 30 to 100 mmscf/day from January to August. Then remains at 30 mmscf/day till the end of December 2017. TEN tie-in work by Ghana Gas and Tullow Ghana is expected to result in the cessation of natural gas supply to thermal plants in Aboadze from February 3 -20, 2017.

4.5.3 Transmission System Losses

For the period under review, average transmission losses were 607.38 GWh representing 4.43 % of total energy transmitted, compared to the PURC requirement of 4 %. The increase in transmission losses was mainly due to lack of adequate generation to allow for a geographical balance in generation in operation at all times. It is also due to congestion in some portions of the network.

Table 6 shows system transmission losses for the period 2014 -2016

Table 14: Transmission losses 2014-2016

Year	*2014*	*2015*	*2016*
Transmission Losses %	4.22	3.79	4.4

4.5.4 Fuel Allocation

Due to the limited quantities of natural gas supply in 2017 as projected above, fuel usage at the Tema and Takoradi power enclaves shall be strategized as follows:

a. Tema:

- Nigeria Gas is allocated to the Sunon-Asogli Power Plant Phase-I units;
- CENIT operates on LCO;
- KTPP operates on diesel (on standby except in the month of February);
- TT1PP operates on LCO (on standby from April to December);
- MRP/TT2PP/TT2PP-X operate on natural gas (all on standby).

b. Takoradi:

- Ghana Gas supply is allocated to AMERI power plant;
- TAPCO runs mainly on Gas (on LCO during periods of gas shortage);

- TICO runs mainly on LCO but switches to fire on gas whenever there is enough.

4.1.2 Fuel Price

The following assumptions on delivered fuel price were made:

- Nigeria Gas – US$ 8.45/mmbtu
- Ghana Gas – US$ 9.0/mmbtu
- Delivered LCO – US$ 60/barrel
- Delivered Diesel – US$ 90/barrel (@ 1.5 x LCO price)
- Delivered HFO – US$ 72/barrel (@ 1.2 x LCO price)

4.6 2017 Demand/Supply Analysis

Supply projections for 2017 were carried out on the basis of the above assumptions. Chart 10 below shows a graphical representation of the projected percentage energy contributions of hydro generation, thermal generation, solar powered generation and imports. The chart indicates that thermal generation in 2017 is planned to be twice as much as hydro generation while imports in 2017 will constitute about 4% of electricity supplied.

Chart 9: Contribution of Energy Supply by Types of Generation

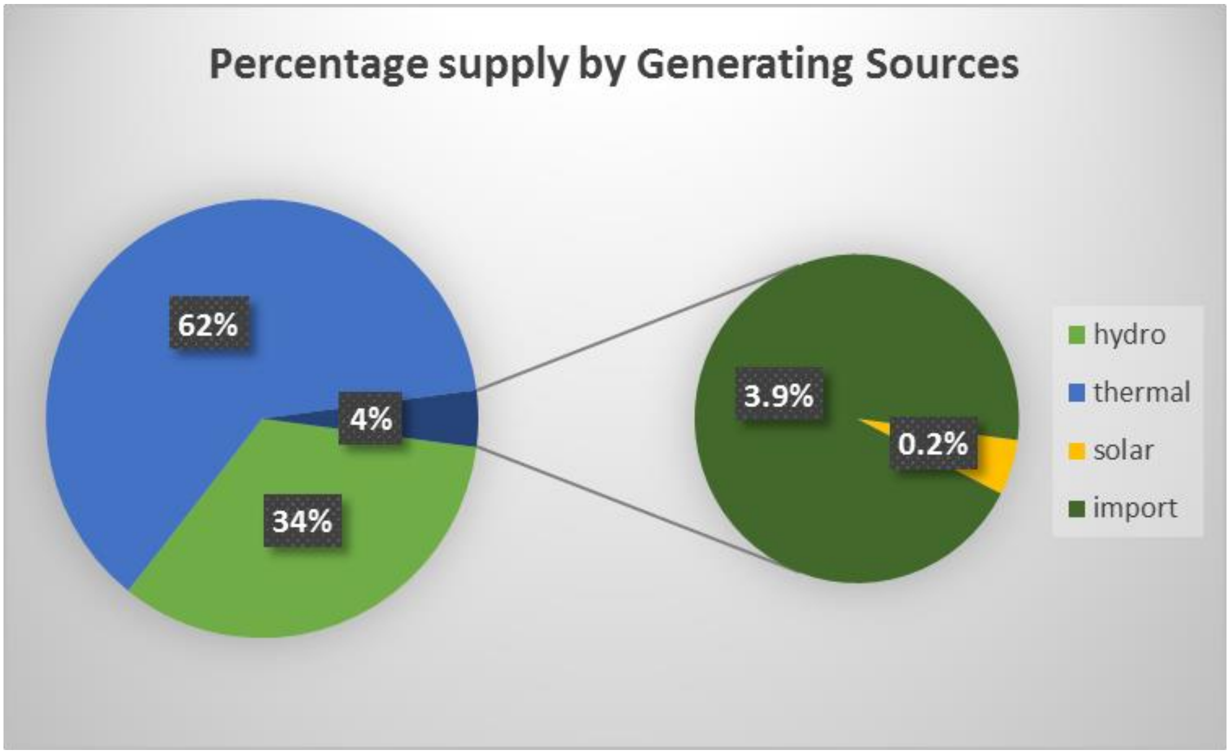


Table 15 further shows the Demand/Supply balances for 2017. From the Table, the total generation from the VRA, the major power producer is 7,883 GWh representing about

50.5% of the total electricity generated in 2017. Imports from CIE are expected to make up for supply shortfall to a total of 615 GWh.

Table 15: 2017 Projected Demand/Supply Balance in GWh

Projected Demand/Supply	**Demand/Supply (GWh)**
Total Domestic	**14,055**
VALCO	620
Exports (CEB+SONABEL+CIE)	940
Total Projected Demand	**15,615**
Projected Supply	
Total VRA Hydro (Akosombo & Kpong GS)	4,400
Bui GS	841
VRA Existing Thermal & Solar Generation	
T1	1,258
T2	1,983
TT1PP	177
TT2PP + TT2PP-X	0
MRPP	0
KTPP	62
Solar	4
Total VRA Thermal Generation	**3,484**
Existing IPP Thermal Generation	
SAPP (includes new plant)	1,477
CENIT	154
AMERI	1,619
Karpower Barge	1,802
AKSA	1,174
Trojan	19
Central Solar	**32**
Total IPP Thermal Generation	**6,277**
Total VRA Supply	**7,884**
Total Non-VRA Supply	**7,118**
Import	613
Total Supply	**15,615**

Expected generation from TT1PP, KTPP, MRP, and TT2PP etc are low because they are projected to be operated as reserve plants only. The monthly projected plant generation is detailed in Table 16 below:

Table 16: Projected Monthly Energy Generation **(GWh)**

	2017 Projected Consumption (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	14,054	1,167	1,032	1,173	1,211	1,218	1,133	1,133	1,129	1,127	1,237	1,217	1,278
VALCO	620	48	53	51	53	51	53	53	51	53	51	53	53
Export (CEB+SONABEL)	940	80	72	80	77	80	77	80	80	77	80	77	80
Projected System Demand	**15,614**	**1,294**	**1,157**	**1,304**	**1,341**	**1,349**	**1,263**	**1,265**	**1,259**	**1,257**	**1,367**	**1,347**	**1,411**
Generation Sources	**Projected Supply (GWh)**												
Akosombo	**3,680**	388	362	348	307	285	279	288	288	279	288	279	288
Kpong GS	**720**	72	69	70	61	57	55	57	57	55	57	55	57
TAPCO	**1,258**	25	-	95	88	95	92	95	152	136	159	158	162
TICO	**1,983**	104	94	170	184	190	184	193	165	159	182	176	182
TT1PP	**177**	60	58	60									
MRP	**-**												
KTPP	**62**		62										
TT2PP	**-**												
TT2PP-x	**-**												
VRA Solar	**4**	0.4	0.3	0.3	0.3	0.2	0.3	0.4	0.4	0.3	0.4	0.3	0.4
Imports From Cote d'Ivoire	**615**	147	133	95	91	45	20	33	10	10	10	10	10
Total VRA Available Generation	**8,498.3**	**797**	**778**	**838**	**731**	**672**	**629**	**667**	**672**	**638**	**697**	**678**	**700**
AMERI Power Plant	**1,619**	149	40	144	140	145	140	147	144	140	145	140	145
Karpower Barge	**1,802**	152	140	147	148	155	150	155	155	145	150	145	160
SAPP	**414**	55	62	55	96	96	51						
SAPP (Phase 2)	**1,062**				95	87	92	92	107	113	144	151	180
CENIT	**154**	60	55	39									
AKSA	**1,174**				69	120	129	131	107	149	157	161	152
Trojan	**19**	7	5	7									
Genser	**-**												
Bui GS	**841**	72	74	71	59	71	69	71	71	69	71	69	71
Solar (Central Region)	**32**	2.7	2.4	2.7	2.6	2.7	2.6	2.7	2.7	2.6	2.7	2.6	2.7
Total Available Generation (GWh)	**15,614.0**	**1,294**	**1,157**	**1,304**	**1,341**	**1,349**	**1,263**	**1,265**	**1,259**	**1,257**	**1,367**	**1,347**	**1,411**

4.7 Projected Capacity Situation

Taking planned maintenance and fuel constraint into consideration the projected monthly capacity situation is shown in Table 17.

Table 17: Projected Monthly Capacity **(MW)** Situation in 2017

	2017 Projected System Peak (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	2,137	1,898	1,926	1,943	2,028	2,030	1,975	1,953	1,948	2,024	2,003	2,066	2,137
VALCO	75	75	75	75	75	75	75	75	75	75	75	75	75
Export (CEB+SONABEL)	173	133	133	133	133	133	133	173	173	173	173	173	173
Projected System Demand	**2,385**	**2,106**	**2,134**	**2,151**	**2,235**	**2,238**	**2,183**	**2,200**	**2,195**	**2,271**	**2,250**	**2,313**	**2,384**
Generation Sources	**Dependable Capacity (MW)**												
Akosombo	750	900	900	900	600	600	600	600	600	600	600	600	600
Kpong GS	105	105	105	105	105	105	105	105	105	105	105	105	105
TAPCO	300	-	-	150	150	150	150	150	300	300	300	300	300
TICO	320	165	165	165	320	320	320	320	320	320	320	320	320
TT1PP	100	100	100	100									
MRP	40												
KTPP	200		100										
TT2PP	30												
TT2PP-x	28												
VRA Solar	3												
Imports From Cote d'Ivoire	200	200	200	150	150	60	30	45	15	15	15	15	15
Total VRA Available Generation	**2,076**	**1,470**	**1,570**	**1,570**	**1,325**	**1,235**	**1,205**	**1,220**	**1,340**	**1,340**	**1,340**	**1,340**	**1,340**
Bui GS	345	230	345	230	230	230	230	230	230	230	230	230	230
SAPP	180	100	100	100	170	170	170	170	170	170	127	42	170
SAPP (Phase 2)	330				320	320	160	160	160	320	320	320	320
CENIT	100	100	100	100									
AMERI Power Plant	230	230	-	230	230	230	230	230	230	138	138	138	138
Karpower Barge	225	200	200	200	200	200	200	200	200	200	200	200	200
AKSA	330						240	240	240	330	330	330	330
Trojan	25	12	12	12	12	12	12	12	12	12	12	12	12
Genser	22				18	18	18	18	18	18	18	18	18
SAFISANA	0												
Solar (Central Region)	20												
Total Available Generation (MW)	**3,883**	**2,342**	**2,327**	**2,442**	**2,505**	**2,415**	**2,465**	**2,480**	**2,600**	**2,758**	**2,715**	**2,630**	**2,758**
Surplus/Deficit (MW)	**1,478**	**236**	**193**	**291**	**270**	**177**	**282**	**280**	**405**	**487**	**465**	**317**	**374**
Reserve Margin	**62%**	**11%**	**9%**	**14%**	**12%**	**8%**	**13%**	**13%**	**18%**	**21%**	**21%**	**14%**	**16%**

Analysis of the capacity situation *(assuming there is adequate thermal fuel to run all the thermal plants)* indicates that for all the months projected supply is enough to serve forecasted demand, with reserve margin ranging from 8% to 21%. This includes power imports of up to 200 MW to make up for shortages.

4.8 Fuel Requirements

Light Crude Oil (LCO). Natural gas, and Heavy Fuel Oil (HFO) are the main fuels that will be required for thermal power generation. The quantities of the various fuels required are presented in Table 18 below:

Table 18: Summary of Annual Fuel Requirement

PLANT	LCO	Natural Gas	DFO	HFO
	(Barrels)	(mmbtu)	(Barrels)	(Barrels)
T1	612,808	6,507,602		
T2	1,434,113	7,980,777		
TT1PP	411,060			
TT2PP + TT2PP-X				
MRPP				
KTPP			136,013	
TOTAL VRA	**2,457,981**	**14,488,379**	**136,013**	**0**
CENIT	356,970			
AMERI		16,450,142		
SAPP		3,865,800		
SAPP PHASE 2	1,540,179			
Karpower Barge				2,369,862
AKSA				2,581,782
TOTAL IPP	**1,897,149**	**20,315,942**	**0**	**4,951,644**
TOTAL (VRA&IPP)	**4,355,130**	**34,804,321**	**136,013**	**4,951,644**

- **LCO**

  The total LCO requirement for 2017 is approximately 4.4 million barrels of which 2.5 million barrels would be required for the VRA power plants and about 1.9 million barrels for non-VRA plants. Based on a cargo size of 405,000 barrels, the annual LCO cargo requirement for VRA plants is about 6 cargoes and about 5 cargoes for the CENIT and Sunon Asogli plants. Thus a total of 11 cargoes of LCO would be required.

- **Natural Gas**

  Based on the assumed volumes of natural gas supply from WAPCO and Ghana Gas, the total natural gas consumption is projected to be about 34.8 million mmbtu. An estimated 14.5 million mmbtu would be used by VRA plants and 20.3 billion mmbtu will be used by IPPs.

- **HFO**

  HFO would be used by the Karpower Barge and the incoming AKSA plant. An estimated 4.9 million barrels would be required. This translates to 12.2 cargoes, assuming a cargo size of 405,000 barrels.

- **DFO**

  Diesel would be used mainly by the KTPP plant and for start and stop of all thermal plants. About 136,000 barrels would be used by the KTPP in February. An estimated 60,000 barrels would be required for starting and stopping all VRA thermal power plants. Another 50,000 barrels of diesel is estimated to be used by IPPs for starting and stopping of the plants.

Details of the estimated monthly fuel requirements and costs are shown in **Appendix E.**

4.9 Fuel Cost

The breakdown of the estimated cost of fuel for running all the thermal plants is shown in Table 19 below. Based on the assumed unit prices, the total cost of fuel for running thermal plants in 2017 is about US$ 951 Million. The total cost of fuel for the VRA plants is US$ 296 Million. This translates into approximately US$ 24.7 Million on monthly basis.

Table 19: Breakdown of Estimated Fuel Cost for thermal power 2017

TYPE OF FUEL	COST (Million USD)
VRA – LCO	147
VRA – GAS	130
VRA – DFO	18
TOTAL VRA FUEL COST	**296**
IPP – GAS	181
IPP – LCO	114
IPP – HFO	357
IPP – DFO	5
TOTAL IPP FUEL COST	**656**
TOTAL VRA & IPP COST	**951**

5 TRANSMISSION SYSTEM PERFORMANCE

5.1 State Of the NITS

Electricity transmission in Ghana is effected predominantly through a 161 kV network together with a 69 kV network in the Volta region and two 330 kV circuits. There is a 225 kV tie-line which interconnects the Ghana grid with that of Cote d'Ivoire and two 161 kV tie-lines that interconnect us with Togo. The National Interconnected Transmission System (NITS) consists of approximately 5,207.7 circuit kilometres (km) of high voltage transmission lines which connect generation plants at Akosombo, Kpong, Tema, Bui and Aboadze to sixty four (64) Bulk Supply Points across the nation. The transmission lines consist of 364 km of 330 kV line, 4,636.6 km of 161 kV and 132.8 km of 69 kV lines. In addition, there is a single circuit 225 kV tie-line of 74.3 km linking GRIDCo network with CIE of Cote d'Ivoire.

The network has 123 transformers installed at various load centres across the country with a Total Transformer Capacity of **4,598.86** MVA.

The NITS has 636 MVAr of static capacitor banks installed in various substations such as Achimota, Mallam, Smelter, Winneba, Takoradi, Kumasi etc. and a 40 MVAr Static Var Compensator (SVC) installed at the Tamale substation. The capacitor banks and the SVC provide reactive power compensation on the NITS, in order to maintain good voltages and minimize transmission losses on the Ghana Power System.

The System Control Centre (SCC) is responsible for the real time dispatch (monitoring, coordination and control) of power system operations on the Ghana Power System as well as cross-border power exchanges with neighboring countries. SCC is equipped with an ABB 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

- All existing transmission lines are expected to be in service for transmission of electricity generated at the generation centers to bulk supply points across the nation and as well to enable the execution of power exchange programs with neighboring countries.
- Maintenance work on transmission lines and substations are not expected to significantly affect power supply to customers except for single transformer substations and consumers served on single radial lines.
- With a total transformer capacity of 4,598.86 MVA and a projected peak load of 2,384 MW (at an average power factor of 0.9) the 2017 projected Transformer Utilization

Factor (TUF) is 57.6 %. Most transformers in operation on the NITS are designed with a capability of 100% continuous loading (100% TUF). Therefore the projected TUF of 57.6% for 2017 suggests there is adequate transformer capacity on the NITS for the supply of power under normal operating conditions.

5.3 Steady State System Analysis

Steady state network analysis have been carried out to determine transmission line loadings, substation bus voltages and energy loss levels across the transmission network. In particular, the analysis sought to determine:

- Possible transmission line constraints that could hinder the secure and reliable transmission of power from generating plants to the load centres;
- The ability of the entire power system to withstand a contingency (i.e. forced outage of a single network element);
- Levels of reactive power demand on generating units;
- Network voltage stability ;
- Adequacy of reactive power compensation on the NITS;
- Overall transmission system losses during peak and off-peak periods;
- The optimal scheduling of generation to achieve voltage stability and minimise losses.

5.3.1 Technical Adequacy Criteria

The criteria used to set the limits of acceptable system performance under both normal and contingency conditions are detailed below:

a. Normal Condition

Parameter	Range
Bus Voltages	0.95 pu to 1.05 pu
Transmission Line Power flows	not exceeding 0.85 pu
Transformers	Not exceeding 1.00 pu *(nameplate rating)*
Generators	Not exceeding their Capability Curve

Table 20: Criteria, normal condition

b. Contingency Conditions

Parameter	Range
Bus Voltages	0.90 pu to 1.10 pu
Transmission Line Power flows	not exceeding 1.00 pu
Transformers	Not exceeding 1.20 pu
Generators	Not exceeding their Capability Curve

Table 21: Criteria, contingency condition

5.3.2 Summary of Steady State System Analysis Results

a. The analysis reveals poor voltages on the Kumasi bus (149.5kV).This is attributed to poor customer load power factor. Not having adequate dynamic voltage support on the bus, low voltages at Kumasi contribute significantly to system losses.

b. With a projected generation of 1,981 MW from the Tema and Akosombo generation enclaves, the load flow analyses show overloads of 111% on the Volta–Achimota transmission corridor and 18.1 MW losses on power evacuated through the corridor (representing 16 % of total system losses) in normal operating conditions.

   The situation will be worsened by:

   - Increased power generation when all the various generation projects currently under construction in Tema are commissioned into operation,
   - Expected increases in demand in Accra as domestic demand grows.

   This will cause the Volta-Achimota (V-H) transmission corridor to operate above its thermal limits. A contingency on any line on the corridor could lead to the cascaded tripping of other lines in the corridor on overload, thereby triggering a system disturbance.

c. The projected total power generation from the Aboadze generation enclave including the Ameri emergency power plant is 860 MW. The simulation shows that the existing transmission infrastructure in the corridor is capable of evacuating the projected generation under normal system conditions. However, a contingency on any of the outgoing lines (i.e. the Takoradi-Tarkwa and Tarkwa–Prestea lines) results in overloading of adjacent lines and low voltages in the Western corridor.

d. To ensure stability of the grid in normal operating conditions, the following minimum generation limits require to be kept at all times:

   - 300 MW power generation from Aboadze, and
   - Three (3) Akosombo units.

5.4 Analysis of Transmission System Constraints

5.4.1 Transmission Capacity Analysis

The capacity of existing transmission infrastructure to evacuate power on the Ghana system is analyzed for the following three (3) scenarios;

- Balanced Generation
- High Generation from the Eastern corridor
- High Generation from the Western corridor

a. Balanced Generation

The results of Load Flow analysis carried out on the existing transmission network using the 2017 projected demand and supply indicates that the transmission network has just enough capacity to transmit the projected power generation from all generation stations to the load centers during normal operating condition(s) for some sections of the network, assuming a balanced geographical distribution of Generation.

However, there are some critical lines for which a single contingency will put the power system in alert state, resulting in overload on adjacent lines, low NITS voltages and in some cases, severe system disturbances. These are:

- Lines in the Volta–Achimota corridor;
- Achimota-Mallam line;
- Aboadze–Tarkwa line;
- Tarkwa – Prestea line;
- 330 kV Aboadze –Volta line etc.

b. High Generation from the Eastern corridor

The Table below shows the geographical location (i.e. East or West) of generating plants projected to be in operation in 2017.

Table 22: High east generation schedule

	PLANTS	NO. OF UNITS	SCHEDULED CAPACITY (MW)	TOTAL (MW)
East Generation	Akosombo	4	120	480
	Slack Bus	1	76	70
	Kpong GS	3	35	105
	SAPP Ph I	6	30	180
	TT1PP	1	100	100
	CENIT	1	100	100
	MRP	0	0	0
	TT2PP	0	0	0
	Asogli Expansion (Phase II)	4	(100x2) + (50x2)	300
	AKSA	16	20	320
	Kpone Thermal KTPP	1	100	100
	Kar Power-Tema	1	220	220
West Generation	TAPCo	0	0	0
	TICO	0	0	0
	T3	0	0	0
	T3- Steam	0	0	0

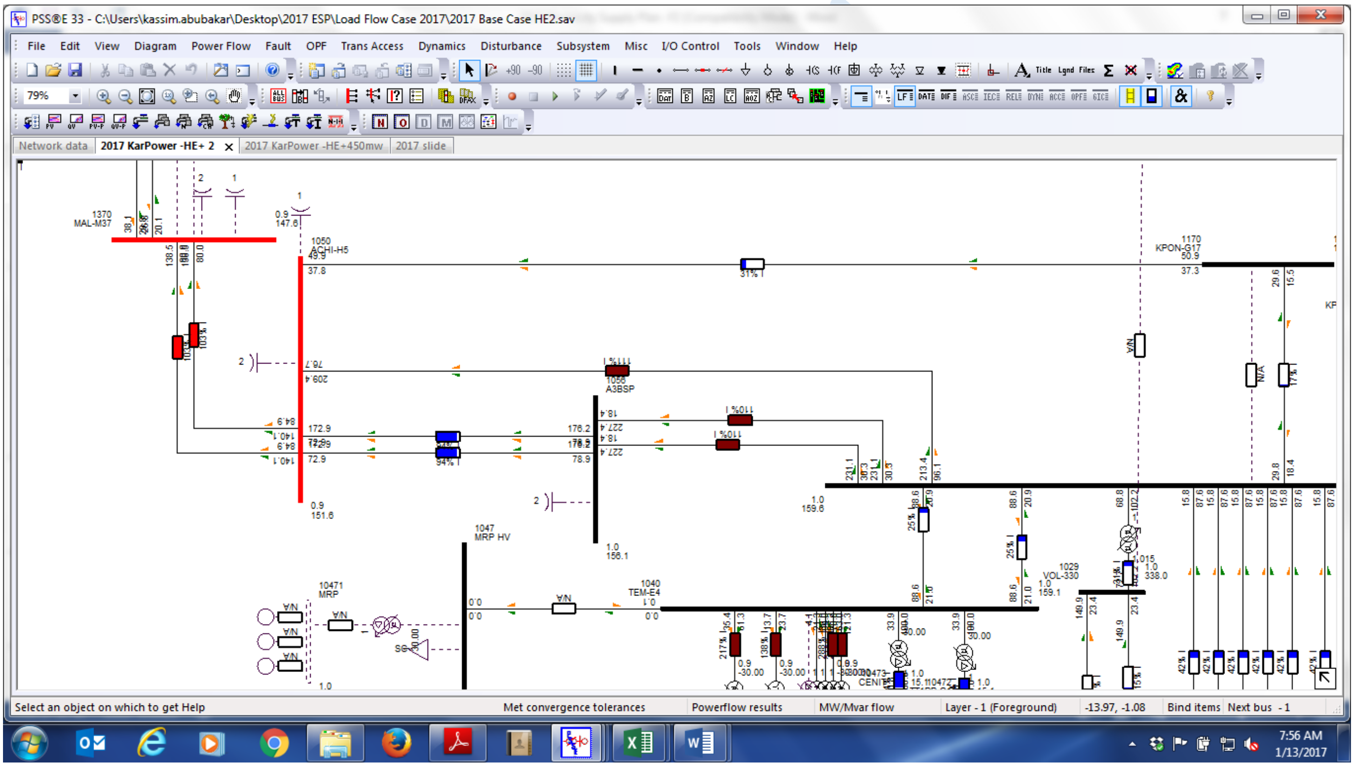
	AMERI	10	20	200
	Import			7
Bui		2	115	230
Total				**2,418**

With the high levels of generation from the East (Tema, Akosombo, Akuse) as shown in the Table above, the results indicate overloads on the Volta – Achimota transmission corridor as follows:

- Volta-Achimota - 111%
- Volta –A3BSP -110%
- A3BSP – Achimota - 94%
- Mallam – Achimota – 103%

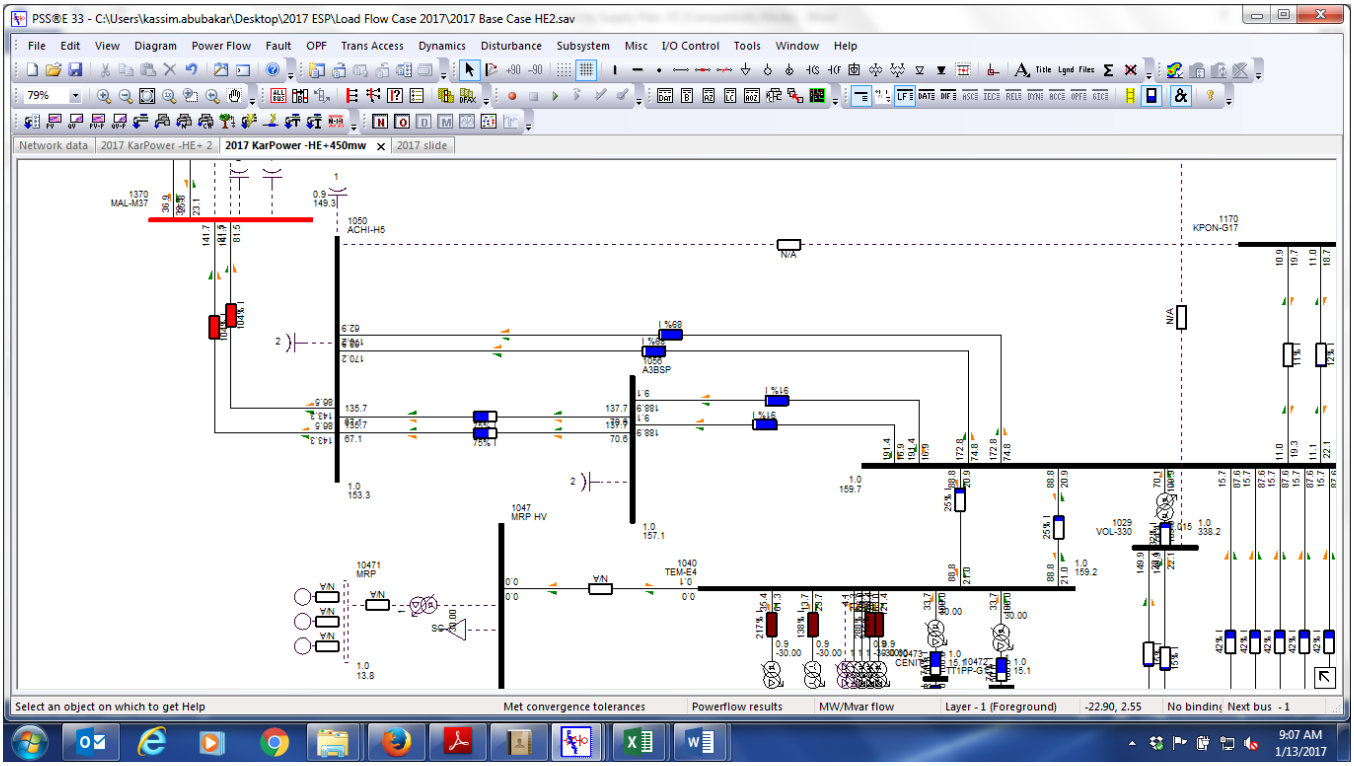
Power flow on the Kpong SS – Achimota line is low, with power flows of only approximately 31% of the line capacity as shown in the load flow slide below.

Figure 1: Load Flow results of Volta –Achimota Corridor



The results of analysis presented in the slide below indicate the impact of temporarily terminating the Kpong SS - Achimota line at Volta to form a Kpong SS-Volta–Achimota circuit:

Figure 2: Load Flow results for the termination of the Kpong SS – Achimota line at Volta



The results indicate a significant reduction in loadings on the transmission lines in the Volta – Achimota corridor as shown below:

Table 23: Transmission line loadings

- Transmission lines	Kpong-Achimota line	
	Not terminated @ Volta	Terminated @ Volta
Volta-Achimota	111%	89%
Volta –A3BSP	110%	91%
A3BSP – Achimota	94%	75%
Mallam – Achimota	103%	104%

The Mallam – Achimota corridor however, remains overloaded at 104 % of its thermal capacity under normal operating conditions. This suggests that under this schedule, not all the available generation could be evacuated if the transmission line loading conditions/criteria of 85% is to be respected.

The 330/161 kV Auto transformers at Volta are loaded to only 32 % of their capacities, about 197 MW of generation out of 300 MW from Asogli Phase II is observed to be flowing towards Aboadze through the 330kV line.

- Voltage

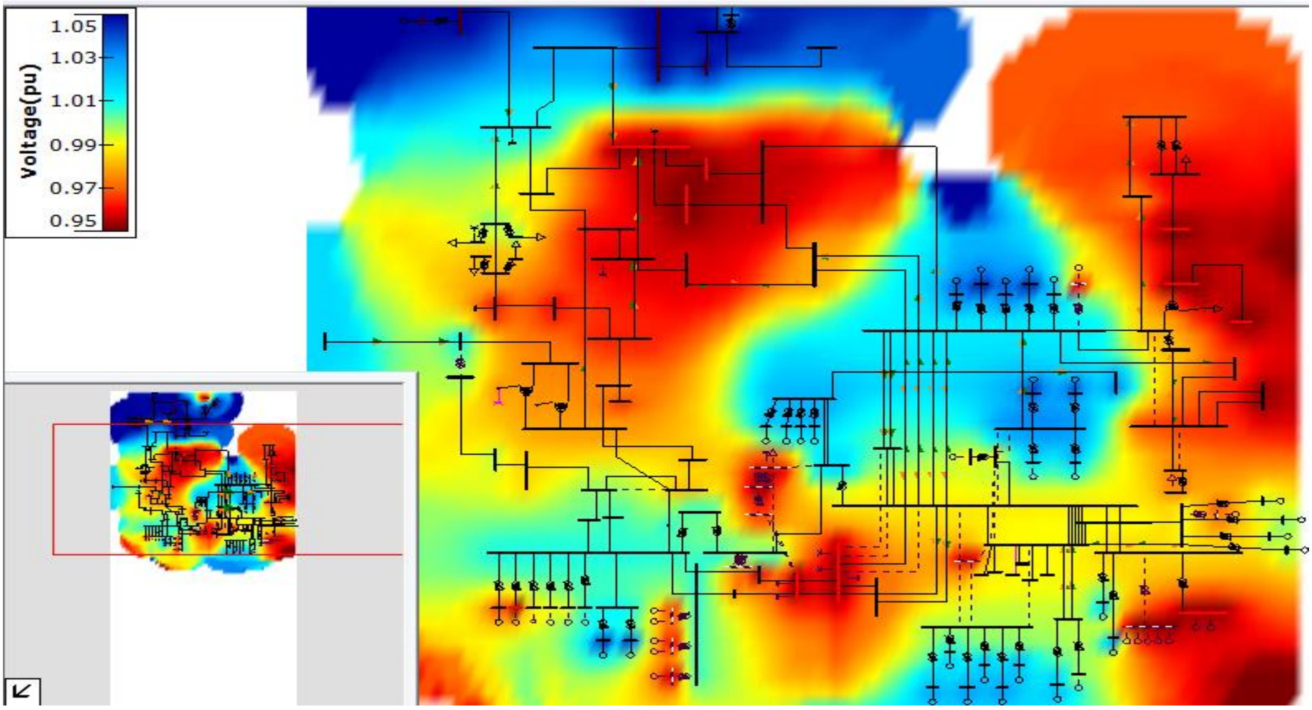
Bus voltage violations are recorded at Mallam, Achimota, Winneba, Kumasi and Konongo with high levels of generation from the east as indicated in the Table and figure below:

Table 24: Load Flow results of selected bus voltages (NOTE- Voltage violations are shown in red font)

Bus Name	Nominal kV	Simulated kV
Volta	161	159.03
Achimota	161	151.4
Winneba	161	152.09
Mallam	161	147.6
Tarkwa	161	157.7
New Tarkwa	161	157.41
Dunkwa	161	154.6
Kumasi	161	150.7
Nkawkaw	161	153.35
Konongo	161	150.95
Asawinso	161	154.3
New Obuasi	161	153.67

These Voltage violations are also presented graphically in the picture below.

Figure 3: Graphical illustration of selected bus voltages (Regions with poor voltages are in red)



The analysis shows that there are low voltages in Kumasi and its environs. This is an indication of lack of sufficient reactive power compensation in Kumasi and its surroundings. It is also attributable to low capacity transmission lines into Kumasi and the high customer load levels relative to the long circuit distances from Kumasi to the generation centres.

The temporal termination of the Kpong SS – Achimota line at Volta (as discussed in the previous section) improves upon voltages in Accra significantly as shown in Table 25 below:

Table 25: Load Flow results of selected bus voltages - impact of Terminating the Kpong SS line at Volta (NOTE- Voltage violations are shown in red font)

Bus Name	Nominal kV	No Termination Simulated kV	With Termination Simulated kV
Volta	161	159.03	159.04
Achimota	161	151.39	152.9
Winneba	161	152.09	153.26
Mallam	161	147.6	149.1
Tarkwa	161	157.73	158.15
New Tarkwa	161	157.41	157.84
Dunkwa	161	154.56	154.97
Kumasi	161	150.71	151.14
Nkawkaw	161	153.35	153.83
Konongo	161	150.95	151.41
Asawinso	161	154.3	154.69
New Obuasi	161	153.67	154.1

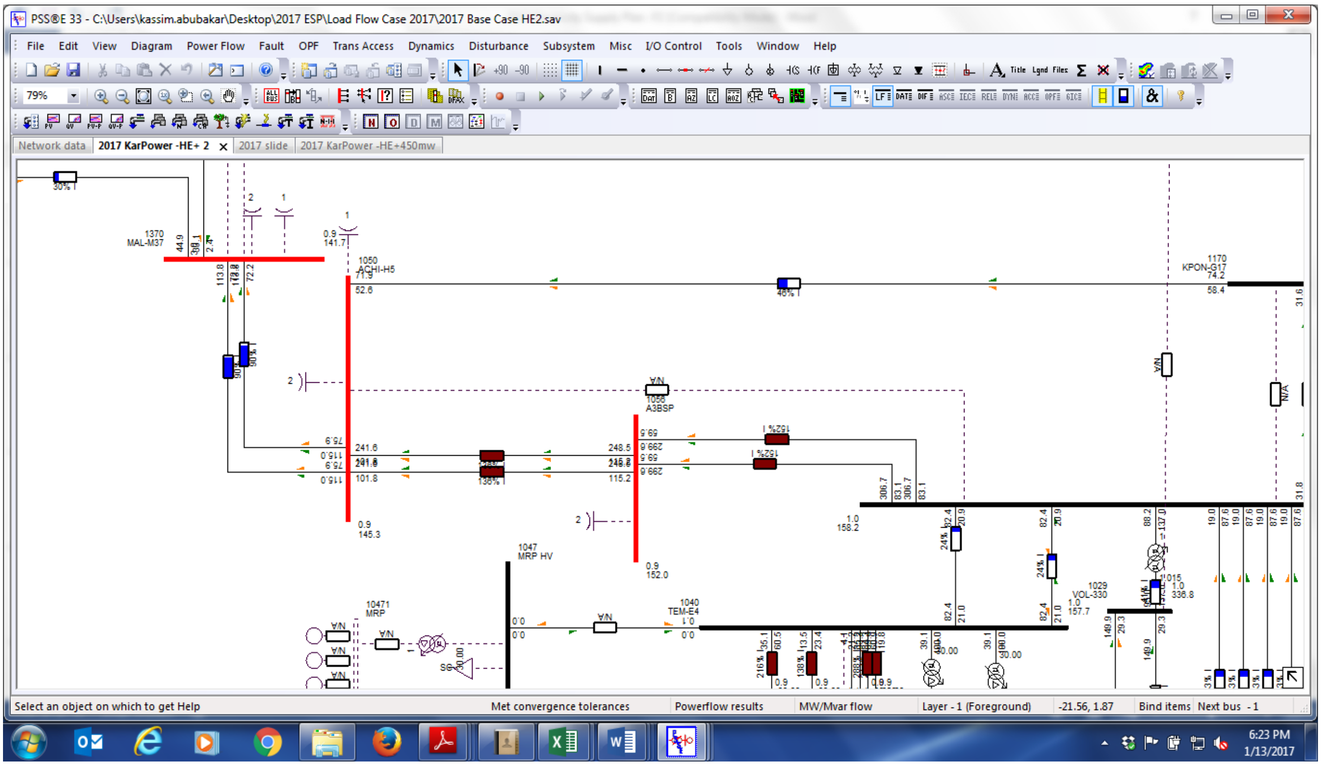
- Contingency Analysis

The loss of the Volta – Achimota line results in severe line loading violations as shown below:

- Volta – A3BSP : 152 %
- A3BSP – Achimota : 136 %
- Achimota –Mallam : 106 %

The figure below show the impact of a single contingency on the Volta – Achimota line:

Figure 4: Load Flow results of Volta - Mallam corridor-Loss of Volta – Achimota line



Also bus voltage violations are recorded as shown below:

- A3BSP – 152.0 kV;
- Achimota – 145.3 kV;
- Mallam – 141.7 kV; and
- Winneba – 147.3 kV.

Similarly the loss of any of the lines in the corridor leads to overloads on adjacent ones.

- Transmission Losses

The analysis shows that 113.2 MW representing 4.7% of generating capacity is lost in transmission when there is high generation in the East (that is generation from Tema, Akosombo and Kpong).

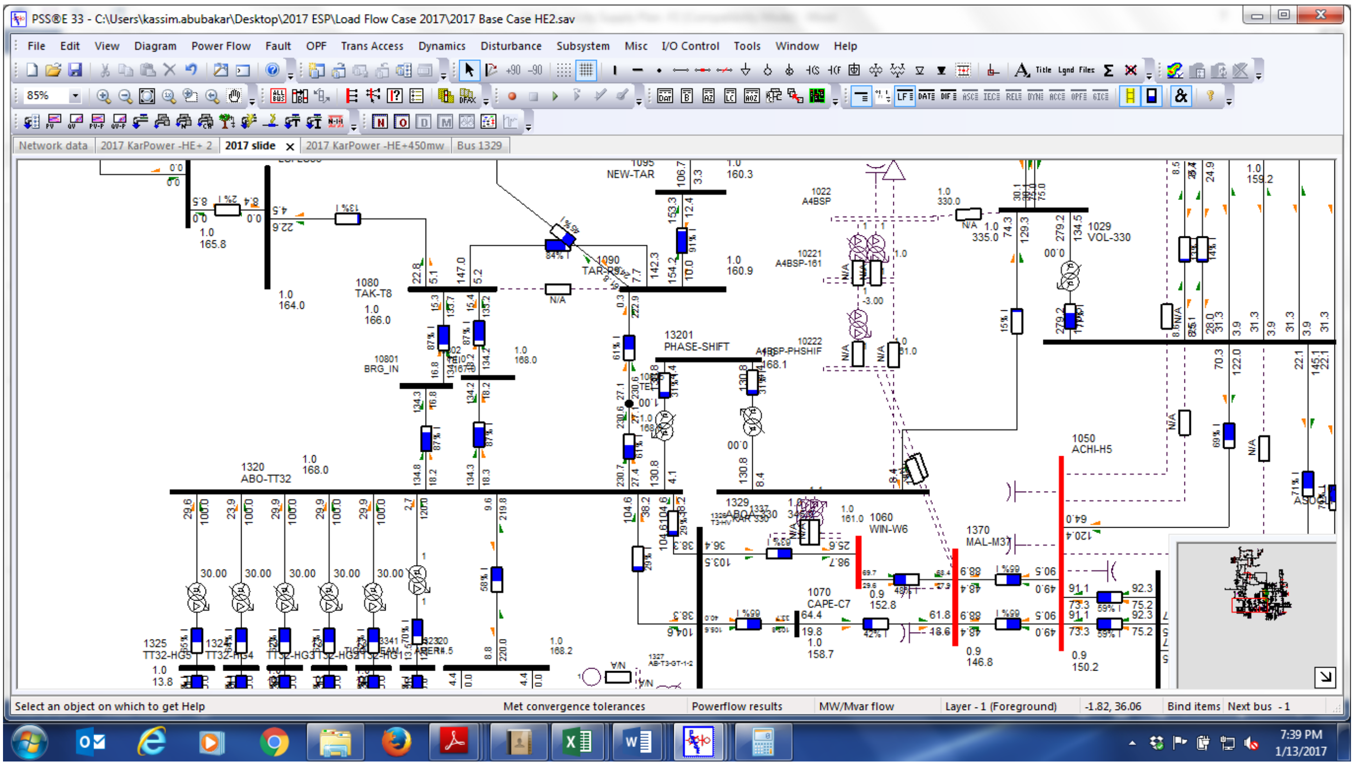
In this scenario, losses reduce to 107.3 MW (representing 4.4% of generation capacity) when the Kpong GS – Achimota line is terminated at Volta.

c. **High Generation from the Western corridor**

- Transmission line Capacity

In this scenario, a total of **2,413.6** MW generation capacity is scheduled to meet the projected load. It comprises of 1,343 MW generation from the East and 840 MW from the West. Two Bui hydroelectric Units of 115 MW each are also scheduled. A snapshot of the analysis is shown below;

Figure 5: Load Flow results -high west generation



The results of load flow analyses show the following line loadings:

- Aboadze – Takoradi - 87 %
- Aboadze – Volta 330 kV -15%
- Aboadze – Cape Coast - 65%
- Aboadze – Winneba -63%

With this schedule the overload on the Volta – Achimota Corridor is cleared as shown in the figure below:

- Volta – Achimota – 84%
- Volta – A3BSP – 85 %
- A3BSP – Achimota – 72%
- Achimota –Mallam – 65%

Transmission losses reduce to 107.7 MW or 4.5 % of generation as compared to the High eastern generation scenario which recorded losses of 113.2 MW (4.7 %.).

- Contingency Analysis

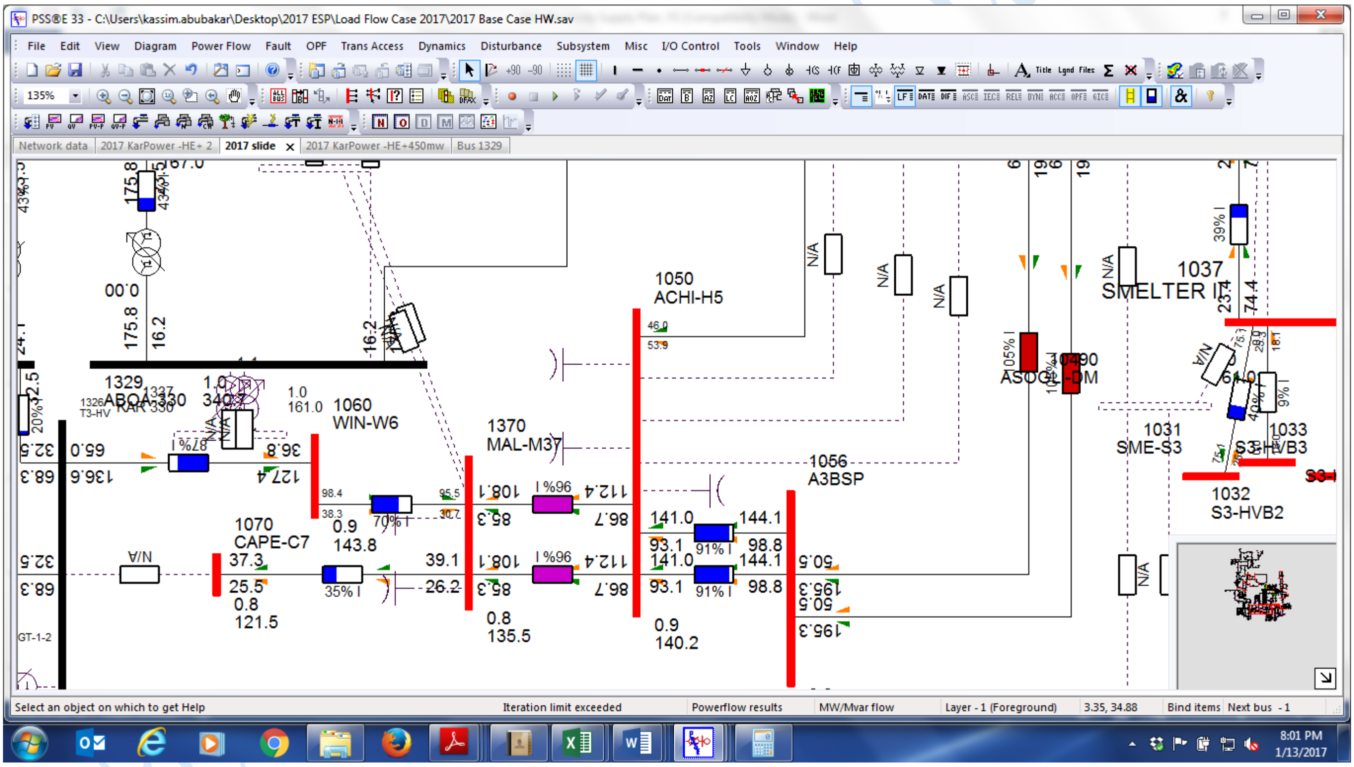
i. Loss of 330kV Aboadze – Volta line

With a high generation schedule from the west of 840 MW, the loss of the 330 kV line results in the non-convergence of load flow case. This is attributed to lack of adequate transfer capacity between the generation hub at Aboadze in the west and the load center at Accra in the East.

ii. Loss of Aboadze – Cape Coast line

The load flow case solves with the loss of any of the coastal 161 kV lines between Aboadze and Accra. However, it results in overloads on the Volta – Achimota –Mallam corridor. This is because of increased flow of power on the Aboadze - Volta 330 kV line towards Volta and back to Accra as show on the slide below. Also, poor voltages are observed in Accra with Mallam recording **135 kV** as shown below:

Figure 6: Load Flow results -high west generation-Contingency on Aboadze –Cape



iii. Loss of Aboadze – Takoradi line

The loss of the line results in overload on the adjacent circuit of up to **162 %** of its thermal ratings.

iv. Loss of Takoradi – Tarkwa line

This leads to high loading on the Aboadze – Tarkwa line of up to **95%** of it thermal ratings.

5.5 Dynamic Simulations

Simulations were performed on the grid to analyse the effect of contingencies with the loss of an Akosombo unit as well as the loss of a 3-phase fault on a line between Volta and Achimota. The results of the simulations are shown in the plots below. The grid operates normally for 2 secs without any network event after which disturbances are applied and the effect on system frequency, rotor angle and active power output are observed.

5.5.1 3 phase fault on Volta-Achimota line

Based on peak loading conditions, a three phase fault was simulated on a Volta-Achimota line which was cleared in 5 cycles followed by a line trip. The frequency and angle plots below show this simulation;

a. Angle Spread Plot

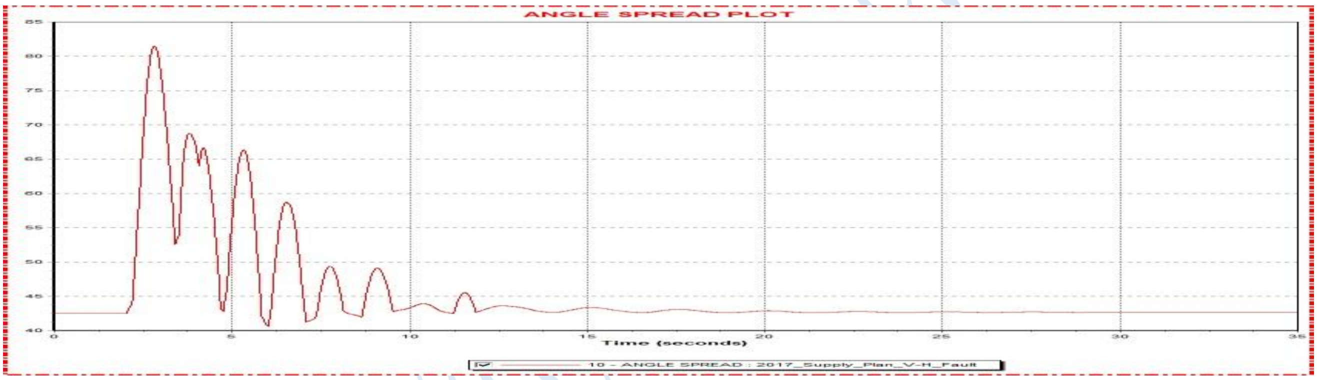


Figure 7: Angle spread plot-Loss of Volta –Achimota line

The angle spread plot above shows the wide swings on the grid as a result of the fault. The fault is cleared in 5 cycles, followed by damped oscillations which die out completely.

b. Frequency Plot

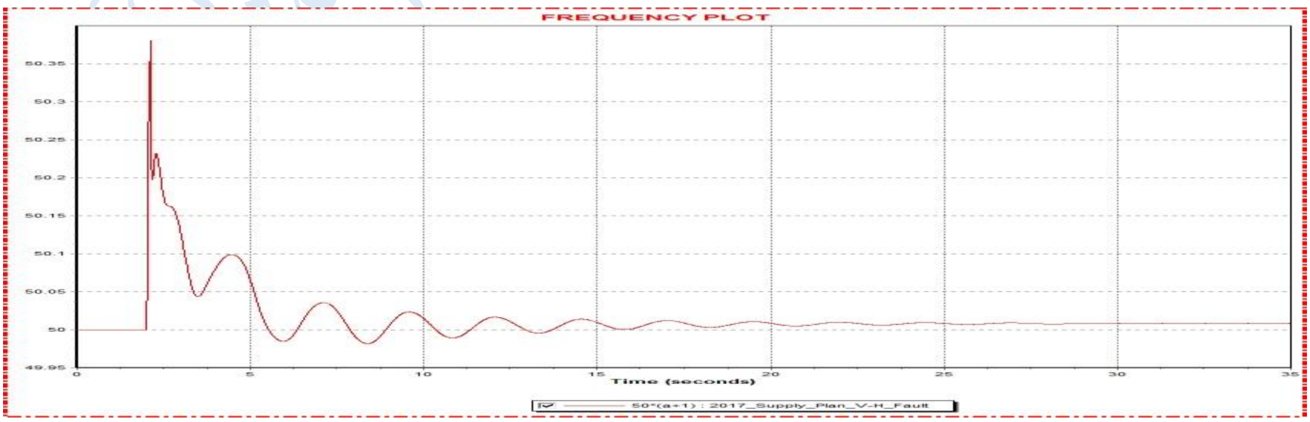


Figure 8: Frequency plot-Loss of Volta –Achimota line

The frequency plot shows the occurrence of the fault with the sudden spike which recovers and finally settles at the initial operating frequency under normal conditions.

c. Relative Machine Angle Plots

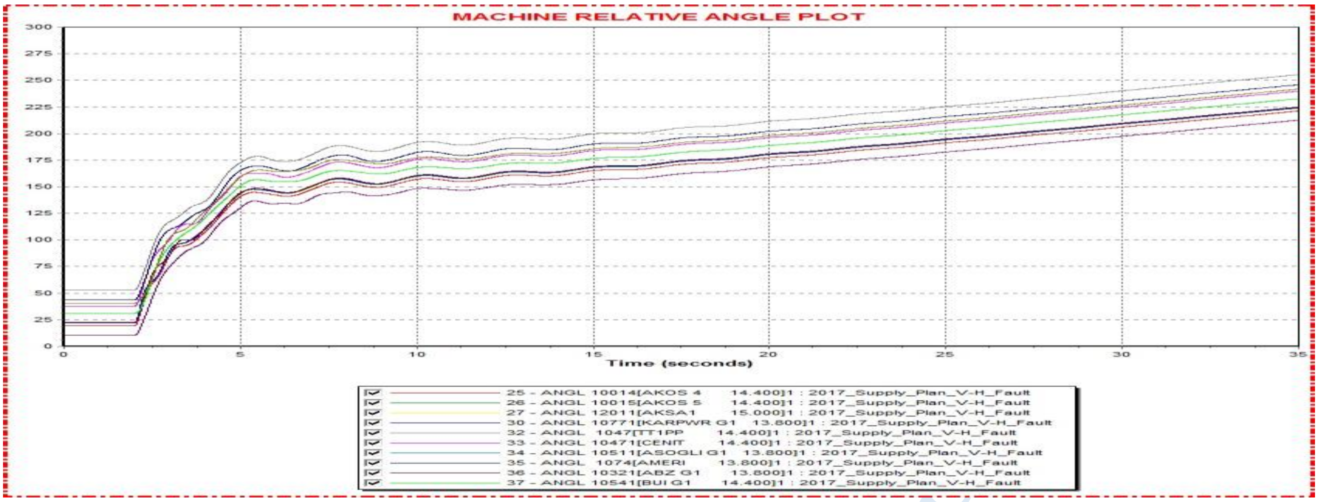


Figure 9: Machine angle plot-Loss of Volta –Achimota line

Above shows the relative machine angles of the various machines monitored on the grid. The plots indicate a disturbance in the operation of these machines which settle eventually after the line trips, clearing the fault.

5.5.2 Tripping of one of five Akosombo units in service

Based on peak loading conditions, one of five Akosombo units in service was tripped and the effect of the incident on the grid and other connected units is as below:

d. Angle Spread Plot

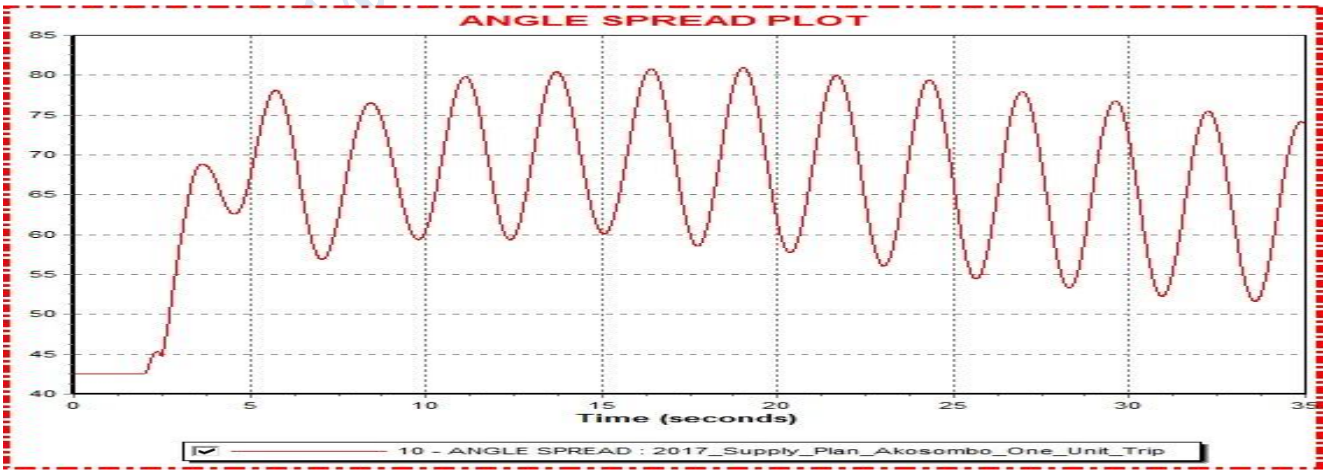


Figure 10: Angle spread plot-Loss of one Akosombo unit (out of 5)

After 2 seconds of normal system operation, one of the units in Akosombo was tripped and the angle spread plot above indicates that the loss of this unit causes undamped oscillations on the grid which are sustained for the entire duration of the simulation.

e. Frequency Plot

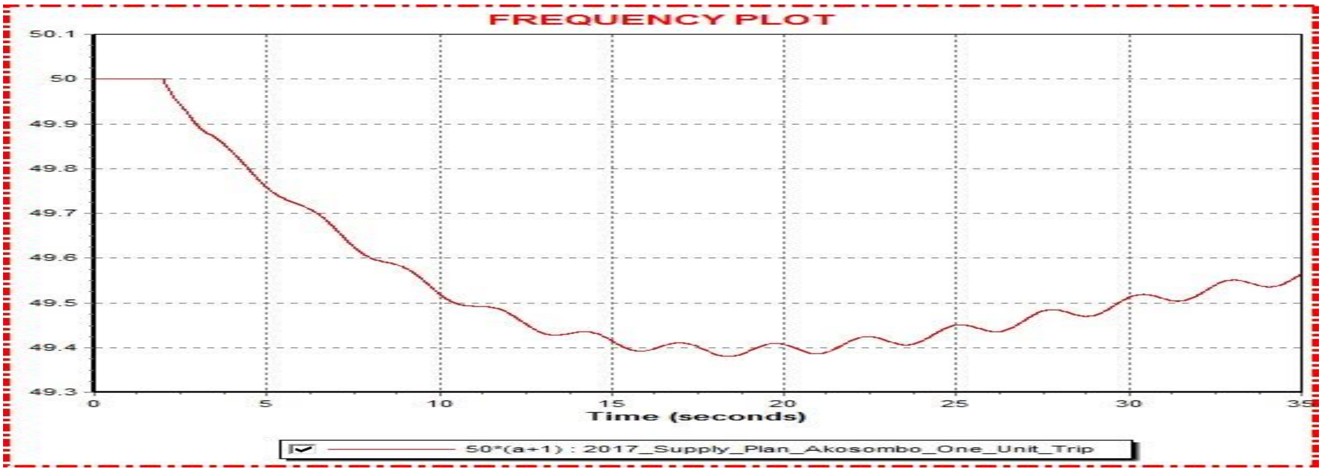


Figure 11: Frequency plot-Loss of one Akosombo unit (out of 5)

The frequency plot above for the loss of an Akosombo unit shows that the frequency settles at 49.4Hz without any load shedding. However, this loss makes the network unstable and this is seen in the oscillations observed on the frequency plot.

f. Machine Active Power Output Plot

The active power plot in the chart below clearly indicates the response of the remaining Akosombo units in service to the loss. The output of the remaining 4 units increases to make up for the lost generation. The frequency rises but does not recover to the initial operating frequency under normal system conditions.

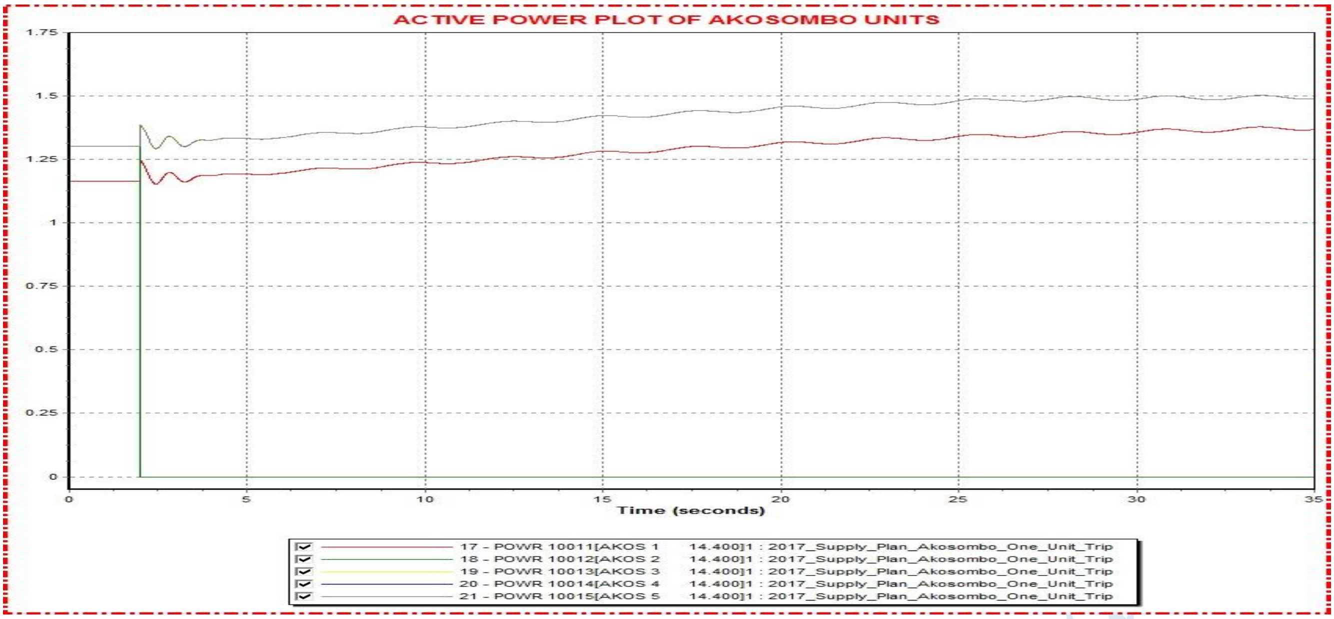


Figure 12: Machine active power output-Loss of one Akosombo unit (out of 5)

5.6 Recommended System Expansions and Upgrades

In order to address the above network constraints, we recommend the implementation of the following projects:

- ✓ Upgrading of transmission lines in the Volta – Achimota corridor from 213 MVA to a 488 MVA, twin Tern ACSR 2x430 mm2 line. This would increase the evacuation capacity from Tema generation hub to the load centre of Accra. Especially, this is necessary to ensure the evacuation of generation from the new thermal power plants in Tema, namely Karpower (225 MW), Sunon-Asogli Phase-2 (180MW) and the Kpone Thermal Power Plant (KTPP - 200 MW).
- ✓ Fast tracking the ongoing construction of Aboadze-Prestea-Kumasi 330kV line. This would improve upon bus voltages in Kumasi and adjacent substations and consequently reduce overall system losses.
- ✓ Upgrade of Achimota–Mallam 161 kV transmission line conductor from 170 MVA to 488 MVA, twin Tern ACSR 2x430 mm2 line to improve bus voltages at Achimota and adjacent substations. It would also reduce overall transmission losses and lines loading on the NITS. This project has already been awarded on contract.
- ✓ Construction of A4BSP 330kV substation with a 161kV, double circuit twin bundle (364x2 MVA) link to Mallam BSP. This would increase the reliability of supply to Accra and increase transfer capacity between the generation hub of Aboadze and Tema to the load Centre at Accra.

- ✓ Upgrade of the 161 kV Aboadze- Mallam transmission line into a double circuit twin Tern ACSR 2x430 sqmm line.
- ✓ Upgrade of the 161 kV Aboadze -Takoradi transmission line into a double circuit twin Tern ACSR 2x430sqmm line.
- ✓ Upgrade of the 161 kV Takoradi - Esiama transmission line into a double circuit twin Tern ACSR 2x430 sqmm line.
- ✓ Upgrade of 161 kV Tarkwa – New Tarkwa into a single circuit twin Tern ACSR 2x430 sqmm line.
- ✓ Upgrade of 161 kV Takoradi – Tarkwa into a single circuit twin Tern ACSR 2x430 sqmm line.

6 POTENTIAL SUPPLY CHALLENGES IN 2017

From the review of the 2016 power system performance in Chapter 2, a number of challenges were identified. In this chapter, we take a critical look at the major challenges anticipated which can adversely impact on reliability of supply in 2017.

6.1 Hydro Risk

- The Akosombo Hydropower plant will be required to operate 6 units in the 1st quarter of the year to make up for reduced thermal generation as a result of some scheduled plant outages which coincide with the cessation of gas supply from GNGC for the TEN tie-in works (which will lead to a temporary shutdown of the Ameri Plant). The plan is to reduce the number of units to a maximum of four (4) for the rest of the year in order to maintain the reservoir level above the minimum operating level of 240 feet. With the current water level (249.22 feet as of January 25, 2017), it will be prudent to limit Akosombo operations to running not more than four (4) units from the second quarter onwards. Failure to adhere to the plan for hydro could significantly compromise reservoir operations for subsequent years.

6.2 Fuel Supply

- In (Section 2.7), we asserted that:
- Gas supply inadequacy remains one of the major risks to reliable electricity supply in Ghana. Although, installed generating capacity is high, unavailability of fuel to run thermal units has rendered some thermal plants inoperable. Examples of these are the MRP, TT2PP, KTPP, Sunon Asogli Phase-2 plants, etc.;
- There is a need to make advanced arrangements to secure adequate LCO cargoes both at Tema and Takoradi for running thermal plants as detailed in (Section 4.2.3) above;
- The fuel supply challenge has more to do with funding than technical constraints. There is a need to pay off any indebtedness to gas suppliers so that the required Gas volumes would be obtained for the thermal generation. Advanced arrangements require to be made for LCO purchases to ensure their timely delivery. It is therefore necessary to arrange to secure the needed funds to purchase the needed quantities of fuel on time.

6.3 Supply Reliability

6.3.1 Operating Reserves

- The power system will operate without the required margin of operating reserve to adequately cover for forced outages to generating units until August 2017.
- The low reserve margin in the first half of the year will affect the reliability of supply and could lead to some power outages in the event that some of the projected generating plants are unable to deliver as much as projected.

6.3.2 Radial lines

A contingency on any of the following radial lines would result in outage to consumers:

- Tamale – Yendi line;
- Takoradi – Esiama line;
- Bogoso – Akyempim line;
- Bolga - Zebila line;
- Zebila – Bawku line, etc.

6.3.3 Single Transformer Stations

Akosombo, Kpong GS, Yendi, Esiama etc. are single load transformer stations. At these stations, there are often challenges in securing outages to carry out planned maintenance work and/or to upgrade the network.

6.4 Power Evacuation

- There are transmission capacity constraints in some portions of the network which could lead to transmission line overloads;
- Insufficient reactive power compensation could lead to poor customer supply voltage in areas such Kumasi, Accra and some parts of the western region;
- Some sections of the NITS do not satisfy the 'N-1 criteria' and will be unable to withstand some single line/transformer contingencies;

7 DISTRIBUTION OUTLOOK

7.1 ECG Network Reliability Assessment

Reliability of supply within the distribution network has been a major concern recently. Accordingly, reliability studies were carried out within the ECG network, focusing on the following operational areas: Accra, Tema, Kumasi and Takoradi. These ECG operational regions accounted for 79.56 % of ECG's total demand recorded in 2015.

7.1.1 Constraints Identified in the 2016 ECG Reliability Study for Selected Areas

Three analyses were carried out to assess the reliability of the sub-transmission system. (See Figure 13). Firstly, Total Transfer Capability (TTC) analysis was carried out to determine the amount of power that the sub-transmission system can adequately deliver to primary substations without a need for load management. We also used the TTC analysis to assess if there was any potential amount of demand that the sub-transmission would be unable to serve due to inadequate sub-transmission transfer capability.

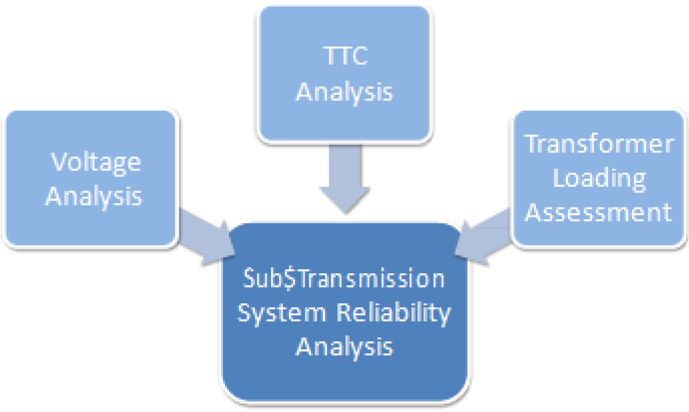


Figure 13: Aspects of Sub-Transmission System Reliability Analysis

A power quality analysis was also carried out to assess voltage performance at ECG primary substations. 33 kV substation voltages are required to be within ±10 % of the nominal. Voltage deviations outside these limits could cause damage or destruction to customer equipment. Furthermore, low voltages significantly reduce the ability to transfer power within the sub-transmission network.

Finally, the transformer capacity installed at each primary substation was assessed to determine its adequacy to serve peak load at the station. Adequate transformer capacity is necessary for the reliable operation of the distribution system. ECG adequacy standard considers the normal rating of transformers at 70% of their name plate capacity, so that a transformer loaded at 70% of its rating is considered fully loaded. Under contingency or emergency conditions, transformer loading of up to 120% of the nameplate capacity is permissible, but only for short durations.

The results of the analysis performed for the four heaviest load centers: Accra, Kumasi, Tema and Takoradi are discussed below

a. Accra

i. Sub – transmission constraints

In normal operations, the study revealed that all the loads supplied from the Achimota BSP network can be served on the existing sub-transmission network capacity with the exception of the following feeders which recorded significant demand above the ECGs feeder loading limit *(thermal loading limit of the feeders were however not exceeded):*

- Kokomlemle feeders from Avenor substation (“D”) to Kokomlemle substation (“F”) within the Achimota BSP network.
- The Alajo circuits from the Achimota BSP to the Avenor substation (“D”)

Under normal operating conditions, the study revealed that all loads supplied from the Accra East BSP network can be served on the existing sub-transmission network capacity with the exception of supply from the Accra East BSP to the Baatsona substation (“Y”) line.

ii. Voltage constraints

Poor voltages below the allowable limits were recorded on the 33kV and 11kV buses at Ofankor, Nsawam, Aburi and Kwabenya. These are attributable to increasing demand and their relatively long distances from the Mallam BSP where they have their source.

iii. Transformer Capacity constraints

Under normal operating conditions, the power transformers at the following substations – Avenor (“D”), Legon (“M”), and Kwabenya (“A”) were loaded in excess of their allowable loading limit but did not exceed their thermal loading limits.

b. Kumasi

i. Sub – Transmission Constraints

Under normal operating conditions in 2016 the following feeders recorded demand above the 70% loading limit;

- Kumasi 1st BSP to Neoplan (“B”) feeders, and
- Neoplan (“B”) to Suame (“E”) feeders.

It should be noted however that these feeders did not exceed their thermal loading limits.

ii. Voltage Constraints

The following load points under the Kumasi BSP experienced low operational voltages:

- Mankraso all the way to Manso Adubia
- Effiduase
- Nsuta
- Kumawu
- Nkwanta

iii. Transformer Capacity constraints

Under normal operating conditions, the power transformers at the following substations exceed ECGs loading limit, but not their thermal loading limits: Amanfrom, Neoplan (“B”), Suame (“E”), Airport Roundabout (“C”) and Ridge (“A”).

c. Tema

i. Sub – Transmission Constraints

Under normal operating conditions, the Tema 33 kV network had adequate capacity to serve all customer loads.

ii. Voltage Constraints

The 33 kV Bondase distribution line from Dawhenya heading towards Sogakope experienced low operational voltages. This is because the 33 kV line serving these areas is quite long.

iii. Transformer Capacity constraints

Under normal operating conditions, all the substation transformers within the Smelter II BSP and New Tema BSP network will be operating below 70% of their ONAN ratings.

d. Takoradi

i. Sub – Transmission Constraints

Under normal operating conditions the existing transmission capacity is adequate to serve all load within the Takoradi 33 kV network.

ii. Voltage Constraints

The bus voltages at all the 33kV primary substations were within limits.

iii. Transformer Capacity constraints

The primary substation transformers at the Takoradi BSP were loaded below 70% of their ONAN ratings.

7.2 INTERVENTIONS BEING PUT IN PLACE BY ECG

Appendix C details the short term interventions being carried out by ECG to resolve the constraints highlighted above.

7.3 NEDCO Distribution Network

NEDCo's distribution network covers Brong-Ahafo, Northern, Upper East and Upper West Regions. It also extends to portions of the Ashanti, Volta and Western Regions of Ghana. Some border communities in Burkina Faso, Togo and Cote d'Ivoire are also supplied by NEDCo. In terms of geographical Area, NEDCo covers about 64% of the landmass of Ghana. The energy demand for NEDCo in 2016 was 1,139.5 GWh and has been projected to reach a value of 1,213 GWh by the end of 2017, an increase of about 6.4 % over the period. There are however some pertinent constraints in the NEDCo distribution network which require to be addressed to guarantee the reliability and quality of supply to consumers.

7.3.1 Sub-Transmission and Distribution Constraints:

Currently, capacity and voltage constraints within some sections of NEDCo's sub-transmission and distribution networks constitute the main bottlenecks to power supply delivery. Details of the main constraints at bulk supply points, primary substations, on the sub transmission as well as the distribution networks are discussed below.

7.3.2 Bulk Supply Points:

GRIDCo's bulk supply points across the operational areas have adequate capacity to serve projected 2017 demand. However, there are some underground cables which evacuate power to the overhead distribution networks that are overloaded and overaged. These overloaded cables have been earmarked for upgrade in 2017. The shield wire transformer at the Techiman substation which serves communities such as Abofour and Nkenkansu in the Ashanti Region also have some capacity constraints. Consequently, NEDCo plans to upgrade the existing 30kV shield wire network through the construction of a 34.5kV conventional line from Techiman to address the challenge in 2017.

7.3.3 Primary Substations:

NEDCo currently has fifteen (15) primary substations including a booster station. The primary substation in Wa is currently overloaded and NEDCo has initiated a programme to upgrade the Wa substation in 2017. Bawku and Navrongo primary substations also have a number of obsolete switchgear in operations which are earmarked to be replaced in 2017 as part of activities to be implemented under the second phase of the Network Protection System Improvement Project (NPSIP II). The Contract has already been awarded.

7.3.4 Sub-transmission and distribution lines

Due to its large geographical area of operation NEDCo has a number of long radial sub-transmission and distribution feeders which are saddled with poor voltages at the feeder ends. Feeders serving Ejura, Atebubu and beyond at Techiman, Tamale feeders serving the Dalun and beyond as well as Yendi feeders serving Bimbilla, Kete-Krachie and beyond are examples.

A new 34.5kV line is however under construction from the Kintampo Substation to take up part of the load on the Techiman feeder and reduce the circuit length. When completed reliability of supply and customer voltage profile will be significantly improved. The new line is expected to be completed in 2017. In order to improve reliability and voltage profile on the Tamale and Yendi feeders, switching stations have also been earmarked for construction at Gumo in Tamale and Bimbilla.

NEDCo has over 5,500 distribution transformers in service, some of which are overloaded. In 2017, seventy (70) distribution transformers are expected to be upgraded or have additional transformers installed to provide relief to existing ones as well as to enable the connection of additional customers. In the same period, about 200km of low voltage lines are expected to be upgraded.

8 OVERVIEW OF MEDIUM-TERM SUPPLY: 2018 - 2022

In this chapter we analyse the medium-term (2018 - 2022) projected peak demand and energy consumption to serve as a guide for power system investment planning. It noteworthy that a typical power plant construction project takes an average of four (4) years from inception through arrangement for financing, detail design, construction until commencement of commercial operation. To that effect, this section provides an outlook for generation and transmission system requirements for the next five years (2018 – 2022) to enable adequate and timely arrangements to be initiated for their implementation to assure security of supply in Ghana over the medium term.

It is noteworthy that delays in the implementation of recommendations in the 2010 Supply Plan for generation expansion projects led to the most recent energy crisis from the last quarter of 2011 through to 2016, which led to widespread and intensive load shedding, the collapse of some industries and the suspension of some industrial and commercial projects, severely stunting economic growth.

8.1 Demand Outlook

Projected demand for electricity over the period asserts the natural growth of domestic demand together with some spot loads that are expected to lead to increased system demand. The expected spot loads for the period are as follow:

- Enclave Power demand is projected to increase from 64.82 MW in 2017 to 85 MW by 2022;
- VALCO demand is expected to increase from 1 pot-line operation in 2017 to 2 pot-lines in 2018, 3 pot-lines in 2019 and the entire 5 pot-line operation is assumed from 2020 onwards;
- Newmont Mines, Ahafo (New Projects) demand is expected to increase from 52 MW in 2017 to 89 MW by 2022. Azuma Mine, 23 MW by 2019 at Yagha (50km NW of Wa);
- Exports potentials are: Burkina Faso are expected at 150 MW by 2019; Mali 150 MW by 2021, Togo and Benin 200 MW by 2020, etc.

Total electricity consumption on the Ghana power system including power exports to Togo, Benin, Burkina Faso and Mali (from 2019) is projected to increase from 17,768 GWh in 2018 to 26,302 GWh in 2022 at a Compound Annual Growth Rate (CAGR) of approximately 10.99 %.

The system peak demand is projected to increase from 2,646 MW in 2018 to 3,828 MW in 2022.

Table 26: Projected Energy Demand (GWh) (2018- 2022)

Forecast: Energy (GWh)	2018	2019	2020	2021	2022
Domestic	14,305	15,364	16,139	16,700	17,388
VALCO	1,630	2,909	3,881	4,845	4,845
EXPORTS	1,214	2,328	2,913	3,209	3,209
Transmission Losses/Network usage	619	664	744	800	860
Total	17,768	21,265	23,676	25,554	26,302

Table 27: Projected Peak Demand (MW) (2018- 2022)

Forecast: Peak demand (MW)-Coincident	2018	2019	2020	2021	2022
Domestic	2,161	2,317	2,433	2,518	2,623
VALCO	186	332	443	553	553
EXPORTS	193	365	458	503	503
Transmission Losses/Network usage	107	115	129	138	149
Total	2,646	3,128	3,462	3,712	3,828

8.2 Projected Supply Outlook

The power supply outlook was prepared considering the existing and committed generation capacities. The assessment of generation adequacy is based on ensuring sufficient generation resources are available to meet the forecast demand plus a 25% required reserve. A 340 MW combine cycle generation modules is then planned for any supply gap identified.

8.2.1 Existing Generation

The existing power supply facilities are made up of hydro, thermal and renewable generation resources as shown in Chapter 3. A detailed breakdown of projected demand versus expected supply from the existing generation resources is as shown in the Table below:

The following assumption were made for Hydro Power Generation:

- **Akosombo & Kpong GS.** Provision was made for the recovery of the Akosombo reservoir, average of 4 units were assumed in 2017, 5 units in 2018 and 2019. From 2020 all the 6 units are expected to be available to support peak demand. Akosombo & Kpong generation are assumed to be 4,404 GWh in 2017 and 4,800 GWh in 2018. It is assumed that from 2019 the firm Akosombo and Kpong supply of 5,300 GWh would be maintained.

- **Bui Generating Station.** Bui hydro is assumed to produce about 760 GWh of electricity/year from 2017. Bui GS is assumed to provide 230 MW of generation capacity to support peak demand.

As indicated in the Demand and Supply Table 28 below, there would be a deficit in supply of 306 MW in 2019 and the shortage increases to 1,180 MW in 2022.

Table 28: Projected Demand Versus Supply (existing) balance (2018- 2022)-

Projected System Peak Demand (MW)	**2018**	**2019**	**2020**	**2021**	**2022**
Domestic	2,161	2,317	2,433	2,518	2,623
VALCO	186	332	443	553	553
Export (CEB+SONABEL)	193	365	458	503	503
Transmission System losses/Network Usage	107	115	129	138	149
Projected System Demand (MW)	**2,646**	**3,128**	**3,462**	**3,712**	**3,828**
Reserve Margin MW (25% of peak demand)	**662**	**782**	**865**	**928**	**957**
Required Total Supply(Demand +Reserve)	**3,308**	**3,910**	**4,327**	**4,640**	**4,784**
Hydro Dependable Capacity					
Akosombo	750	750	750	750	750
Kpong GS	140	140	140	140	140
Bui GS	230	230	230	230	230
Total Hydro Capacity MW	**1,120**	**1,120**	**1,120**	**1,120**	**1,120**
Thermal Dependable Capacity					
TAPCO	300	300	300	300	300
TICO	300	300	300	300	300
TT1PP	100	100	100	100	100
MRP	40	40	40	40	40
KTPP	200	200	200	200	200
TT2PP	30	30	30	30	30
TT2PP-x	32	32	32	32	32
SAPP	180	180	180	180	180
SAPP (Phase 2)	360	360	360	360	360
CENIT	100	100	100	100	100
VRA/AMERI Power Plant	230	230	230	230	230
Karpower Barge	220	220	220	220	220
AKSA	240	340	340	340	340
Trojan	12	12	12	12	12
Genser	18	18	18	18	18
Total Thermal Capacity (MW)	**2,362**	**2,462**	**2,462**	**2,462**	**2,462**
Renewables					
SAFISANA					
VRA Solar	2.5	3	2.5	2.5	2.5
Solar (Central Region)	20	20	20	20	20
Total Available Generation (MW)	**3,504.50**	**3,604.50**	**3,604.50**	**3,604.50**	**3,604.50**
Surplus/deficit (MW)	**197**	**(306)**	**(723)**	**(1,035)**	**(1,180)**
Additional Generation Requirement (MW)	0	306	723	1035	1180

8.2.2 Committed Generation Projects

The following are the committed generation addition projects expected to come online in the period:

- 225 MW Karpower (Phase 2) - This is the second phase of the 450MW Emergency Power Project. It is expected to come online in the last quarter of 2017;
- 360 MW Cenpower Project – Construction for this project has commenced and based on the project timeline, the plant should be commissioned by fourth quarter of 2017. However in this analysis the plant is assumed to be available from January 2018;
- 400 MW Early Power Plant is expected to be implemented in two phases. The first phase of 142 MW is expected to be commissioned by the fourth quarter of 2017 and it is to be connected onto the 34.5kV ECG system at New Tema. The first five units of the trailer mounted units have already been shipped to the country. The second phase consisting of the balance the 400 MW is come online in the last quarter of 2018;
- GPGC is a 107 MW thermal power plant. Arrangements for the construction and installation of the plant are yet to be firmed;
- The existing Takoradi Thermal Extension Plant (T3) is a 132 MW combine cycle plant which is currently out of service due to damage to its gas turbine engines. Arrangements are in place to refurbish/replace the unit engines.

8.2.3 Additional Generation Requirements

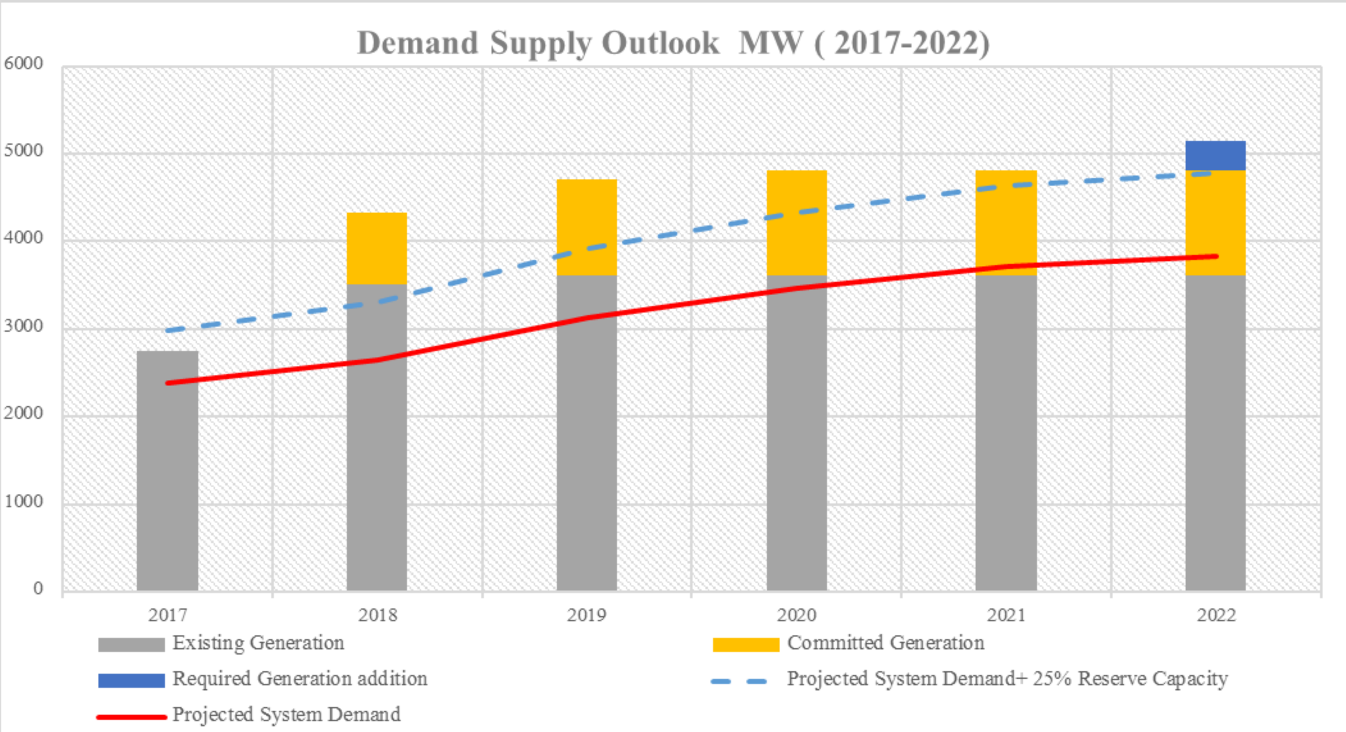
Table 29 and figure 14 below show that supply surplus keeps reducing from 2018 to 2022.

Table 29: Projected Demand Versus Supply (+committed generation) balance (2018- 2022)

Year	**2018**	**2019**	**2020**	**2021**	**2022**
Domestic	2,161	2,317	2,433	2,518	2,623
VALCO	186	332	443	553	553
Export (CEB+SONABEL)	193	365	458	503	503
Transmission System losses/Network Usage	107	115	129	138	149
Projected System Demand (MW)	**2,646**	**3,128**	**3,462**	**3,712**	**3,828**
Reserve Margin MW (25% of peak demand)	**662**	**782**	**865**	**928**	**957**
Required Total Supply(Demand +Reserve)	**3,308**	**3,910**	**4,327**	**4,640**	**4,784**
Total Existing Hydro Capacity (MW)	**1,120**	**1,120**	**1,120**	**1,120**	**1,120**
Total Existing Thermal Capacity (MW)	**2,362**	**2,462**	**2,462**	**2,462**	**2,462**
Total Existing Renewables (MW)	**22.5**	**22.5**	**22.5**	**22.5**	**22.5**
Committed Thermal Generation Projects					

Karpower Phase II	220	220	220	220	220
CENPOWER	360	360	360	360	360
Early Power	142	300	400	400	400
GPGC	100	100	100	100	100
VRA T3		120	120	120	120
Total Committed Generation (MW)	**822**	**1,100**	**1,200**	**1,200**	**1,200**
Expected Total Generation (MW)	**4,326.50**	**4,704.50**	**4,804.50**	**4,804.50**	**4,804.50**
Surplus (MW)	**1,019**	**794**	**477**	**165**	**20**

Figure 14: Projected Demand Versus Supply balance (2017- 2022)



Taking into consideration the fact that the average lead time of four (4) years for development of major generation projects**, it is recommended for urgent steps to be taken to attract investment in additional generation to ensure adequate supply capacity with reserve margin for 2022 and beyond.**

8.3 Strategic Medium Term NITS Requirements

System network analyses were carried out assuming the Medium-Term demand and supply projections detailed in Table 28 above. The results indicate congestion, especially in the southern parts of the NITS. It further indicates that in the medium term the addition of the following transmission infrastructure will improve the reliability of Power Supply;

- Construction of a second Prestea - Dunkwa – Kumasi 330 kV line;
- Construction of a second 330 kV Aboadze – A4 BSP line;

- Construction of a double 330 kV A4BSP to Kumasi line;
- Eastern Transmission Corridor Projects:
  - ✓ Kpando – Juale - 161kV Line
  - ✓ Juale – Yendig -161kV Line
- Construction of 330 kV substation at Dunkwa with a link to the existing 161 kV station
- Construction of a third Bulk Supply Point in Kumasi at 330kV level

8.3.1 New Generation Enclave on immediate West of Accra.

Analysis have been carried out on the impact of developing a new generation enclave of up to 200 MW on the immediate West of Accra (i.e. **between Kasoa and Winneba**). Studies carried out for this analysis assumed Winneba as the point of connection for the new generation enclave. Below are some load-flow results from the analysis:

Figure 15: Base Case: high East Generation

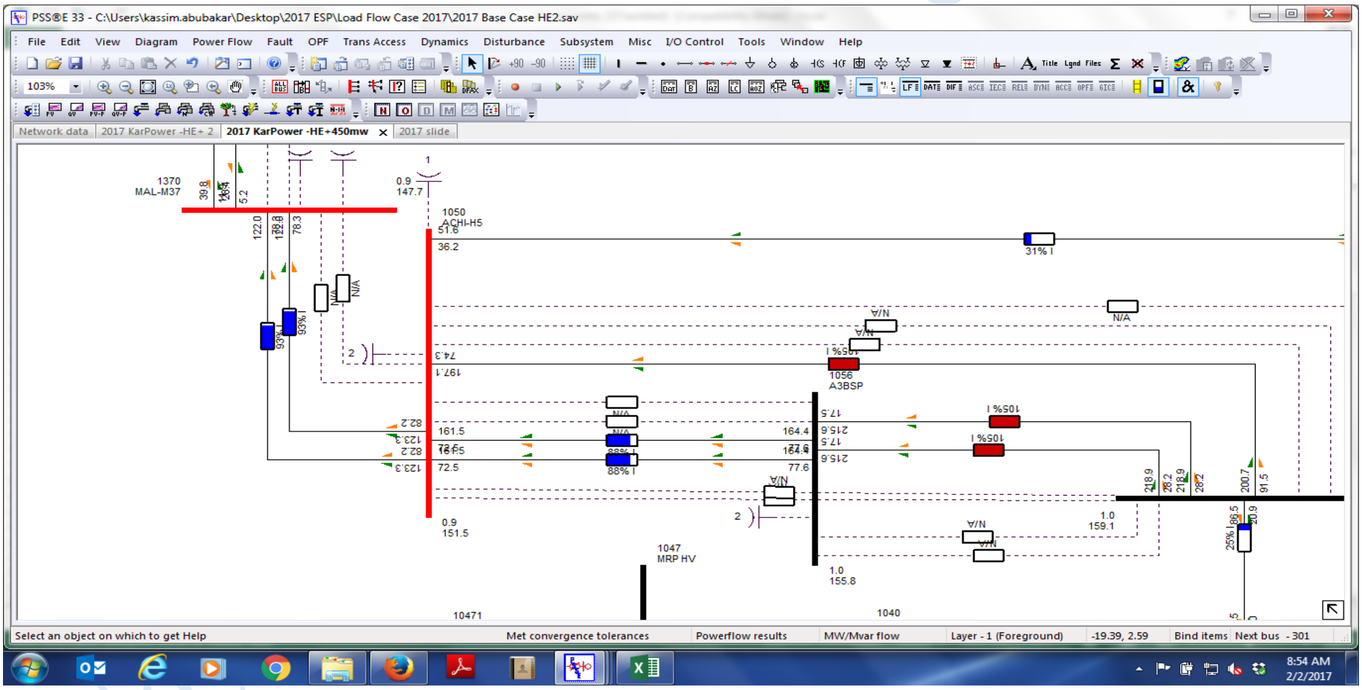
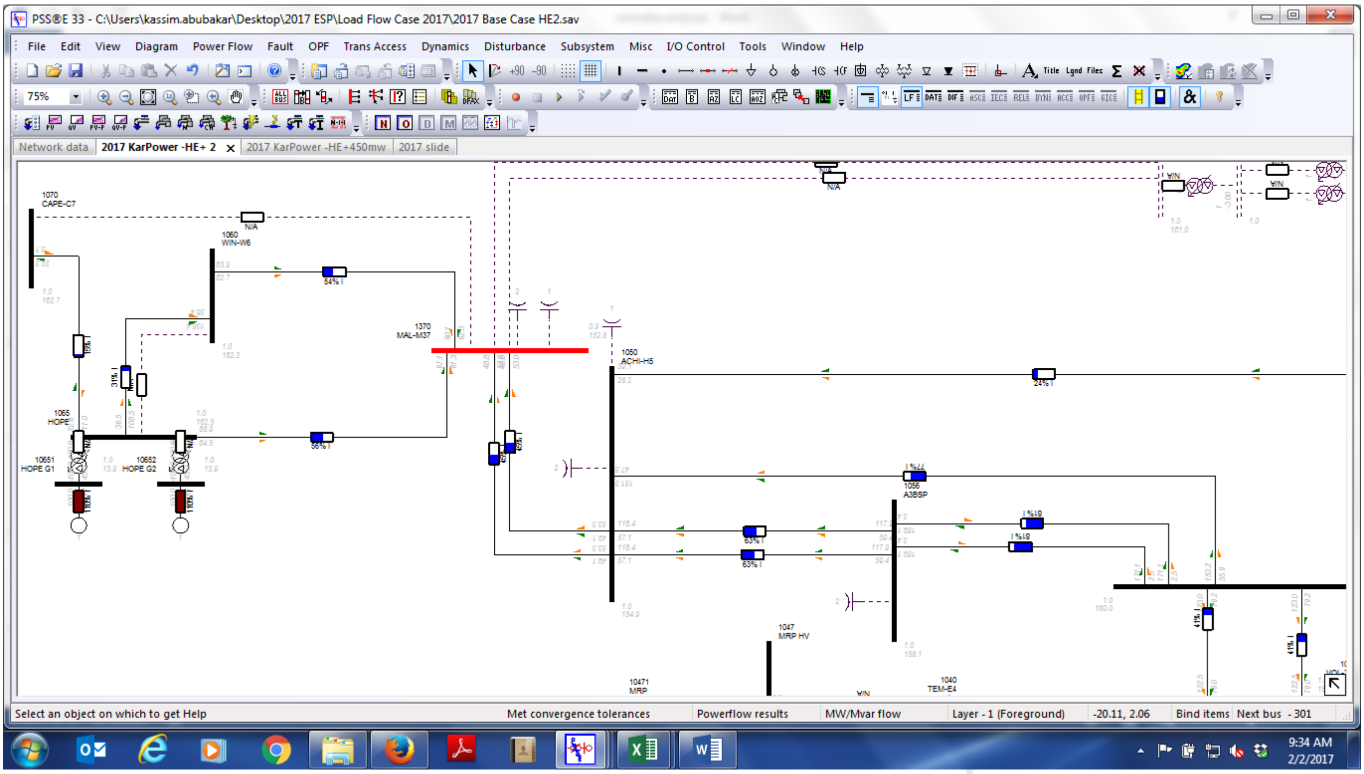


Figure 16: With a 200 MW generation at Winneba



The results of the analysis shows that with generation at this location:

- System losses reduce tremendously to **95.1 MW 3.96%** *(from 106 MW or 4.4 % of generation – Refer to Section 5.4.1);*
- Congestion/overloading on the Volta-Accra East-Achimota-Mallam corridor is reduced thereby delaying the need for future reinforcement of the corridor;
- Voltages in Accra and surrounding locations improve significantly;
- System reliability is improved;
- System stability is consequentially improved.

The following tables summarise the load flow results:

Table 30: Comparison of system losses - Generation at Winneba and No Generation

	No Generation at Winneba	With Generation at Winneba
Losses	106 MW	95.1 MW

Table 31: Comparison of Line Loadings

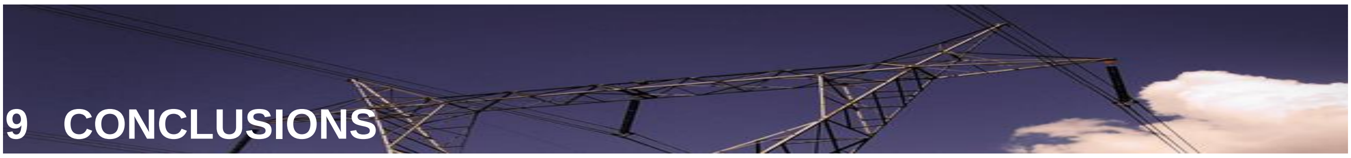
Line	No Generation at Winneba	Generation at Winneba
Volta - Achimota	105	77
Volta - A3BSP	105	80
A3BSP - Achimota	88	62
Mallam -Achimota	93	45

Table 32: Comparison of bus Voltages

Bus Name	No Generation	Generation at Winneba
Mallam	147.7	153.8
Achimota	151.7	155.7
Winneba	152.2	163.9

8.3.2 Impact of Siting Generation in Kumasi

- Network analyses carried out in Chapter 5 revealed poor voltages in Kumasi and its surroundings, especially when there is less than 300 MW generation in the West. Furthermore, in case of a contingency on any of the lines in the Aboadze – Prestea Corridor, Kumasi voltages decay.
- Medium term analysis reveals that siting 200 MW generation resources in Kumasi addresses the voltage challenge. This confirms the Transmission Master Plan proposal to site a 300 MW combine cycle plant in Kumasi or Dunkwa to address the reactive power challenges.



9 CONCLUSIONS

The following conclusions are drawn in respect of the electricity supply and demand situation for 2017:

9.1 Demand and Supply Outlook

a. 2017 total system demand is projected to be 2,386 MW, representing a 14.2 % growth over the 2016 peak demand of 2,087 MW;

b. The projected energy consumption for 2017 is 15,615 GWh of which;

- ✓ Hydro - 5,241 GWh *representing 34% of the total energy supply;*
- ✓ Thermal - 9,729 GWh *representing 62% of total energy supply; and*
- ✓ Renewables - 32 GWh representing 0.2% *of total energy supply.*

c. A total of 613 GWh energy import is estimated for the year to make up for supply deficit representing 4% of total supply. The total annual cost of import (assuming a price of 12 US Cent/KWh) is US$ 73.6 Million;

d. In view the relatively low water level in the Akosombo lake, it is required to manage the operation of the Akosombo generating station so that the reservoir elevation does not drop below the minimum operating level of 240 feet.

e. Based on assumed quantities of natural gas expected from Nigeria and Ghana fields an estimated US$ 951 million will be required to purchase LCO, Natural Gas, HFO and diesel to run the thermal plants. About US$ 296 million will be required by VRA and about US$ 656 million will be required by the IPPs;

f. To ensure stability of the grid in normal operating conditions, the following minimum generating limits required to be kept at all times:

- ✓ 300 MW generation at Aboadze and
- ✓ Three (3) Units at Akosombo.

9.2 Requirements for Grid Reinforcement

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

h. For radial lines and single transformer stations, significant percentage of network loads are islanded in the event of outage of such lines and transformers.

i. **The analysis shows that in normal operation, there is congestion on the Volta – Accra East – Achimota - Mallam transmission corridor especially when there is high generation in the east. From the analysis, terminating the Akosombo – Achimota (A1H) line at Volta increases the transfer capacity in the corridor significantly. Further analyses show that creating a generation enclave in the immediate west of Accra (between Kasoa and Winneba) eliminates the congestion and reduces total transmission losses.**

j. Voltages at Kumasi, Accra and surrounding areas are low because of poor customer end power factors.

k. Analysis has shown that a fair East-West balance in generation is required for system stability and minimal overall transmission system losses.

9.3 Distribution Systems

l. At current demand levels on the ECG network, Ofankor, Nsawam, Aburi and Dodowa will experience low voltages. In the short term ECG is procuring voltage regulators to address the low voltage problem. It has been identified that, the construction of the Pokuase BSP will improve voltages in the communities above in the long term.

m. ECG is expected to expedite ongoing project of converting the single busbar arrangement at the Adenta substation to the double busbar arrangement. This is expected to improve flexibility of operation and reliability of supply to Adenta, Kwabenya, Dodowa and Mampong.

n. NEDCo is also experiencing some challenges in its operational areas. These include;

- The Shield-Wire transformer at Techiman which serves Abofour and Nkenkansu in the Ashanti Region has capacity constraints.
- The transformer serving Wa Township and its environs is overloaded.
- Bawku and Navrongo Distribution Stations have obsolete switchgear.
- There are also low voltages at Ejura, Atebubu, Dalung, Bimbilla, Kete-Krachi due to long radial distribution lines.

9.4 Medium Term Supply

o. Over the medium term (2018 – 2022) system demand is expected to grow to 3,828 MW. Hence to meet the reliability requirement of the Ghana power system an additional reserve margin of 25% representing 957 MW is required. This adds up to a total required supply capacity of 4,784 MW.

p. The development of a new generation enclave to the immediate West of Accra (between Kasoa and Winneba) will tremendously reduce transmission losses, reduce power-flow and thereby delay the need for future transmission system reinforcement in the Volta-Accra East-Achimota-Mallam corridor as well as improve the reliability and security of supply to the capital city.

q. Low voltage challenges are observed in Kumasi. The construction of generation resources of up to 200 MW in Kumasi in the medium term addresses the challenge.

10 RECOMMENDATIONS

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

a. Due to expected supply challenges during the 1st quarter Akosombo Generating Station should run up to 6 Units meet the expected system demand. The dispatch strategy for the rest of the year should be to run 3 units during off-peak and 4 units during peak periods. This mode of operation is expected to keep reservoir elevation at 240.55 ft. before the onset of the inflow season;

b. The necessary financial arrangements should be made to secure the required monthly quantities of fuel for running the thermal plants throughout the 2017 as follows;

Fuel Type	Quantity	Total Annual Cost (USM)
LCO	4,355,129 barrels	261
Gas	34,804,321 mmbtu	311
DFO	136,013 barrels	23
HFO	4,951,644	357

c. The planned 2017 grid expansion programmes especially those connected with transmission upgrades should be expedited and completed on schedule.

   a. The termination of Akosombo – Achimota transmission line at Volta.
   b. Prestea-Kumasi 330 kV line,
   c. Aboadze – Prestea double circuit 330kV line,
   d. Kpando - Kedjebi line
   e. Volta - A3BS – Achimota - Mallam line upgrade
   f. The construction of A4BSP.

d. All load entities should invest in reactive power compensation facilities to ensure that their customer-end power factors comply with the Grid Code (Article 9.33) requirement of 0.9 pu lagging.

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

f. Towards ensuring that there is adequate supply including reserve margin for reliability at all times in the medium term to serve ever-increasing demand, immediate steps should be taken to install additional as required. **NOTE: a typical thermal generation project takes averagely four (4) years to implement**;

g. Initiate steps to develop a new generation enclave to the immediate West of Accra (between Kasoa and Winneba) to reduce losses, reduce congestion and delay the need for future investment on the Volta-Mallam corridor;

h. Initiate steps to install non-intermittent generation facilities *(such as waste-to-energy, etc.)* totalling up to 200 MW in Kumasi in the medium term. This would help to improve voltages in Kumasi and its surroundings. This is in accordance with the Transmission Master Plan proposal to site a 300 MW combine cycle plant either in Kumasi or Dunkwa to address the reactive power challenges.

i. The following substation projects should be expedited;

    a. The completion of the Afienya BSP.

    b. Expansion of the transformer capacity at the Sogakope BSP.

    c. Construction of the Pokuase BSP to improve voltage supply in the Ofankor – Nsawam environs.

j. The interventions detailed in Appendix C1 to address constraints on the ECG network in Accra, Kumasi, Tema and Takoradi should be expeditiously implemented to ensure that they are completed on schedule.

k. Put in necessary and timely financial arrangements to ensure the supply of the required quantities of fuel for running thermal plants at all times.

11 APPENDICES

Appendix A –Forecast Peak Demand and Energy Consumption

A1: Medium Term Peak Demand Forecast (MW): 2017 - 2022

A2: Projected Energy Consumption (GWh) -2017-2030

Appendix B –Actual Peak Demand and Energy Consumption

B1: Projected Actual Energy Consumption

B2: Projected Actual Peak Demand per BSP

Appendix C – Distribution Network Interventions

C1: Short term interventions being carried out by ECG to resolve network constraints

C2: Northern Electricity Distribution Company –Actual Energy Consumption (GWh) -2016

Appendix D – 2017 Planned Generating Units Maintenance

Appendix E – Estimated Fuel Requirement and Cost

Appendix F – Glossary

Appendix G – Grid Map

APPENDIX A - FORECAST PEAK DEMAND AND ENERGY CONSUMPTION

A1: Medium Term Peak Demand Forecast (MW): 2017 - 2022

Load forecast: Energy (GWh)	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
ECG	10,326	10,873	11,476	12,010	12,466	13,067	13,697	14,357	15,049	15,774	16,535	17,332	18,167	19,043
NEDCo	1,213	1,297	1,391	1,475	1,548	1,646	1,749	1,859	1,975	2,099	2,230	2,369	2,516	2,673
MINES	1,498	1,681	2,021	2,164	2,185	2,162	2,175	2,175	2,157	2,153	2,153	2,153	2,153	2,153
Other Bulk Customers	425	455	476	489	501	513	529	541	553	553	553	553	553	553
VALCO	620	1,630	2,909	3,881	4,845	4,845	4,845	4,845	4,845	4,845	4,845	4,845	4,845	4,845
CEB(Togo/Benin)	750	850	980	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220	1,220
SONABEL(Burkina)	172	346	986	986	986	986	986	986	986	986	986	986	986	986
CIE(Ivory Coast)	18	18	18	18	18	18	18	18	18	18	18	18	18	18
EDM(Mali)	0	0	345	689	986	986	986	986	986	986	986	986	986	986
Network Usage	8	8	9	11	11	12	13	13	13	14	14	15	15	16
LOSSES	585	611	654	733	788	848	874	902	929	959	990	1,022	1,056	1,095
Total	15,614	17,768	21,265	23,676	25,554	26,302	27,091	27,901	28,731	29,607	30,530	31,499	32,516	33,588

A2: Projected Energy Consumption (GWh) -2017-2030

Load forecast: Peak demand (MW)-Coincident	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
ECG	1,572	1,655	1,747	1,828	1,897	1,989	2,085	2,185	2,291	2,401	2,517	2,638	2,765	2,899
NEDCo	185	197	212	225	236	250	266	283	301	319	339	361	383	407
MINES	204	228	275	294	297	294	296	296	293	293	293	293	293	293
Other Bulk Customers	75	80	84	86	88	90	93	95	97	97	97	97	97	97
VALCO	75	186	332	443	553	553	553	553	553	553	553	553	553	553
CEB(Togo/Benin)	120	140	160	200	200	200	200	200	200	200	200	200	200	200
SONABEL(Burkina)	50	50	150	150	150	150	150	150	150	150	150	150	150	150
CIE(Ivory Coast)	3	3	3	3	3	3	3	3	3	3	3	3	3	3
EDM(Mali)	0	0	52	105	150	150	150	150	150	150	150	150	150	150
Network Usage	1	1	1	1	2	2	2	2	2	2	2	2	2	2
LOSSES	101	106	113	127	137	147	151	156	161	166	171	177	183	190
Total	2,384	2,646	3,128	3,462	3,712	3,828	3,948	4,073	4,200	4,334	4,475	4,623	4,779	4,943

APPENDIX B - ACTUAL PEAK DEMAND AND ENERGY CONSUMPTION

B1: Electricity Company of Ghana-Monthly Actual Energy Consumption (GWh) by BSP's in 2016

STATIONS	*JANUARY*	*FEBRUARY*	*MARCH*	*APRIL*	*MAY*	*JUNE*	*JULY*	*AUGUST*	*SEPTEMBER*	*OCTOBER*	*NOVEMBER*	*DECEMBER*	*TOTAL*
KPONG	18.5	17.3	18.0	19.9	19.2	15.6	17.8	17.6	15.5	14.9	15.4	14.8	**204.4**
AKUSE	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	**1.8**
NEW TEMA	108.6	105.1	107.5	112.9	108.9	101.3	99.3	97.8	91.6	98.0	98.3	90.5	**1220.0**
ACHIMOTA	169.2	173.5	171.8	159.1	161.4	144.6	141.1	136.0	147.3	160.6	176.1	187.5	**1928.2**
MALLAM	102.4	80.2	90.9	105.0	96.3	79.9	70.4	92.6	96.2	99.2	85.2	80.6	**1078.6**
WINNEBA	8.9	21.5	20.4	23.0	22.3	19.5	20.4	26.7	25.9	27.1	27.3	29.7	**272.6**
ACCRA EAST	54.4	57.9	63.7	69.7	65.9	52.2	46.3	57.2	45.3	52.3	75.5	79.7	**720.1**
SMELTER II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	15.9	9.6	11.0	**39.2**
CAPE COAST	20.0	20.2	21.4	20.9	19.8	17.6	18.0	18.0	19.1	21.2	22.3	23.1	**241.5**
TAKORADI	33.1	31.9	31.9	32.0	30.3	26.5	26.4	29.2	28.7	31.8	33.1	33.4	**368.4**
ESSIAMA	5.9	6.1	5.8	5.8	5.7	4.9	4.9	5.1	5.2	5.6	5.3	6.2	**66.4**
BOGOSO	5.8	4.9	5.2	5.2	5.5	1.7	1.8	5.0	5.0	5.4	6.2	6.5	**58.2**
PRESTEA	1.7	1.8	2.0	1.9	1.9	4.5	4.5	1.7	1.7	1.8	1.9	2.0	**27.4**
TARKWA	30.7	29.0	29.5	27.6	31.2	29.9	29.9	32.4	30.8	31.9	31.9	26.9	**361.8**
AKYEMPIM	0.3	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.3	**3.0**
DUNKWA	2.9	2.9	3.2	3.1	3.1	2.6	2.5	2.6	2.7	2.9	3.1	3.2	**34.8**
ASAWINSO	24.4	23.0	23.3	23.9	21.8	20.8	22.9	24.2	23.9	23.7	23.4	26.2	**281.6**
OBUASI	10.3	10.3	11.1	11.1	10.6	9.1	8.9	9.9	9.7	10.4	10.8	11.5	**123.8**
KUMASI	101.3	100.9	102.8	94.6	100.7	87.2	80.5	88.2	92.3	93.1	96.7	103.1	**1141.4**
ANWOMASO	25.7	21.4	29.1	29.3	25.5	20.9	18.2	26.7	21.8	29.5	29.5	31.1	**308.8**
KONONGO	5.1	4.9	5.3	5.0	5.3	4.7	4.7	5.0	4.7	4.9	5.3	5.8	**60.6**
NKAWKAW	6.3	6.5	7.0	6.8	6.4	5.9	5.8	6.0	5.8	6.6	6.6	6.7	**76.5**
AKWATIA	12.0	11.6	11.5	11.5	11.2	10.0	10.6	10.1	10.5	11.0	11.0	12.6	**133.6**
TAFO	16.8	16.6	17.3	17.4	16.9	15.3	15.4	15.4	15.3	16.3	17.1	18.3	**198.1**
HO	5.2	5.1	5.7	5.6	5.4	4.8	4.9	5.0	5.1	5.6	5.4	5.5	**63.3**
KPEVE	2.3	2.2	2.4	2.5	2.5	2.3	2.3	2.3	2.2	2.3	2.6	3.0	**28.7**

KPANDU	6.6	6.6	7.3	7.2	7.2	6.5	6.7	6.6	6.3	6.7	7.1	7.5	**82.4**
ASIEKPE	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.4	**4.4**
SOGAKOPE	6.1	5.9	6.3	6.2	6.0	4.9	5.1	5.9	7.4	7.9	6.9	6.7	**75.2**
AFLAO	5.5	5.3	5.4	5.3	5.2	4.3	4.5	5.1	4.8	5.3	5.6	6.1	**62.5**
TOTAL	**790.5**	**773.5**	**806.5**	**813.2**	**796.9**	**697.8**	**674.5**	**732.9**	**728.3**	**793.0**	**819.8**	**840.2**	**9267.1**

B2: Electricity Company of Ghana-Actual Peak Demand – 2016

STATIONS	***January***	***February***	***March***	***April***	***May***	***June***	***July***	***August***	***September***	***October***	***November***	***December***	***HIGHEST***
KPONG													0
AKUSE	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.0	0.3
NEW TEMA	204.6	201.4	201.3	208.2	204.8	185.3	192.6	189.9	198.0	191.7	202.3	193.9	208.2
ACHIMOTA	325.3	333.1	339.2	261.3	324.5	357.5	308.0	351.6	298.7	311.6	375.4	0.4	375.4
MALLAM	220.9	191.1	199.3	230.5	256.0	219.2	161.6	201.4	180.5	255.8	192.3	149.2	256.0
ACCRA EAST	114.3	114.1	132.7	126.6	124.0	114.2	122.7	110.4	133.1	121.9	166.8	168.3	168.3
WINNEBA	26.0	52.3	51.3	54.5	63.4	59.5	0.0	59.5	77.0	59.3	61.1	80.3	80.3
SMELTER II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.8	32.1	38.0	67.1	67.1
CAPE COAST	46.0	42.4	42.3	83.0	63.8	64.6	0.0	51.1	41.2	23.3	45.3	44.1	83.0
TAKORADI	66.2	68.3	67.6	65.5	65.2	61.6	0.0	57.1	64.9	73.1	65.9	64.1	73.1
ESSIAMA	14.9	15.0	15.0	12.6	12.8	15.2	0.0	12.0	13.1	11.7	12.0	13.6	15.2
BOGOSO	12.9	12.7	12.2	12.6	12.6	11.0	11.1	10.6	11.7	12.1	13.5	14.0	14.0
TARKWA	66.3	50.0	49.7	75.8	74.9	71.0	63.2	60.4	50.1	72.7	51.8	64.1	75.8
AKYEMPIM	0.6	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
DUNKWA	5.7	6.0	6.0	6.2	5.9	5.5	5.4	5.1	5.4	5.7	5.8	5.9	6.2
PRESTEA	3.1	3.4	3.5	3.5	3.4	3.2	3.2	2.9	2.7	3.3	3.3	3.5	3.5
ASAWINSO	46.7	48.5	48.2	46.6	43.3	41.3	43.4	42.6	42.7	45.0	45.8	47.6	48.5
OBUASI	22.0	21.4	25.0	24.4	31.3	28.2	8.0	7.0	19.7	20.3	20.9	26.1	31.3
ANWOMASO	115.8	62.7	68.6	60.7	101.7	110.9	65.4	79.4	79.0	86.5	72.0	95.5	115.8
KUMASI	221.8	251.6	237.9	234.0	251.3	239.1	259.5	179.2	211.8	201.7	200.2	220.7	259.5
KONONGO	96.8	10.3	10.5	10.4	10.0	10.9	10.1	9.4	9.6	9.7	10.4	10.7	96.8
NKAWKAW	13.5	21.9	21.7	21.9	14.8	18.7	13.7	12.3	13.3	16.0	16.5	14.5	21.9
AKWATIA	27.3	29.1	30.9	28.8	26.2	31.5	27.0	22.9	23.8	25.9	24.7	27.0	31.5

TAFO	33.2	34.9	33.8	34.0	33.6	32.0	0.0	5.1	31.2	32.5	0.0	34.3	34.9
HO	8.3	14.2	8.9	10.7	13.8	13.2	9.7	9.7	10.2	11.0	18.0	13.8	18.0
KPONG	34.8	34.5	25.7	36.0	35.8	37.2	37.3	36.7	35.4	29.7	27.3	26.3	37.3
KPEVE	4.3	4.4	4.4	4.6	4.9	4.5	4.5	4.2	4.5	4.5	5.3	5.2	5.3
KPANDU	13.4	13.9	15.2	0.0	14.6	14.5	14.8	14.0	14.1	14.5	14.2	14.0	15.2
ASIEKPE	0.8	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0
SOGAKOPE	11.7	12.4	15.8	13.1	14.7	11.4	12.7	14.0	15.0	15.2	15.5	13.0	15.8
AFLAO	10.7	10.8	10.6	12.1	11.0	10.0	9.9	9.9	10.2	10.6	10.8	14.0	14.0
TOTAL	**1768.2**	**1662.0**	**1678.7**	**1679.0**	**1819.6**	**1772.8**	**1385.4**	**1560.0**	**1627.3**	**1698.9**	**1716.7**	**1432.8**	**1819.6**

APPENDIX C – DISTRIBUTION NETWORK INTERVENTIONS

C1: Short term interventions being carried out by ECG to resolve network constraints

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
1	Completion of Double bus bar 33 kV Switchgear arrangement at Adenta substation	Currently the single bus bar at Adenta does not permit flexibility for transfer of supply to customers	1. Permit supply of one transformer at Kwabenya and Valley View load up to Mampong from Achimota BSP leading to significant improvement in voltages and power quality to customers. 2. Significant reduction in loading on the Achimota to Adenta line leading to improved supply reliability at Adenta substation.	1. Severe loading constraint on the Achimota to Adenta line leading to intermittent outages at the Adenta substation. 2. Severe low voltages at Dodowa which even worsens when Mampong is additionally supplied. 3. Low voltages at Kwabenya substation. 4. Poor quality of power supply to Adenta, Kwabenya, Dodowa and Mampong	Mid - 2017

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
2	40 MVA Double Circuit Tower Line, 22 km from Adenta to Dodowa switching station has been commissioned	1. Currently Dodowa switching station is supplied through a single circuit 26 MVA distribution line, 26 km from Adenta to Dodowa. 2. This results in severe low voltages at the Dodowa switching station even during light load periods.	1. Significant improvement in voltages at Dodowa ; 2. Improved power supply reliability at Dodowa	1. Poor quality of power supply towards Dodowa 2. Increase in power outages towards Dodowa	Already in circuit

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
		3. Reliability of supply is poor on the distribution line from Adenta to Dodowa.			
3	Currently, Shunt Capacitor banks each at Ofankor and Nsawam have been installed	Currently Ofankor to Nsawam and Aburi corridor are experiencing severe low voltages of around 28 kV leading to poor quality of supply of power to customers	1. Improved voltages at Ofankor, Nsawam, Aburi and Mampong. 2. Provide firm supply of power to Mampong from Aburi to allow for the line capacity upgrade from Dodowa to Mampong.	1. Voltages will further degrade from Nsawam towards Aburi when Aburi station starts picking load which will result into high suppressed demand at Nsawam and on the Akwapim ridge 2. Challenge in upgrading the Dodowa to Mampong corridor to improve power supply reliability to Mampong	Already in circuit

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
4	Voltage Regulators (In the absence of Distributed Generation (DG) support along the Ofankor to Nsawam lines)	As an alternative solution to the DG option to improve voltages at Ofankor, Nsawam, Aburi and Mampong	1. Improve voltages at Ofankor, Nsawam, Aburi and Mampong.	1. Severe low voltage leading to poor power supply. 2. Limited power transfer capability from Ofankor towards Aburi as a result of the severe low voltages 3. Increase in technical losses in the network	By mid of 2017

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
5	Expanding GRIDCo transformer at the Sogakope BSP to transfer part of the load on it to the Ada 33kV distribution feeder from Sogakope BSP	To provide alternative supply to the tail end of the Bondase feeder.	Improve voltage levels and reliability of supply to the load points.	1. Poor voltages 2. High frequency of outages with no alternative of supply to the feeder	
6	Ongoing construction of the Asakyem primary substation	To support load on the Kumasi Ridge ("A") and Amanfrom substations	To avoid potential overloading of the existing surrounding substations and improve voltage levels	1. Poor voltages 2. Poor reliability of supply	By mid of 2017

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
7	Construction of the Afienya BSP with its associated circuits & Other Distributed Generation Plants (Renewables)	1. The Dodowa switching station and Mampong substation are currently supplied through a single circuit 26 MVA distribution line about 27 km from Adenta. 2. This results in severe voltage levels at Dodowa and beyond. Afienya BSP will serve as an alternative supply to Dodowa,	1. Improve power supply reliability to Dodowa, Mampong and possibly Aburi 2. Improve voltages at the Dodowa switching station. 3. Reduce technical losses	1. Severe low voltages at Dodowa 2. Potential power outages to customers supplied from the Dodowa switching station 3. High suppressed demand	By second quarter of 2017

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
		Mampong and possibly Aburi			

C2 a: Northern Electricity Distribution Company –Actual Energy Consumption (GWh) -2016

STATIONS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCTOBER	NOVEMBER	DECEMBER	TOTAL
SUNYANI	19.6	19.9	22.0	20.9	21.2	18.2	18.5	19.1	18.3	20.1	21.0	21.8	240.8
TECHIMAN	15.1	15.3	17.4	16.3	16.8	15.1	15.2	15.4	14.5	15.7	16.5	17.1	190.4
TAMALE	20.1	20.9	24.3	23.9	24.4	23.4	22.1	22.4	21.5	25.1	25.5	24.6	278.2
BUIPE (PBC)	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	5.0
BOL'TANGA	4.6	6.9	8.5	8.6	8.3	7.2	6.7	6.8	6.9	8.0	7.8	7.7	88.0
YENDI	7.8	7.6	8.6	8.6	8.5	8.5	8.4	8.4	8.1	9.3	9.9	9.8	103.5
SAWLA	2.4	2.6	3.0	2.9	2.9	2.9	2.8	2.9	2.8	3.2	3.3	3.1	34.8
ZEBILLA	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.7	0.7	0.7	7.9
MIM	5.1	5.2	5.4	5.0	5.4	5.0	4.9	5.0	5.0	5.3	5.7	5.9	62.9
KINTAMPO	1.1	1.2	1.4	1.3	1.2	1.1	1.2	1.1	1.1	1.2	1.3	1.5	14.8
WA	5.4	5.7	6.8	6.6	5.9	5.6	5.4	5.2	5.3	6.4	6.3	6.0	70.5
TUMU	2.6	0.8	1.1	0.9	0.8	0.7	0.7	0.7	0.7	0.8	0.9	0.8	11.7
BAWKU	2.2	2.4	2.7	2.6	2.7	2.6	2.4	2.5	2.5	2.8	2.7	2.7	30.8
TOTAL	**87.1**	**89.5**	**102.5**	**98.9**	**99.2**	**91.4**	**89.3**	**90.6**	**87.7**	**98.9**	**102.2**	**102.1**	**1139.5**

C2 b: Northern Electricity Distribution Company –Actual Peak Demand (MW) -2016

STATIONS	January	February	March	April	May	June	July	August	September	October	November	December	Maximum
SUNYANI	39.1	41.2	41.8	41.6	42.2	42.3	39.9	38.2	38.5	40.3	41.0	42.2	42.3
TECHIMAN	29.6	32.4	32.4	40.7	32.8	33.3	31.1	30.7	34.4	35.7	40.5	33.1	40.7
TAMALE	39.7	41.6	43.3	42.8	44.4	46.2	46.2	49.3	53.9	47.9	53.7	53.7	53.9
BOL'TANGA	16.2	16.5	17.1	18.6	16.8	17.4	15.8	16.8	15.9	16.5	16.6	16.0	18.6
YENDI	15.4	15.8	15.9	15.8	18.2	17.4	17.2	17.2	17.6	18.4	18.5	18.5	18.5
SAWLA	5.0	3.3	5.6	5.9	5.8	6.5	5.8	5.7	5.8	6.3	6.4	6.3	6.5
BUIPE (PBC)	0.9	1.0	1.3	1.3	1.0	9.5	0.8	0.9	0.9	1.0	1.2	1.1	9.5
ZEBILLA	1.5	1.4	1.4	1.5	5.4	1.6	1.5	1.3	1.3	1.4	1.4	1.4	5.4
MIM	1.0	1.1	1.0	10.5	10.6	10.5	10.2	9.7	10.1	10.9	11.0	11.4	11.4
KINTAMPO	2.4	3.9	2.6	2.6	2.6	2.6	2.5	2.3	3.7	2.5	2.9	3.1	3.9
TUMU	8.9	3.5	3.6	3.5	2.7	2.9	2.4	2.4	2.5	2.9	3.5	3.4	8.9
WA	11.2	12.5	15.7	13.0	12.0	13.0	0.0	11.2	11.7	12.5	12.7	12.4	15.7

BAWKU	7.9	9.0	9.1	8.1	7.9	1.5	9.9	8.3	8.6	9.7	11.4	9.9	11.4
TOTAL	**178.8**	**183.1**	**190.8**	**205.9**	**202.4**	**204.7**	**183.3**	**194.0**	**204.8**	**206.0**	**220.8**	**212.5**	**246.8**

C2 c: Mines-Energy Consumption (GWh)-2016

CUSTOMERS	*JANUARY*	*FEBRUARY*	*MARCH*	*APRIL*	*MAY*	*JUNE*	*JULY*	*AUGUST*	*SEPTEMBER*	*OCTOBER*	*NOVEMBER*	*DECEMBER*	*TOTAL*
Goldfields New Tarkwa	24.7	23.0	24.8	23.8	25.3	24.2	25.2	25.4	24.8	26.1	25.4	19.0	291.8
NCM Prestea	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	0.9	1.0	1.1	1.2	11.3
SANKOFA Prestea	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	4.5
OWERE Konongo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.5
ANGLOGOLD-Obuasi	1.5	1.5	1.5	1.6	1.6	1.5	1.7	1.4	1.4	1.5	1.5	1.5	18.3
ANGLOGOLD New Obuasi	8.1	6.2	5.8	5.8	5.9	5.5	5.8	5.7	4.9	4.8	4.7	5.0	68.3
G.C.D. Akwatia	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.1
GOLDEN STAR-Bogoso	3.2	3.3	4.2	3.9	4.3	3.8	3.7	3.9	3.8	4.3	3.9	4.1	46.4
GOLDEN STAR Wassa	6.7	6.2	7.2	5.0	6.8	6.7	6.9	7.1	7.4	7.5	7.3	7.7	82.6
ADAMUS GOLD-Esiama	2.9	2.5	3.2	3.0	3.2	3.1	3.4	3.0	3.2	3.4	3.4	3.4	37.7
PERSEUS GOLD-Ayanfuri	11.4	9.0	10.1	8.2	9.5	10.5	10.6	12.3	11.5	6.5	8.4	9.9	118.1
NEWMONT-New Abirem	19.7	17.5	17.0	17.0	19.5	18.3	19.8	19.2	18.2	19.1	18.3	18.7	222.4
NEWMONT-Kenyase	21.8	19.5	22.2	19.7	22.6	20.2	22.5	20.9	21.3	22.0	22.3	20.3	255.3
ADANSI GOLD-Obotan	3.4	5.9	8.4	6.4	7.3	8.0	8.5	8.7	9.2	8.9	9.0	8.5	92.1
TOTAL	104.9	96.1	105.9	95.8	107.1	103.2	109.6	109.2	107.2	105.6	106.0	99.6	1250.3

C2 d: - Consumption (GWh)-2016

CUSTOMERS	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*	*Maximum*
G.F.G.-New Tarkwa	37.9	37.8	37.1	37.7	37.7	37.5	38.0	37.8	38.6	39.3	70.2	39.1	70.2
NCM Prestea	2.1	2.2	2.3	2.3	2.4	2.3	2.3	2.5	2.7	2.5	2.8	2.7	2.8
SANKOFA-Prestea	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.6	0.9
TALOS / OWERE-Konongo	0.1	0.1	0.1	0.0	0.0	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.5
ANGLOGOLD Obuasi	3.6	3.6	3.2	3.4	5.1	3.9	3.0	3.1	2.9	3.4	2.9	3.9	5.1
OBUASI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANGLOGOLD-New Obuase	10.3	12.8	21.4	18.4	17.9	9.1	9.0	17.5	11.4	8.2	8.1	9.5	21.4
G.C.D. LTD-Akwatia	0.3	0.3	0.3	0.0	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3
GOLDEN STAR-Bogoso	6.7	10.9	12.9	7.1	7.4	12.3	13.4	6.7	6.8	6.9	7.0	6.6	13.4
GOLDEN STAR-Wassa	11.0	11.2	11.5	11.4	11.3	11.2	11.0	11.3	11.6	11.5	11.5	11.9	11.9
ADAMUS GOLD MINES-Esiama	5.4	5.0	5.2	5.3	5.3	5.4	0.0	5.3	5.2	5.7	5.5	5.5	5.7
PERCEUS-Ayanfuri	17.9	18.2	18.4	18.2	17.5	17.8	18.3	19.0	19.0	18.7	16.7	17.2	19.0
NEWMONT-New Abirem	30.6	31.3	43.2	30.2	59.2	30.4	40.9	44.2	30.2	37.2	29.3	29.6	59.2
NEWMONT-Kenyase	32.2	32.1	32.4	32.3	32.6	31.7	32.1	31.7	32.4	32.6	0.0	63.2	63.2
ADANSI GOLD LTD-Obotan	10.6	12.6	14.0	13.3	13.1	13.5	13.2	14.2	14.5	14.5	14.6	13.9	14.6
TOTAL	169.6	178.8	202.7	181.5	210.5	176.2	182.9	194.5	176.3	181.7	169.8	203.9	210.5

Appendix D – 2017 PLANNED GENERATING UNITS MAINTENANCE

Station	Unit	Scheduled maintenance (2017)
Akosombo	1G1	JAN 23-FEB 03; SEP 04-SEP 22
	1G2	FEB 06-FEB 15; OCT 02-OCT 20
	1G3	FEB 16-FEB 27; MAY 29-JUN 16
	1G4	FEB 28-MAR 09; JUL 03-JUL 21
	1G5	MAR 10-MAR 21; APR 24-MAY 12
	1G6	MAR 22-MAR 31; APR 03- APR 21
KPONG	19G1	JAN - MAY
	19G2	
	19G3	MAR 20-MAR 27; JUNE 15 -DEC 31
	19G4	APR 18-APR 25; OCT 23-OCT 30
Bui	54G1	FEB 15 - 28; MAY 17 - 31; AUG 17 - 31; NOV 16 - 30
	54G2	JAN 17 - 31; APR 16 - 30; JUL 17 - 31; OCT 17 - 31
	54G3	MAR 17 - 31; JUN 16 - 30; SEPT 16 - 30; DEC 17 - 31
TAPCO	32G1	MAR 20 2016 - FEB 28; OCT 6 - 27
	32G2	JAN 8 - JUL 31
	32G3	
TICO	35G4	
	35G5	JAN 25 - MAR 2
	35G6	JAN 25 - MAR 2
KTPP	67G1	
	67G2	
TTPC	47G1	
	46G1a	JAN 21 - 25; MAR 13 - 17; JUN 8 - 12; SEP 3 - 7
	46G1b	FEB 6 - 10; OCT 10 - 14
	46G2	
	46G3	
	50G1	JUN 1 - 21
	50G2	JUN 24 - 30
	50G3	JUL 17 - AUG 9
	50G5	
	50G6	
CENIT	47G2	
SUNON ASOGLI	51G1	
	51G2	
	51G3	
	51G4	
	51G5	
	51G6	
	51G7	
	51G8	
	51G9	
	51G10	
KARPOWER	77G1	
	77G2	
	77G3	
	77G4	
	77G5	
	77G6	
	77G7	
	77G8	
	77G9	
	77G10	
	77G11	
	77G12	
	77G13	

LEGEND:
- : MAJOR RETROFIT
- : ANNUAL MAINTENANCE
- : QUARTERLY MAINTENANCE
- : SEMI ANNUAL MAINTENANCE (1 WEEK)
- : ACTUATOR PANEL ANNOUNCIATION REPLACEMENT (RELAY REPL. PROJECT PHASE II)
- : ENGINE SWAP
- : ROTOR GROUND
- : HOT SECTION INSPECTION
- : HOT GAS PATH INSPECTION
- : MAJOR INSPECTION

APPENDIX E – ESTIMATED FUEL REQUIREMENT AND COST

	2017 Projected Consumption(GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Estimated Thermal Fuel Requirement	**Units**													
TAPCO - LCO	barrels	147,250	133,300	294,500	258,850	238,700	212,350	-	-	-	-	-	-	**1,284,950**
TAPCO - GAS	mmbtu	-	-	-	-	-	-	573,420	573,420	679,050	716,775	1,026,120	1,056,300	**4,625,085**
TICO - LCO	barrels	147,250	133,300	294,500	285,200	294,500	240,250	-	-	-	-	-	-	**1,395,000**
TICO - GAS	mmbtu	-	-	-	-	-	-	1,214,745	1,214,745	1,169,475	1,214,745	1,169,475	1,214,745	**7,197,930**
TT1PP - LCO	barrels	-	-	-	-	-	-	-	-	-	-	-	-	**-**
MRP - GAS	mmbtu	-	-	-	-	-	-	-	-	-	-	-	-	**-**
KTPP - Diesel	barrels	-	-	-	-	-	-	-	-	-	-	-	-	**-**
TT2PP - GAS	mmbtu	-	-	-	-	-	-	-	-	-	-	-	-	**-**
TT2PP-x - GAS	mmbtu	-	-	-	-	-	-	-	-	-	-	-	-	**-**
IPP Plants														-
VRA/AMERI Power Plant - GAS	mmbtu	1,382,032	731,664	609,720	1,422,680	1,473,490	1,422,680	1,493,814	1,463,328	1,422,680	1,473,490	1,422,680	1,473,490	**15,791,748**
Karpower Barge - HFO	barrels	203,825	189,360	203,825	197,250	203,825	197,250	203,825	203,825	190,675	197,250	190,675	210,400	**2,391,985**
SAPP - GAS	mmbtu	447,840	895,680	849,030	-	-	-	-	-	-	-	-	-	**2,192,550**
SAPP (Phase 2) - GAS	mmbtu	760,104	760,104	760,104	862,500	786,600	634,800	634,800	634,800	841,800	1,048,800	1,041,900	1,242,000	**10,008,312**
CENIT - LCO	barrels	-	-	-	-	-	-	-	-	-	-	-	-	**-**
AKSA - HFO	barrels	-	101,200	101,200	264,000	264,000	349,800	418,000	400,400	385,000	418,000	385,000	396,000	**3,482,600**
ESTIMATED FUEL COST														
Total VRA LCO - Cost @ US$ 60/bbl	MMUS$	17.67	16.00	35.34	32.64	31.99	27.16	-	-	-	-	-	-	**160.80**
Total VRA Gas - Cost @ US$ 9.0/mmbtu	MMUS$	-	-	-	-	-	-	16.09	16.09	16.64	17.38	19.76	20.44	**106.41**
Total VRA Fuel Cost	**MMUS$**	**17.67**	**16.00**	**35.34**	**32.64**	**31.99**	**27.16**	**16.09**	**16.09**	**16.64**	**17.38**	**19.76**	**20.44**	**267.20**
Total VRA Imports Cost @ US$ Cents 12/kWh	**MMUS$**	**18.00**	**15.60**	**9.00**	**1.56**	**3.60**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**47.76**
Total VRA Cost of Fuel & Imports	**MMUS$**	**35.67**	**31.60**	**44.34**	**34.20**	**35.59**	**27.16**	**16.09**	**16.09**	**16.64**	**17.38**	**19.76**	**20.44**	**314.96**
IPP Fuel Cost														
Total IPP LCO - Cost @ US$ 60/bbl	MMUS$	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Total IPP Gas - Cost @ US$ 9.0/mmbtu	MMUS$	23.31	21.49	19.97	20.57	20.34	18.52	19.16	18.88	20.38	22.70	22.18	24.44	**251.93**
Total IPP HFO - Cost @ US$ 72/bbl	MMUS$	14.68	20.92	21.96	33.21	33.68	39.39	44.77	43.50	41.45	44.30	41.45	43.66	**422.97**
Total IPP Fuel Cost	**MMUS$**	**37.99**	**42.41**	**41.93**	**53.78**	**54.02**	**57.90**	**63.93**	**62.39**	**61.83**	**67.00**	**63.63**	**68.10**	**674.90**
Total Cost	**MMUS$**	**73.66**	**74.00**	**86.27**	**87.98**	**89.62**	**85.06**	**80.02**	**78.48**	**78.47**	**84.38**	**83.39**	**88.54**	**989.87**

APPENDIX F: 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 G – GRID MAP