FREEDOM AND JUSTICE

REPUBLIC OF GHANA

2018

Electricity Supply Plan

for the Ghana Power System

A 2018 Power Supply Outlook with Medium Term projections

2018 ELECTRICITY SUPPLY PLAN FOR GHANA

An Outlook of the Power Supply Situation for 2018 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:

- Benjamin Ntsin – Ghana Grid Company Limited *(Chairman)*
- Frank Otchere – Ghana Grid Company Limited
- Kassim Abubakar – Ghana Grid Company Limited
- Monica Debrah (Mrs.) – Ghana Grid Company Limited
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EXECUTIVE SUMMARY

As per the requirement of the Ghana Electricity Grid Code, we submit the Electricity Supply Plan (ESP) for the year 2018 as prepared by the Supply Plan Committee.

The ESP presents an outlook of power demand and supply for 2018 taking into consideration all the committed projects and existing generation sources. It assesses the available hydro generation taking into consideration low reservoir elevations at Akosombo and Bui. The Report thus, presents the possible power supply situation in 2018. Additionally, it presents fuel requirements and associated cost to meet electricity demand in 2018 and evaluates the associated power evacuation requirements to ensure reliable power supply. The Report further highlights the anticipated challenges in meeting the 2018 demand and makes recommendations on the best course of action to be taken to ensure reliable power supply in 2018. Finally, the report provides an outlook of electricity demand and supply for the next five years.

Review of 2017 Performance

Peak Demand

In 2017, the power system recorded a coincident system peak demand of 2,192.15 MW on November 13, 2017. This figure represents an increase of 105.15 MW (5%) over the 2016 coincident system peak demand of 2,087 MW.

Energy Consumption

The total energy consumed (including losses) for the period was 14,177.33 GWh. Compared to the 2016 figure of 13,699.89 GWh, this represents an annual growth in energy consumption of 3.48%.

Energy Supply

The total energy supplied (including imports from Cote d'Ivoire) over the period was 14,178.53 GWh. This comprises 5,615.51 GWh from hydro, 8,242.21 GWh from thermal and 320.81 GWh from Imports. The 1.2 GWh difference between the supply and the consumption was consumed at the various generating plants.

Transmission Losses

In 2017, the transmission network recorded total losses of 587.11 GWh which represents 4.1% of total energy consumed. Compared to the 2016 figure of 607.38 GWh, there was a reduction of 20.27 GWh or 0.33%.

Transmission Lines and Feeder Availability

The Average Feeder Availability (AFA) in 2017 was 99.84 % and the System Average Availability (SAA) for the transmission grid was 99.58%.

2018 Demand Outlook

The projected system peak demand for 2018 is 2,523.49 MW and this represents a 15.11 % (or in absolute terms, an increase of 331.34 MW) growth over the 2017 system peak of 2,192.15 MW. The annual consumption for 2018 is projected at 16,304.79 GWh and this represents a 15.01% (or in absolute terms, an increase of 2,127.46 GWh) growth over the 2017 actual annual consumption of 14,177.33 GWh.

2018 Supply Outlook

Hydro Power Generation for 2018

The total hydro generation for 2018 projected is 4,956.32 GWh. This is made up of 3,599.99 GWh, 600.12 GWh and 756.21 GWh from Akosombo, Kpong and Bui Generating Stations respectively.

Akosombo Hydro Elevation

The Akosombo Lake Elevation on January 1, 2018 was 251.31 feet and this is projected to bottom up at 243.60 feet at the end of the dry season in 2018.

Bui Hydro Elevation

The Bui Lake Elevation at the beginning of 2018 was 175.01 m and this is projected to bottom up at 170.52 m at the end of the dry season in 2018.

Thermal Power Generation for 2018

The projected total thermal generation for 2018 is 11,301.65 GWh. This is made up of generation from VRA and the IPPs as shown in the Table below.

Renewable Energy (RE) Generation for 2018

The total RE (currently only Solar PV) generation for 2018 is projected at 42.64GWh. This is made up of VRA (Navrongo), BXC (Winneba) and Meinergy (Saltpond) as shown in the Table below.

All of these utility-scale Solar PV Plants are connected on the Medium Voltage Distribution System.

Imports

In 2018, no programmed import is expected apart from the usual inadvertent exchanges between the two utilities, CIE and GRIDCo.

Projected Thermal Supply	Energy (GWh)
VRA Existing Thermal & Solar Generation	
T1	1,457.06
T2	2,155.05
TT1PP	352.98
TT2PP + TT2PP-X	0
KTPP	369.24
RE Generation (Solar PV)	4.20
Total VRA Thermal Generation	**4,338.53**
Existing IPP Thermal Generation	
SAPP (Phase I and II)	1,466.11
CENIT	380.93
AMERI	796.53
Karpower Barge	2,708.25
AKSA	558.49
CENPOWER	1,061.21
BXC Solar PV	25.54
MEINERGY Solar PV	12.90
Total IPP Thermal Generation	**7,009.96**
Total VRA Supply	**8,538.64**
Total Non-VRA Supply	**7,766.17**
Import	0
Total Supply	**16,304.79**

Fuel Cost

Based on the projected thermal generation of 11,301.65 GWh, an estimated US$1.0 Billion will be required to purchase the various fuel types, namely; LCO, Natural Gas, HFO and diesel to run the thermal plants. Of this amount, about US$ 336 million representing 33.57% will be required by VRA and the remaining US$ 665 million or 66.43% will be required by the IPPs.

Type of Fuel	Cost (Million USD)
VRA - LCO	42
VRA - GAS	263
VRA - DFO	32
TOTAL VRA FUEL COST	**336**
IPP - LCO	168
IPP - GAS	260
IPP - HFO	184
IPP - DFO	52
TOTAL IPP FUEL COST	**665**
TOTAL VRA & IPP COST	**1,001**

Distribution Outlook in 2018

ECG Network

In the ECG network, a key project expected to come on line is the Accra Central BSP. The completion and commissioning of this Project will significantly improve system reliability, resolve loading constraints on the interconnected 33 kV feeders and reduce overall technical losses within the Accra metropolis. The Project is expected to be completed by the second quarter of 2018. Other similar projects, are currently ongoing within the ECG network and are expected to be completed by the end of the year. The completion of these additional Projects is expected to improve supply reliability to the various ECG customers.

NEDCo Network

NEDCo is faced with capacity and voltage constraints within some sections of its distribution network, thereby limiting its ability to deliver quality of supply to its customers during peak hours.

The Company has therefore outlined a number of interventions to mitigate the effect of these network constraints in 2018.

Medium-Term (2019 – 2023) Demand and Supply Outlook

The Medium-Term (2019-2023) Demand and Supply Outlook as shown in the Table below suggests that there will be adequate generation for the medium term.

Year	2019	2020	2021	2022	2023
Projected System Demand (MW)	**2,980**	**3,245**	**3,576**	**3,745**	**3,919**
Total Supply Required (Demand +Reserve (25%))	**3,725**	**4,056**	**4,470**	**4,681**	**4,899**
Total Existing Hydro Capacity (MW)	**935**	**935**	**1,120**	**1,270**	**1,270**
Total Existing Thermal Capacity (MW)	**2,853**	**2,993**	**2,823**	**2,823**	**2,993**
Total Existing Renewables (MW)	**42.5**	**42.5**	**42.5**	**42.5**	**42.5**
Committed Generation Projects					
AKSA (PHASE II)	120	120	120	120	120
Early Power	142	300	400	400	400
Amandi	190	190	190	190	190
Jecobson Jelco			360	360	360
VRA T3	120	120	120	120	120
Rotan					300
Marinus Energy	26.5	26.5	26.5	26.5	26.5
VRA Solar	12	12	12	12	12
Total Committed Generation (MW)	**610.5**	**768.5**	**1228.5**	**1228.5**	**1528.5**
Expected Total Generation (MW)	**4,398.50**	**4,696.50**	**5,171.50**	**5,321.50**	**5,791.50**
Surplus (MW)	**673.50**	**640.50**	**701.50**	**640.50**	**892.50**

Strategic Medium Term Transmission Infrastructure Requirements

System network analyses carried out on the medium-term system conditions indicated that there could be congestion, especially in the southern parts of the NITS. The analyses further identified that in the medium-term, the addition of the following transmission infrastructure would improve overall reliability of the transmission network:

- Construction of a double circuit 330 kV transmission line from A4BSP to Kumasi.
- Eastern Transmission Corridor Projects:
  - ✓ Construction of a 161kV Line between Kadjebi and Juale
  - ✓ Construction of a 161kV Line between Juale and Yendi
- Construction of a 330 kV Substation at Dunkwa with a link to the existing 161 kV Dunkwa Substation;

- Construction of a Third Bulk Supply Point in Kumasi at 330kV level.

Impact of Siting Generation in Kumasi

The medium-term network analyses also revealed that siting up to 200 MW generation capacity in Kumasi addresses the general low voltage conditions in Kumasi and its environs and improves overall network stability and reliability. It also results in marked reduction in overall transmission losses.

This result confirms the recommendation in the 2011 Generation and Transmission Master Plan to site at least 300 MW Combined-Cycle Thermal Power Plant in the central part of the Transmission Network (around Kumasi or Dunkwa) to improve the overall network performance.

Conclusion

The general conclusions of the 2018 Demand and Supply plan are as follows;

1. The system peak demand for 2018 is projected at 2,523.49 MW, representing a 15.1 % growth over the 2017 peak demand of 2,192.15 MW.
2. In terms of energy, the projected consumption for 2018 is 16,304.79 GWh representing a 15.01% growth over the 2017 actual annual consumption of 14,177.33 GWh.
3. The total energy exports for 2018 are projected at 671.97GWh.
4. In 2018, there will be adequate generation capacity to meet projected demand with as high reserve margin as 47% during the period (the required reserve margin is 25%).
5. VALCO is expected to operate two Potlines with projected total energy consumption of 1,154.19 GWh.
6. Akosombo and Bui Reservoirs performed poorly in terms of inflows into the two Lakes, during the last inflow season.
7. In terms of supply, the following generation mix is expected:
   - Hydro - 4,956.32 GWh *representing 30.4% of total energy supply;*
   - Thermal - 11,305.85 GWh *representing 69.34% of total energy supply;*
   - Renewables - 42.64 GWh representing 0.26% *of total energy supply.*
8. In terms of fuel, the following quantities of the various fuel types are required:
   - LCO - 3,000,000 barrels
   - Natural Gas - 67,000,000 MMBtu.
   - HFO - 455,000 MT

- ➢ Diesel - 100,000 barrels

9. In terms of fuel cost, an annual total of approximately 1.0 billion USD is required, averaging a monthly total of some US$ 83.40 Million.

10. To ensure the stability of the grid in normal operating conditions, the following minimum generating limits are required to be kept particularly at Peak:

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

11. The transmission system has inadequate available transfer capacity to meet the requirements of 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. The low voltages at Kumasi, Accra and surrounding areas are due to poor customer end power factors.

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

13. 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.

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

15. A number of substations and interconnected circuits currently under construction are expected to be completed within the first quarter of 2018. These include the Ogbojo 33 kV / 11 kV substation and associated 33 kV lines from GIMPA to Kwabenya 33 kV / 11 kV substations and from Dodowa switching station to Mobole 33 kV substation.

16. The following operational challenges would be experienced in the NEDCo operational areas due to inadequate network capacities and long radial distribution lines;

    a. Capacity constraints on the Shield-Wire transformer at Techiman which serves Abofour and Nkenkansu in the Ashanti Region.

    b. Transformer overloads at Wa Township and its environs.

    c. Possible switchgear failures at Bawku and Navrongo Distribution Stations due to Obsolescence.

    d. Low voltages at Ejura, Atebubu, Dalung, Bimbilla, Kete-Krachi.

17. In the medium-term, constructing up to 200 MW in Kumasi improves overall system performance.

Recommendation

The report makes the following recommendations;

1. The Akosombo and Bui Reservoirs should be prudently managed in 2018 by:
    a. Operating three Units at Akosombo during off-peak and four units at Peak
    b. Operating on the average, two units at Bui

    This would ensure the recovery of the two lakes over the medium-term to ensure their operational sustainability.
2. In view of the low overall hydro generation, measures should be put in place to ensure security of fuel for the thermal plants to forestall possible supply disruptions to consumers.
3. The players in the gas supply chain, namely; Ghana Gas Company Limited, Tullow, ENI and GNPC should strongly collaborate with the power utilities to ensure effective planning and coordination to avert any possible gas supply curtailments which could have dire consequences for power supply.
4. In view of the huge investments in fuel supply, the Government of Ghana (GoG) should assist the Utilities to raise the necessary financing to procure the required quantities of fuel and on time to avert any possible power supply crisis.
5. The following on-going grid expansion programmes especially those connected with transmission upgrades should be expedited and completed on schedule:
    - Prestea-Kumasi 330 kV line,
    - Aboadze – Prestea double circuit 330kV line,
    - Volta - A3BSP – Achimota - Mallam line upgrade,
    - The construction of A4BSP,
    - Construction of 3x125 MVA GIS station at Accra Central.
    - Construction of 2x66 MVA Bulk Supply Point at Afienya.
6. 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.

7. A well-coordinated maintenance programme should be pursued by both GRIDCo and the Generating Companies (GENCOs) to assure higher operational reliability of both the generating plants and the transmission grid.
8. 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.
9. The interventions detailed above to address constraints on the ECG network in Accra, Kumasi, Tema and Takoradi should be expeditiously implemented to improve the reliability and the overall performance of the ECG distribution network.
10. NEDCo should be assisted with the necessary financing to enable the Company undertake all the identified critical projects to improve its overall operational performance.

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1 INTRODUCTION

This Electricity Supply Plan (ESP) details out projections for electricity demand and supply in 2018, 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 2018 for the information of stakeholders and the general public.

The Plan assesses the capacity of the National Interconnected Power System (NIPS) for power generation and consumption as well as exports. The Plan also evaluates the performance of the Akosombo and Bui Reservoirs over the last in-flow cycle and projects their total contribution to total generation in the next planning period.

The Plan further estimates the amount of thermal generation required, together with the corresponding fuel requirements and associated costs. It further evaluates the grid requirements for meeting the demand for the year, highlighting the anticipated challenges and consequently making recommendations on interventions necessary to ensure reliable and sustainable power supply for Ghana in 2018.

The report was prepared by a team of experts from the Energy Commission (EC), Ghana Grid Company Limited (GRIDCo), Electricity Company of Ghana Limited (ECG), Northern Electricity Distribution Company (NEDCo), Bui Power Authority (BPA) and Volta River Authority (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 vital information required to develop the Supply Plan.
The report further makes projections for the Medium-Term (2019-2023) Electricity Demand and Supply outlook.

The Team first conducted a comprehensive review of the power system performance in 2017 based on which demand and supply projections were made for 2018.

1.1 Organisation of the Report

Chapter 1 is the captures the Introduction, whiles Chapter 2 presents a review of the power system performance in 2017. Chapter 3 presents the electricity demand outlook for 2018, whilst Chapter 4 focuses on the 2018 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 of the entire power system. Chapter 7 presents an outlook of the ECG, NEDCo and Enclave Power Distribution Systems. Chapter 8 provides a Medium-Term outlook for 2019 - 2023. The conclusion of the report is presented in Chapter 9 ending with the recommendations of the analysis which are presented in Chapter 10.

2 SYSTEM PERFORMANCE REVIEW FOR 2017

The review of the 2017 Ghana Power System performance includes among others comparisons of the actual peak demand, energy generation and consumption against the projections for the 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

The power system recorded a coincident peak demand of 2,192.15 MW on November 13, 2017. This figure represents an increase of 105.15 MW (5.0%) over the 2016 coincident peak demand of 2,087 MW. The 2017 peak demand was however, 193.85 MW or 8.1 % lower than the projected peak demand of 2,386 MW for 2017.

A summary of the actual monthly peak demands against the projected over the period is shown in Table 1 below:

Table 1: System Projected and Actual Peak Demand for 2017

Month	Projected Demand (MW)	Actual Demand (MW)	Deviation: Projected – Actual (MW)
January	2106	2100.00	6
February	2134	2084.00	50
March	2151	2153.00	-2
April	2235	2161.00	88
May	2238	2158.00	80
June	2183	2077.00	106
July	2200	2042.00	158
August	2195	1930.00	265
September	2271	2021.00	250
October	2250	2131.00	119
November	2313	2192.15	120.85
December	2386	2135.00	251

Table 1 shows that actual monthly system peak demand was lower than the projected throughout the year except for March. Some of the factors that could have contributed to the low demand realised are as follows:

- **Export**: Export to CEB during the period reduced from a maximum of 120 MW to an average of 20 MW. CEB imported much of its generation needs from Nigeria due to their relatively lower tariffs.

- **Tariff**: The high electricity tariffs across all customer classes after the last increment in December 2015.

- **Discontinued/Suspended Customer Operations** – Some Bulk Customers discontinued or suspended all or part of their operations within the year 2017 due to a number of challenges, which led to a reduction in their average demand. For example;

  - ✓ Owere and Sankofa Mines disconnected their operations from July and August 2017 respectively due to their inability to pay their electricity bills.

- **Embedded/Distributed Generation** – The high rate of embedded and distributed generation following the past energy crisis. The following are some of the embedded generation currently installed:

  - ✓ **Renewable Energy Installations** by licensed installers monitored by the Energy Commission has seen an increase in installed units in **grid connected** areas by about **4,266 KWp** bringing the total to about **37,130 KWp** in 2017. In addition to this, there could be other individual installations that are not captured by the Commission. This however does not include those installed in off-grid areas where renewable energy installed capacity is estimated at 8 MWp.

  - ✓ **Private generating sets** - Some residential, commercial and industrial consumers continue to strategically run their generating sets as substitute for grid supply in order to minimize the cost of electricity for their operations.

2.2 Energy Generation

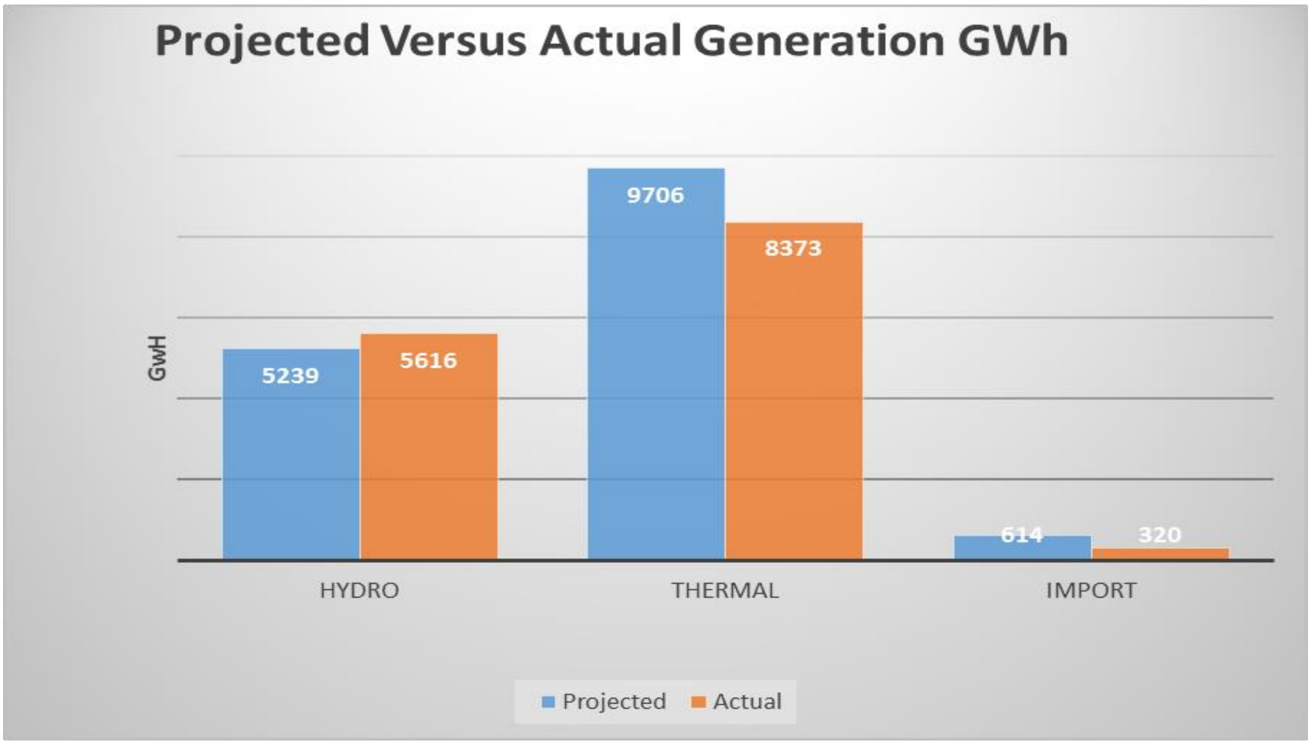
Summary of actual monthly energy generation against the projected is shown in Table 2 below.

Table 2: Projected versus Actual Energy Generation in 2017

	Hydro (GWh)		Thermal (GWh)		Import (GWh)		System Total (GWh)	
Month	**Actual**	**Projected**	**Actual**	**Projected**	**Actual**	**Projected**	**Actual**	**Projected**
Jan	593	532	577	605	81	147	1250	1284
Feb	684	505	373	511	66	133	1123	1149
Mar	668	489	595	710	26	95	1290	1294
Apr	568	427	622	820	32	91	1222	1338
May	504	413	689	888	32	45	1226	1346
Jun	370	403	765	838	18	20	1153	1261
Jul	376	416	735	813	20	33	1130	1262
Aug	337	416	770	830	10	10	1116	1256
Sep	365	403	743	842	8	10	1116	1255
Oct	390	416	821	937	11	10	1222	1363
Nov	379	403	829	931	8	10	1216	1344
Dec	381	416	854	981	8	10	1244	1407
Total	**5616**	**5239**	**8373**	**9706**	**320**	**614**	**14309**	**15559**

Table 2 is presented graphically in figure 1 below.

Figure 1: Projected versus Actual Energy Generation in 2017



The total energy generated including imports from Cote d'Ivoire over the period was 14,178.53 GWh. This comprises 5,615.51 GWh hydro generation, 8,242.21 GWh thermal generation and 320.81 GWh Imports. The generation mix at the end of the period was therefore 39.60% hydro, 58.14% thermal and 2.26% import.

2.3 Energy Consumption

The total energy consumption (including losses) for 2017 was 14, 308.08 GWh in comparison to the projected value of 15,615 GWh. This figure represents an increase of 608.08 GWh (4.43%) over the 2016 value of 13,700 GWh. A summary of actual and projected energy consumption for 2017 is as presented in Table 3 below.

Table 3: Summary of Energy Consumption for 2017, actual vs. projected

Customer	Projection (GWh) 2017	Actual (GWh) 2017	Actual (GWh) 2016	% Growth
ECG	10,326	9,923	9,267	7.07%
NED	1,213	1,236	1,139	8.51%
Mines	1,498	1,151	1,250	-7.97%
VALCO	620	631	617	2.34%
Export	940	377	466	-19.10%
Direct Customers	425	395	345	14.38%
Losses and Network Usage	593	595	615	-3.31%
Total Energy	**15,615**	**14,308**	**13,700**	**4.44%**

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

2.4 Energy Exchanges (Export and Import)

A total energy of 354.94 GWh was transmitted to CEB, comprising 284.23 GWh from VRA and 70.71 GWh wheeled from CIE.

The total interchange flows between Ghana and Cote d'Ivoire on the tie line was 355.41 GWh. This was made up of 320.43 GWh of import and 34.98 GWh of exports to CIE.

2.5 Hydro Reservoir Operation

2.5.1 Akosombo Reservoir

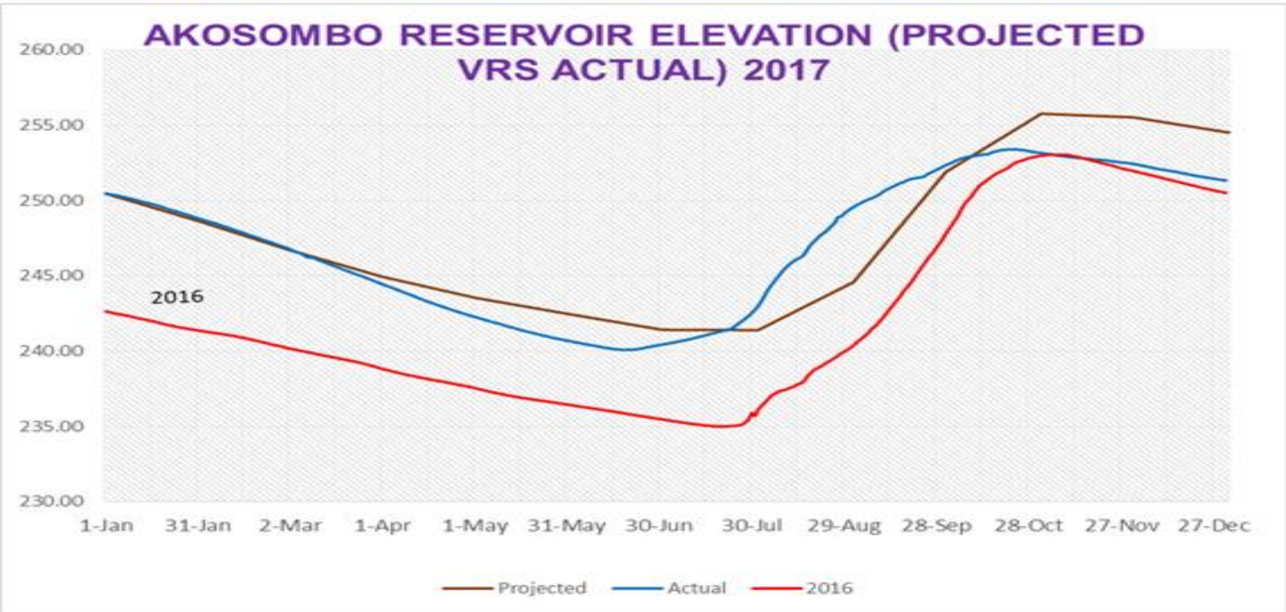
The year start elevation for the Volta Lake for 2017 was 76.34 m (250.47 feet). Based on this unimpressive reservoir elevation, it was recommended to operate three (3) and five (5) units at off-peak and peak respectively. It is to be noted however that, due to anticipated gas supply challenges and a longer duration units' maintenance at Aboadze in the first quarter of 2017, the above recommendation included a specific requirement to run six (6) units at peak in Akosombo in the first quarter.

Following the implementation of the above recommendation in 2017, the reservoir elevation dropped to a minimum of 73.18 m (240.09 feet) during the dry season in 2017. This actual lowest elevation in 2017 of 73.18 m (240.09 feet) was 0.03 m (0.09 feet) higher than the projected.

Inflows in 2017

The recorded Lake elevation at the end of the inflow season was 77.24 m (253.40 feet), a rise of 4.06 m (13.31 feet) above the recorded minimum. This rise in 2017 was lower than the 2016 rise of 5.50 m (18.04 feet). The corresponding total net inflow in 2017 was 25.14 MAF which was 0.14 MAF higher than the long-term average of 25 MAF. Figure 2 shows the Akosombo reservoir trajectory for 2017.

Figure 2: 2017 Akosombo Reservoir Trajectory



2.5.2 Bui Reservoir

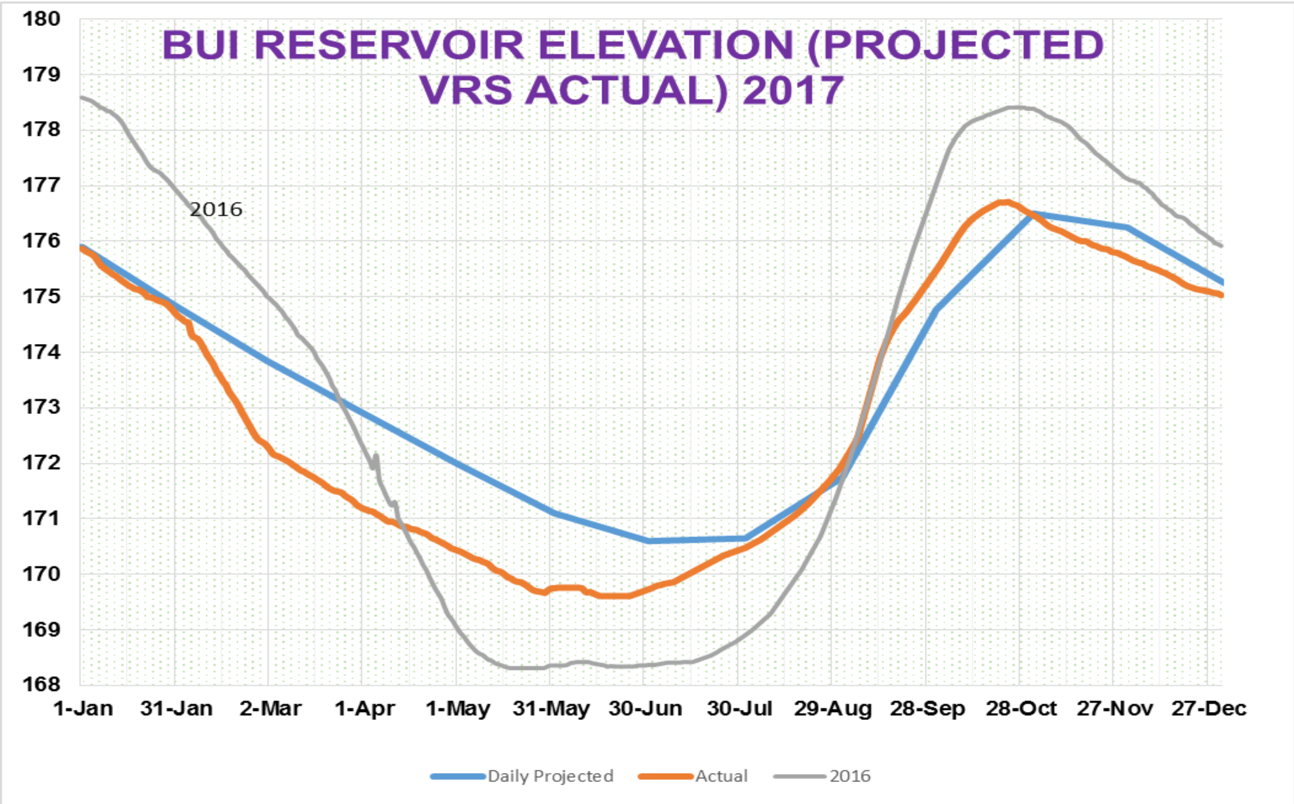
The Bui Reservoir level at the beginning of 2017 was 175.87 masl, dropping to a minimum level of 169.61 masl at the end of the dry season. The minimum level attained was 0.99 masl lower than the projected minimum of 170.60 masl for the year. This drop in elevation below the projected was due to over-drafting of the Lake to make up for the power deficit arising from the shortfall in gas supply from Ghana Gas in the first quarter of 2017.

The total energy generated in 2017 was 581.79 GWh compared to the projected of 841 GWh. The lower than projected generation was due to over-drafting of the reservoir in the first quarter of 2017 as alluded to above, forcing a revised strategy to control the drafting of the dam leading to a lower than anticipated generation.

At the end of the inflow season the reservoir level rose to a maximum level of 176.71 masl on October 22, 2017. The year-end elevation on December 31, 2017 was 175.92 masl.

The reservoir trajectory in 2017 is as shown in Figure 3.

Figure 3: Bui Reservoir Trajectory (Actual)



2.6 Generating Plant Availabilities for 2017

Table 4 below presents the actual generating plant availabilities as against the forecast for the period under review.

Table 4: Generating Plants' actual and estimated availability for the year 2017

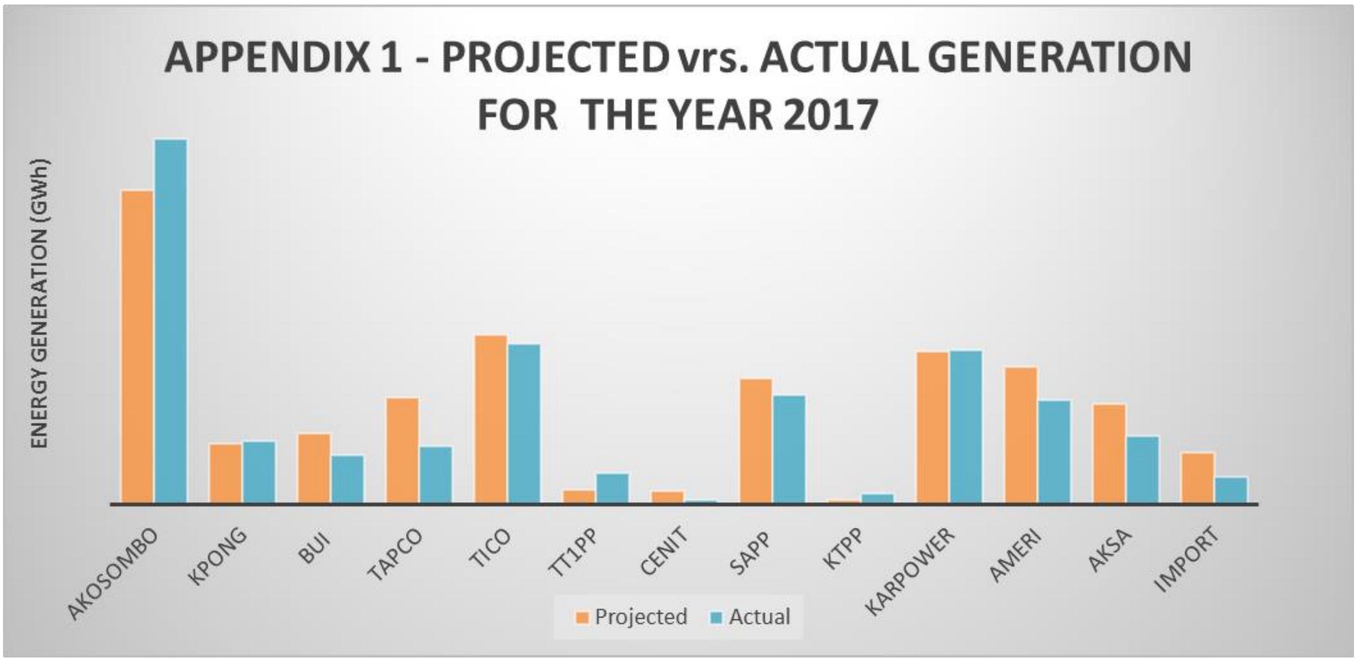
Plant	Forecast (%) Availability	Actual (%) Availability
Akosombo Hydroelectric Plant	90	97
Kpong Hydroelectric Plant	72	74
Bui Generation Station	85	95
Takoradi Thermal Power Plant (TAPCo)	65	40
Takoradi Thermal Power Plant (TICo)	85	82
Tema Thermal Power Plant (TT1PP)	88	65
CENIT	92	24
Karpower	90	97
Tema Thermal Power Plant (TT2PP)	85	13
Sunon Asogli Power Plant	92	93
Ameri	90	97
MRP	80	0
Kpone Thermal Power Plant (KTPP)	85	72
AKSA	90	98

It should be noted that the plant availability factors were determined based on the total plant Dependable Capacities.

The AKSA Thermal Power Plant recorded the highest unit availability of 98% compared to the forecast figure of 90% whiles the MRP Plant was unavailable during the entire period.

Figure 4 shows the actual monthly energy generation against the projected.

Figure 4: Generating Plant projected & actual energy production for the year 2017



2.7 Fuel Supply Issues

There was generally low availability of LCO in the Tema Thermal Complex in 2017. Consequently, the CENIT Plant suspended operations in March 2017.

2.8 Generation Deficiency and Load Shedding

2.8.1 Load management program

In line with the planned maintenance of the gas infrastructure in the 2017 Supply Plan, Tullow Ghana Limited and Ghana National Gas Company carried out planned maintenance works between January and March 2017 that led to the curtailment of gas supply to the Aboadze Enclave. This resulted in some brief incidences of load shedding between 20th February and 3rd March 2017.

2.8.2 Automatic Frequency Load shedding (AFLS)

The period under review registered 42 (no.) automatic frequency load shedding relay (AFLS) operations which cumulatively lasted 41 hours and 7 minutes. The AFLS operations in 2016 were 24 (no.) and lasted 320 hours and 27 minutes. It is therefore observed that, though the number of operations in 2017 was higher, the cumulative duration was much lower.

2.9 Quality of Supply

2.9.1 System Frequency

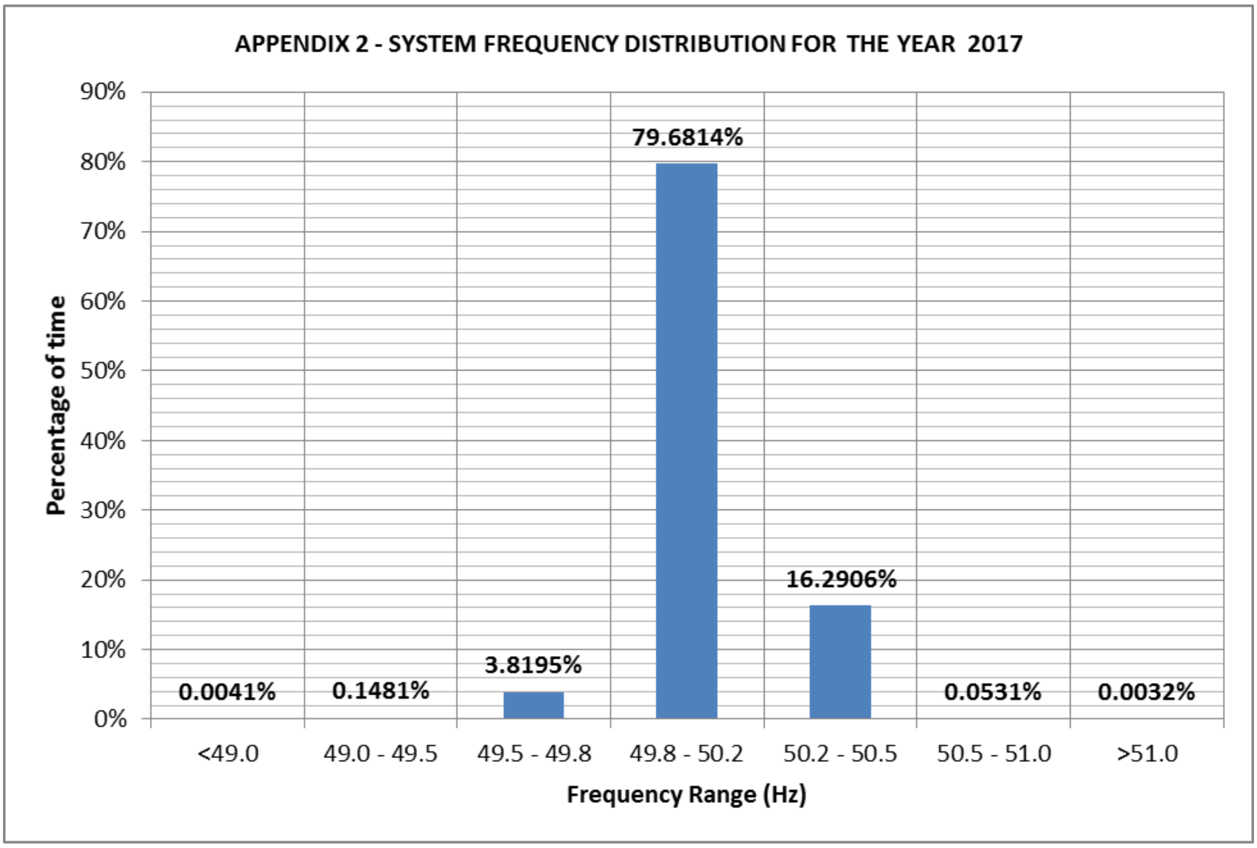
Figure 5 shows system frequency performance during 2017. It is seen from the graph that system frequency was within the normal range (49.8Hz – 50.2Hz) - 79.68% of the time which is higher than the 76.6% recorded in 2016. It was in the alert state 20.32% of the time in the entire year as follows:

- 49.5Hz – 49.8Hz - 3.82% of the time.
- 50.2 Hz – 50.5 Hz - 16.29% of the time.

It was in emergency state 0.20% of the time in the entire year as follows:

- 49.0Hz – 49.5Hz - 0.15% of the time.
- 50.5Hz – 51.0Hz - 0.053% of the time.
- below 49.0Hz 0.00% of the time.
- above 51.0Hz 0.00% of the time.

Figure 5: System Frequency for year 2017



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 as shown in the Table below.

Table 5: System Voltages

Station	Number Of Days of the Year			Percentage for the Year		
	Normal	Below Normal	Above Normal	Normal	Below Normal	Above Normal
Achimota	358	7	0	98.08%	1.92%	0 %
Mallam	332	33	0	90.96%	9.04%	0%
New Tema	365	0	0	100.00%	0.00%	0%
Kumasi	207	158	0	56.71%	43.29%	0%
Takoradi	363	2	0	99.45%	0.55%	0%
Tamale	363	0	2	99.45%	0.00%	0.55 %

Kumasi voltages were below limits 158 days in 2017. 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 2017 was 99.84 % as compared to 97.07% in 2016.

2.10.2 Transmission Lines

The System Average Availability (SAA) for the transmission grid was 99.58 % in 2017

Table 6: The percentage transmission line availability for the year 2017

Voltage Class	Availability (%)
69kV	99.76%
161kV	99.74%
225kV	98.77%
330kV	99.01%
System Average Availability (%)	99.58%

2.11 Transformer Capacity

Over the period under review, transformer capacity on the NITS increased from 4,722.2 MVA to 4,998.2 MVA, an increase of 236.0 MVA.

Table 7 shows the breakdown of transformer additions.

Table 7: Transformer additions for year 2017

Substation	Transformer Code	Voltage level	Rating (MVA)
Juabeso	64T1	161/34	33
Kadjebi	70T1	161/34	13
Kpando	25T2	69/34	25
Takoradi	8T1	161/34	33
Old Kpong	17T1	161/34	33
	17T2	161/34	33
Collector	75T1	161/34	33

Table 8 below shows typical transformer peak loadings in some major substations in 2017.

Table 8: Transformer peak loadings for year 2017

Substation	Transformer Code	Rating (MVA)	Peak Loading (MVA)	% of Rating
Achimota	5T1	66	54.5	111.0
	5T2	66	57.4	92.5
	5T3	66	57.5	0.1
	5T4	66	51.1	97.6
	5T5	66	50.2	106.6
	5T6	66	51.1	84.0
Mallam	37T1	66	71.6	68.5
	37T2	66	57.5	73.3
	37T3	66	54.3	82.2
	37T4	66	55.2	83.6
New Tema	4T1	66	54	81.8
	4T2	33	30.42	92.2
	4T3	66	59.9	90.8
	4T4	20	0.08	0.4
	4T5	66	63.7	96.5
	4T6	20	0.02	0.1
Kumasi	13T1	66	69	104.5
	13T2	66	61.3	92.9
	13T3	66	53.8	81.5
	13T4	66	62.4	94.5
Takoradi	8T1	33	32.3	97.9
	8T2	33	15.89	48.2
	8T3	33	17.92	54.3

2.12 New installations in 2017

Table 9 below shows the projects that were commissioned during the year under review.

Table 9: Commissioned Projects in 2017

Equipment	Projects
Generating Plants	1. 450 MW Karpower plant
	2. 250 MW AKSA Plant
	3. 180 MW Asogli Phase II
Transmission Lines	1. 161 kV AKSA – Enclave
	2. 161kV Asawinso - Juabeso
	3. 161kV Cenpower – Kpone Collector
Substation/ Transformers	1. Juabeso substation was commissioned.
	2. Kadjebi Substation was commissioned

3 DEMAND OUTLOOK FOR 2018Peak Demand

The projected coincident peak demand (base case) for 2018 is 2,523.49 MW. This represents an increase of 331.34 MW, translating into a growth of 15.11 % over 2017 recorded peak of 2,192.15 which occurred on November 13, 2017.

The following spots loads are expected to contribute to peak demand growth in 2018:

a. Second Cell – line operation of VALCO (from 75 MW to 150 MW)

b. Increase in export to SONABEL (Burkina Faso)- from 9.2 MW in 2017 to:

   - ✓ 50 MW in the First half of 2018 and
   - ✓ 100 MW in the second half of 2018.

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

d. Also, various rural electrification projects within the ECG and NEDCo distribution zones earmarked for commissioning in 2018.

3.2 ECG Energy and Demand Forecast Methodology and Assumptions

The external factors affecting the demand for energy consumption in ECG are following;

- GDP growth projection for Ghana
- Customer Population
- Tariff

ECG customers are categorised into Special Load Tariff (SLT) customers and Non – Special Load Tariff (NSLT) customers. The SLT customers are industrial customers whose demand is 100 kVA and above, whilst the Non SLT customers include both residential and commercial customers whose demand less than 100 kVA.

Two (2) energy sales forecast models were developed for each category (SLT and Non – SLT) to forecast the Energy Sales (MWh) from 2017 to 2026. Non-SLT model utilized the Ordinary Least Squares (OLS) – Multiple Linear Regression Model (Log – Log) which examines the historical behaviour of various key variables to build a model for predicting future demand. SLT model utilized the Auto - Regressive Model which includes the lagged values of the dependent variable as independent variables. The EVIEWs software was used to estimate the coefficients.

The forecast values were projected based on assumptions for Low, Base and High case scenarios. Exponential Smoothening forecast methodology was employed to carry out the short term monthly forecast for the year 2018 only.

Tables 10 and 11 show the elasticity's of price, GDP and Customer Population for both the SLT and NSLT energy models.

Table 10: Coefficients for Natural Log of Non SLT model

LN_NSLT		
Coefficient of Natural Log of Population	LNPOP_NSLT	0.227022
Coefficient of Natural Log of GDP	LNGDP	0.752405
Coefficient of Natural Log of Price	LNP_NSLT	-0.109534
Dummy Variables 1	DMN	-0.041879
Dummy Variables 2	DMN-2	-0.154824
Constant	C	-5.692035

Table 11: Coefficients for SLT model

SLT		
Coefficient of Non-Agriculture GDP	GDP	1.06E-05
Dummy Variables 1	DMS	-137621.5
Constant	C	98779.93
Coefficient of lag of SLT sales	S_SLT (-1)	0.888794

ECG Energy purchases (MWh) are also projected for the ten-year period 2017 – 2026 using the relation below;

$$Energy\ Purchases\ (P) = \frac{Energy\ sales\ (S)}{1 - \%System\ Losses}$$

Where Energy sales (S) is the forecast energy sales from the sum of the SLT and NSLT energy forecast results.

% System Losses is the projected system loss in line with ECG Management loss reduction program.

The Annual **Total Non – Coincident Peak Demand (MW)** are projected for the ten year period 2017 – 2026 using the relation below;

$$Maximum\ Demand = \frac{Number\ of\ units\ (kWh)\ purchased\ in\ a\ year}{Annual\ load\ factor\ \times 8760\ hours}$$

Based on the relation above, the Maximum Demand is forecasted for the period 2017 to 2026. The Annual Load Factor for the forecast period is projected based on historical load factors and expected changes in consumption patterns.

The full details of the report can be obtained directly from the Engineering Directorate of the Electricity Company of Ghana.

3.3 Northern Electricity Company of Ghana (NEDCo) Forecast Methodology and Assumptions

It has been established through correlation studies that residential population and economic growth has direct relationship with energy growth in NEDCo, hence, the model for the energy demand took into account the following factors:

- Population (POP),
- GDP per Capita based on Purchasing Power Parity (GDPC) ,
- Tariff (TAR),
- System loss (LOSS)

For purposes of simplicity we assume that these factors have linear relationship with the load demand. The demand equation can therefore be stated as follows:

$P_L = a_0 + a_1POP + a_2TAR + a_3GDPC + a_4\ LOSS$

Here a_0, a_1, a_2, a_3, and a_4 are the regression parameters to be determined by the Least Error Squares (LES) algorithm. The parameters were determined using available historical econometric data. The relationship thus established in table 12 as follows:

Table 12: Coefficients determined from the analysis

a_0	a_1	a_2	a_3	a_4
Constant	Population	Tariff	GDP	Loss
-392.4	1.0458	0.7179	0.2855	11.465

The above relationship was used to project energy demand using the following econometric growth assumptions as indicated below:

3.3.1 GDP Per Capita

The expected overall GDP per capita based on constant Ghana currency is projected to be 6.9% and 4.6% for 2018 and 2019 respectively. The ten-year Average GDP Per Capita is projected at 5.8% between 2014 and 2024 (*IMF Request for a Three-Year Arrangement under the Extended Credit Facility—Debt Sustainability Analysis. pg. 6*).

3.3.2 Tariff

In line with NEDCo's demand for an economic tariff, the average tariff is assumed to grow at an annum average rate of 8.6% over the study period.

3.3.3 Customer Population

NEDCo's customer population is projected to grow at an annual rate of 7.1%, reaching 1,499,450 in 2026.

3.3.4 System Losses

NEDCo's system losses have been reducing consistently since 2004. For this purpose, systems losses are expected to remain at its current value of 23.0% against the target of reducing the losses to internationally acceptable levels.

3.4 Summary of 2018 Peak and Energy Demand Forecast

The Table 13 below shows a summary of 2018 Peak Demand Forecast.

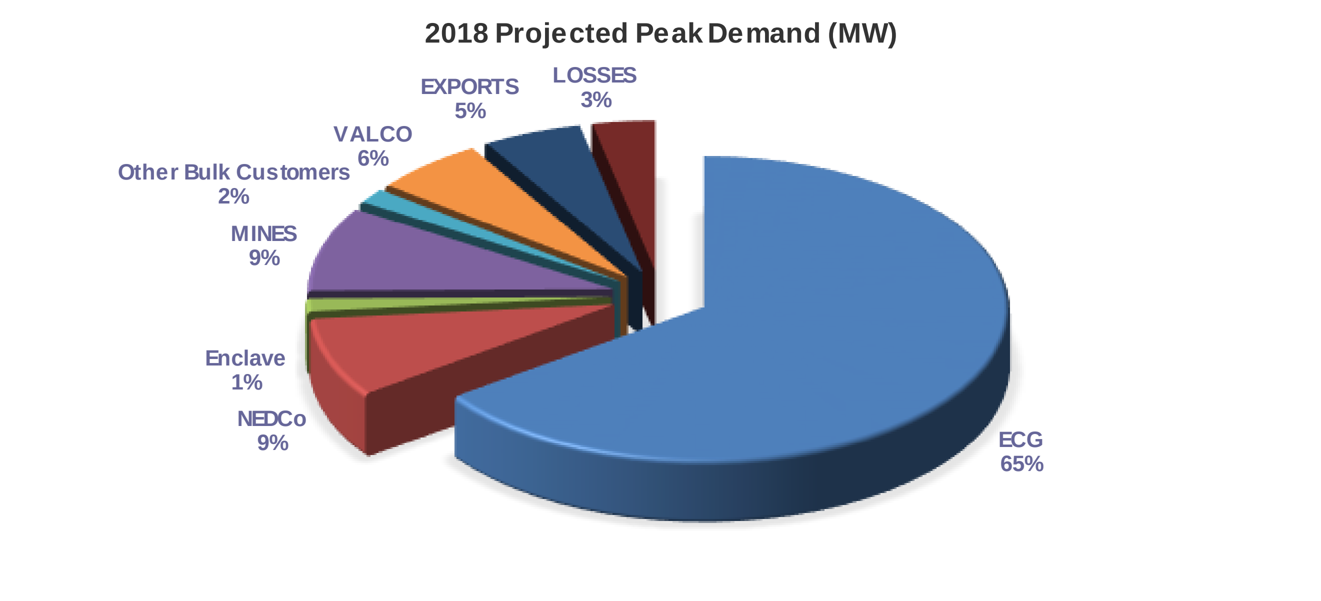
Table 13: Summary of 2018 Peak Demand forecast

Demand	Customer		2018 – Projected Coincident Peak (MW)
Domestic Peak Demand	Discos	ECG	1,642.72
		NEDCo	211.71
		Enclave Power	34.23
	Mines	New Obuasi	226.71
		Obuasi	
		New Tarkwa	
		Prestea	

Demand	Customer		2018 – Projected Coincident Peak (MW)
		Ahafo/Kenyase (Newmont)	
		New Abirim (Newmont)	
		Akyempem (Wexford)	
		Perseus (Ayanfuri)	
		Bogosu	
		Akwatia	
		Konongo	
		Adamus Gold Resources	
		Asanko Gold	
		Drill Works	
	Other Bulk Customers	Akosombo Textiles	**40.74**
		Aluworks	
		Ghana Water Company Ltd	
		Diamond Cement	
		Generation Plants Station Service	
		Volta Hotel	
		Savana Cement (Buipe)	
		VRA Townships	
Losses + Network Usage			**84.37**
Total Domestic Peak Demand			**2,240.49**
Exports	**CEB**		**30**
	CIE		**3**
	SONABEL		**100**
Total Exports			**133.00**
VALCO			**150.00**
Coincident Peak Demand MW			**2,523.49**

The Pie-Chart below is used to describe the Peak Demand, showing the percentage share of each customer class as shown in the Figure 6. From the Chart, ECG's demand constitutes 65% of the total system peak followed by NEDCo and the Mines at 9%. VALCO at two Cell-lines constitutes 6%. Other Bulk Consumers constitute 2 % whilst Exports to CEB and SONABEL together account for 5%.

Figure 6: 2018 projected peak demand



3.5 Outlook of Energy Consumption

Total energy consumption including transmission network losses is projected at 16,304.79 GWh in 2018. This includes estimated transmission losses and network usage of 594.30 GWh, representing 3.6 % of total energy consumption. The projected 2018 energy consumption represents a growth of approximately 15.11 %, over the 2017 actual consumption of 14,177.33 GWh, an increase of 2,127.46 GWh

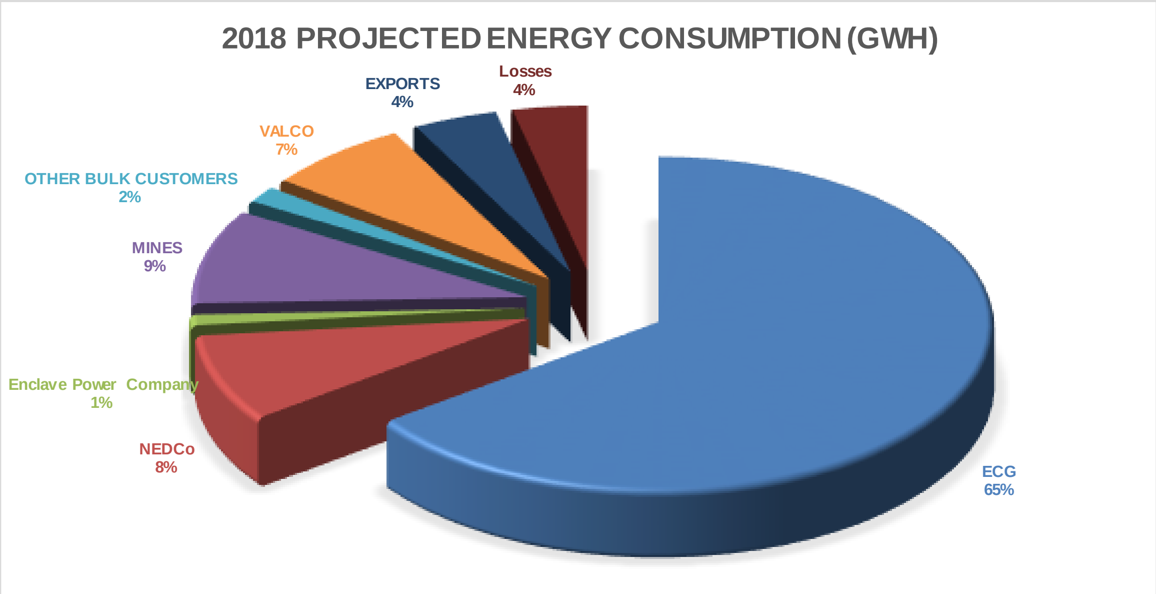
The summary of 2018 energy consumption by customer class is presented in Table 14 below.

Table 14: Summary of 2018 Energy Consumption by Customer Class

	Customer	2018 – Projected Consumption (GWh)
Domestic Consumption	**ECG**	10,588.86
	NEDCo	1,373.10
	Enclave Power Company	167.74
	Mines	1,495.41
	Other Bulk Customers	259.22
	Losses + Network Usage	594.30
Total Domestic		14,478.63
Exports	**CEB**	230.00
	CIE	13.21
	SONABEL	428.76
VALCO		1,154.19
Total Energy (GWh)		16,304.79

Figure 7 below shows a Pie-Chart representation of the projected consumption of the various customer classes and their percentage share in 2018. As shown, ECG's consumption of 10,588.86 GWh represents about 65% of the total projected energy consumption for 2018. It is followed by Mines with a projected consumption of 1,495.41 GWh representing 9% of the total consumption.

Figure 7: 2018 projected Energy consumption by customer



3.6 Projected Monthly Peak and Energy Demand

A detailed summary of the monthly peak demand and the corresponding energy consumption for the various customer classes is shown in Table 15 below.

Table 15: Summary of 2018 Monthly peak (MW) and Energy (GWh) demand forecast

Base Case- Energy and Peak Demand Projection- 2018

Energy (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Energy (GWh
ECG	930.12	822.34	900.28	912.40	916.02	845.16	838.49	850.29	840.25	894.54	896.51	942.46	**10,588.86**
NEDCo	112.28	110.31	117.36	111.92	113.55	111.75	114.15	113.38	112.60	121.00	117.26	117.52	**1,373.10**
Enclave Power Company	8.91	10.16	13.16	13.57	14.40	15.08	15.52	14.46	15.72	15.66	15.59	15.52	**167.74**
MINES	124.73	121.75	123.29	120.19	124.32	120.11	122.00	130.03	126.38	128.15	125.60	128.87	**1,495.41**
Other Bulk Customers	20.14	18.29	20.54	20.13	20.37	20.70	22.03	24.18	21.89	22.39	23.43	25.12	**259.22**
VALCO	53.57	64.51	85.71	103.68	107.14	103.68	107.14	107.14	103.68	107.14	103.68	107.14	**1,154.19**
CEB(Togo/Benin)	19.53	17.64	19.53	18.90	19.53	18.90	19.53	19.53	18.90	19.53	18.90	19.53	**230.00**
SONABEL(Burkina)	5.58	5.04	5.04	27.00	27.90	27.00	55.80	55.80	54.00	55.80	54.00	55.80	**428.76**
CIE(Ivory Coast)	0.89	0.81	0.89	0.86	0.89	0.86	0.89	0.89	0.86	0.89	0.86	0.89	**13.21**
Network Usage	0.73	0.67	0.74	0.76	0.77	0.72	0.74	0.75	0.74	0.78	0.78	0.81	**8.99**
LOSSES	50.02	45.91	50.41	66.72	67.50	63.44	38.89	39.49	38.85	40.98	40.70	42.41	**585.31**
Total	**1326.50**	**1217.43**	**1336.95**	**1396.13**	**1412.40**	**1327.41**	**1335.18**	**1355.95**	**1333.88**	**1406.85**	**1397.32**	**1456.08**	**16,304.79**
Peak demand (MW)-Coincident	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Max. Demand (MW)**
ECG	1604.05	1610.86	1652.07	1656.95	1640.61	1563.99	1485.64	1484.46	1552.04	1613.63	1637.79	1642.72	1656.95
NEDCo	200.95	203.23	201.84	201.45	204.89	205.34	205.08	207.89	209.67	214.34	212.14	211.71	214.34
Enclave Power Company	29.44	29.44	29.44	29.44	29.44	29.44	32.00	32.00	32.00	32.00	32.00	34.23	34.23
MINES	210.90	208.41	207.90	208.63	208.11	209.48	213.98	214.11	216.03	219.27	222.61	226.71	226.71
Other Bulk Customers	39.36	38.19	40.32	40.68	42.63	40.93	40.88	42.21	41.28	41.82	41.27	40.74	42.63
VALCO	75.00	100.00	120.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150
CEB(Togo/Benin)	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30
SONABEL(Burkina)	10.00	10.00	10.00	50.00	50.00	50.00	100.00	100.00	100.00	100.00	100.00	100.00	100
CIE(Ivory Coast)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3
Network Usage	1.30	1.32	1.36	1.40	1.39	1.35	1.34	1.34	1.38	1.42	1.44	1.44	1.44
LOSSES	101.76	103.17	106.01	137.47	136.80	132.37	76.86	76.96	79.36	81.74	82.58	82.93	137.47
System Peak (MW) - Coincident	**2,305.77**	**2,337.62**	**2,401.94**	**2,509.01**	**2,496.88**	**2,415.89**	**2,338.78**	**2,341.97**	**2,414.76**	**2,487.23**	**2,512.83**	**2,523.49**	**2523.49**

4 SUPPLY OUTLOOK

4.1 Sources of Generation

The sources of generation considered are mainly the existing generation and the committed projects expected to come on line in 2018.

4.2 Existing Generation Sources

Akosombo & Kpong Hydro

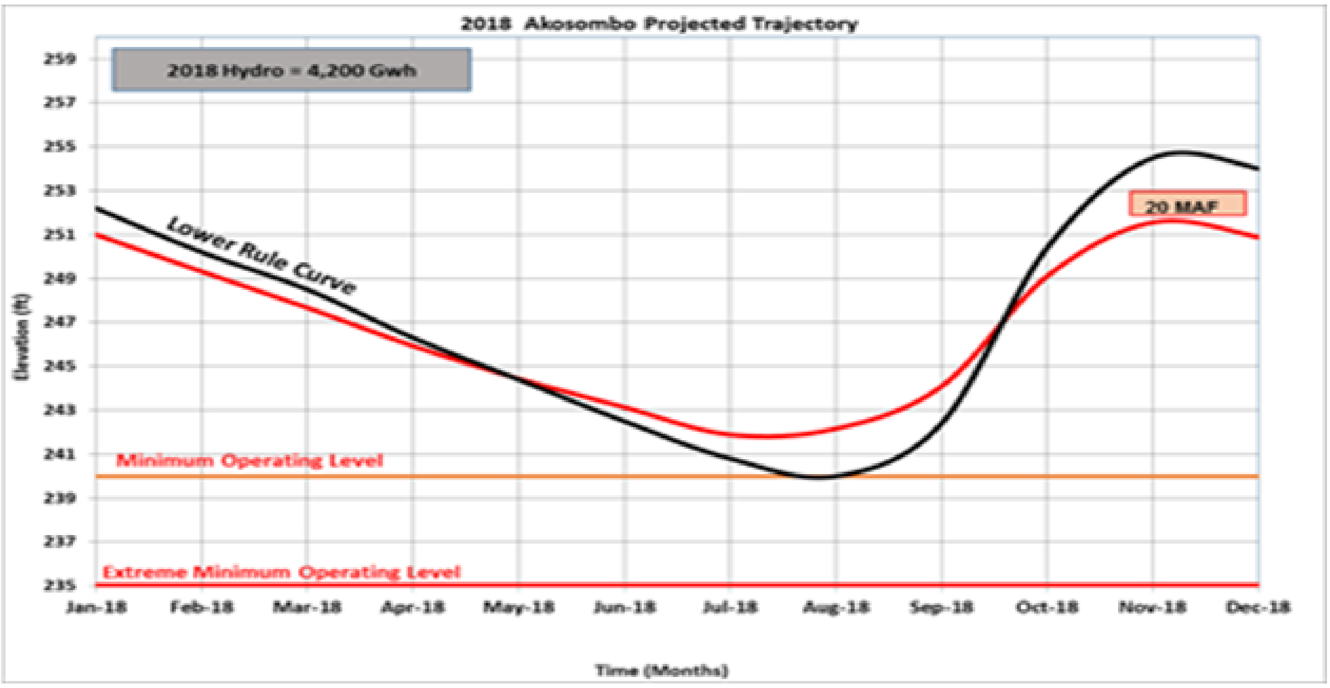
The year start elevation for the Akosombo reservoir is 76.60 m (251.31 ft) which is lower than the Lower Operating Rule Curve of 76.87 m (252.20ft.) for the Reservoir.

In the light of this low elevation for the Akosombo Reservoir, it is planned to operate three (3) Units during Off-peak and up to four (4) Units during Peak periods in 2018. This mode of operation will result in average Plant Output of 600 MW at Akosombo and this will ensure that the Reservoir level is kept above the Minimum Operating Level of 73.15 m (240 ft.) by the end of the dry season.

Kpong GS, which is currently undergoing retrofit, is projected to run 3 out of the 4 total installed Units. Consequently, the total average Plant Output at Kpong GS is projected at 105 MW.
As a result of the above Plants operation, the projected total annual hydro energy generation from Kpong and Akosombo Generating Stations is 4,200 GWh.

The projected monthly elevations for the Akosombo Reservoir in 2018 based on the above-recommended hydro generation are shown in Figure 8 below. The expected minimum elevation of 73.73 m (241.89 ft.) at the end of the dry season is some 0.58m or 1.89ft above the minimum operating level of 73.15, or. 240 ft. The projected Akosombo Reservoir Monthly Elevations is based on an assumed net inflow of 20 MAF (based on a 55% probability of obtaining this level of inflow).

Figure 8: 2018 Projected Akosombo Trajectory



4.2.2 Bui Hydro

In 2018, Bui Hydro Plant is projected to operate an average of two (2) units throughout the year. This mode of operation will lead to a projected annual production of 756 GWh. The plant is assumed to provide an average generation capacity of 220 MW to support demand.

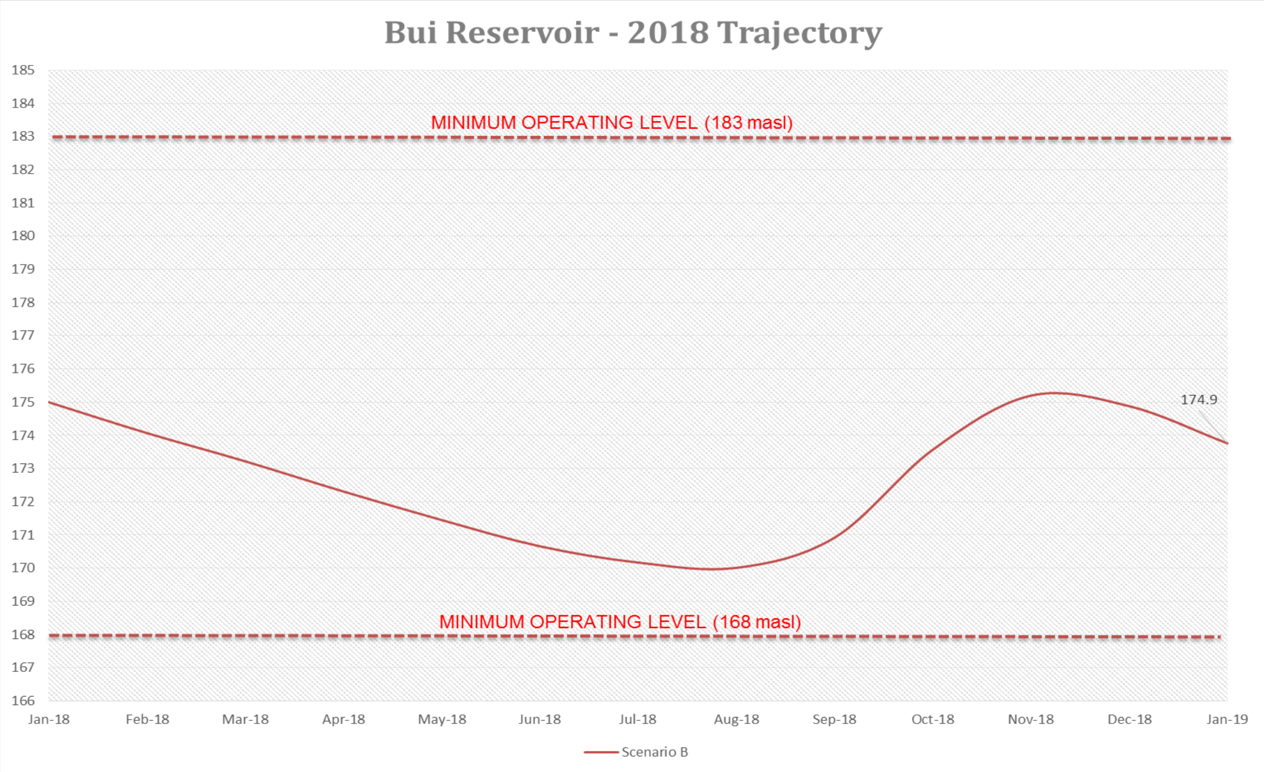
It is estimated that, for continuous and sustainable operation of the Bui GS for 2018 and for the subsequent years (in the likely event of low inflows), the reservoir level at the end of the dry season of 2018 should not drop below elevation 170 MASL.

With a projected year-start elevation of 175 MASL in 2018, and the total estimated total energy production of 756.21 GWh for year 2018, the year-end elevation is projected at 174.9 MASL.

Assumptions for projected 2018 generation from the Bui Hydro Plant:

- 64% Long Term Average Inflow of 6,167 Mm3.
- 2018 Year start elevation of Bui Reservoir – 175 MASL
- Operation of two units in normal mode at 110 MW in 2018.
- Operation of third unit in Synchronous Condenser Mode (SCM) when required by NTIS from January 1 to December 31, 2018.
- Operate Turbinette at 3.75 MW from January 1 to December 31, 2018.

Figure 9: 2018 Projected Bui Reservoir Trajectory



4.3 Thermal Generation

The details of installed and dependable generation sources assumed for the 2018 energy supply plan are shown in Table 16. The total installed capacity of the existing generation sources is 4,313 MW of which 3,868 MW is dependable capacity.

Table 16: Existing Generation Sources

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
Akosombo GS	1020	900	Hydro
Kpong GS	160	140	Hydro
TAPCO (T1)	330	300	LCO/Gas
TICO (T2)	340	320	LCO/Gas
TT1PP	110	100	LCO/Gas
TT2PP	80	70	Gas
KTPP	220	200	Gas/ Diesel
VRA Solar Plant	2.5	0	Solar
TOTAL VRA	**2,263**	**2,030**	
Bui GS	404	360	Hydro
CENIT	110	100	LCO/Gas
AMERI	250	230	Gas
SAPP	200	180	Gas
SAPP 2	360	340	Gas
KAR Power	470	450	HFO

AKSA	260	220	HFO
BXC Solar	20	0	Solar
Meinergy Solar	20	0	Solar
Trojan	44	39.6	Diesel/Gas
Genser	22	18	Coal
TOTAL IPP	**1,646**	**1,478**	
TOTAL (VRA, Bui & IPPs)	**4,313**	**3,868**	

4.4 New Generation Sources

In 2018, a number of new generating plants are expected to be commissioned as follows:

- **340 MW Cenpower Thermal Power Plant.** The Plant started commissioning in November 2017 and expected to reach full COD by the second quarter of 2018.
- **20 MWp Meinergy Solar PV Plant.** The Plant which will feed directly into the Medium Voltage (MV) Network is located in the Central Region and expected to be commissioned in the second half of 2018.

4.5 Key Assumptions Underpinning the Supply Plan

In developing the 2018 Supply Outlook, the following key assumptions were made;

4.5.1 Planned Maintenance

The schedule of key maintenance activities expected to be undertaken in 2018 on generating units at the various power plants is shown in Table 17.

Table 17: 2018 Planned Maintenance

Plants	Planned Maintenance
Akosombo GS	• Each of the six (6) units is scheduled to undergo annual maintenance, one at a time for a duration 18 days • Maintenance at Akosombo GS will be scheduled in a manner that it will not affect overall power supply
Kpong GS	• Unit 1: Post retrofit inspection for 30 days from July 1 – 30, 2018 • Unit 2: Quarterly maintenance for a period of 1 week in April, August and December, 2018 • Unit 3: Major Retrofit from January 1 to October 31, 2018 • Unit 4: Quarterly maintenance for a period of 1 week in February, June and October
Bui GS	• Unit 1 is scheduled for March 7 to April 18, 2018. • Unit 2 is scheduled for July 3 to 31, 2018. • Unit 3 is scheduled for October 1 to 29, 2018.
TAPCO (T1)	• **Unit 1***:* Fuel Nozzle Inspection and Compressor Water Wash from September 16-23, 2018. • **Unit 2***:* Major Inspection and compressor wash from Jan 1 – April 30, 2018 • **Unit 3***:* Minor Inspection from March 30 – April 21.
TICO (T2)	• **Unit 1:** Major Inspection from October 1 to November 29, 2018. • **Unit 3***:* Warranty Clearance Outage from January 13 to 27, 2018
TT1PP	• Unit scheduled for 12 days' maintenance from February 19 to March 2, 2018.

Plants	Planned Maintenance
TT2PP	• **Unit 1**: Core Engine Swap and main gearbox overhaul from July 17 – August 10, 2018. • **Unit 2:** Core Engine Swap and main gearbox overhaul from June 1 – June 25, 2018. • **Unit 3:** Core Engine Swap and main gearbox overhaul from July 24 – July 18. • **Unit 4**: Undergo Maintenance for 12 days from October 1 to 12, 2018 • **Unit 5**: Undergo Maintenance for 12 days from September 14 to 25, 2018 • **Unit 6:** Undergo Maintenance for 12 days from September 22 to October 3 • **Unit 7**: Undergo Maintenance for 12 days from October 9 to 20, 2018 • **Unit 8**: Undergo Maintenance for 12 days from October 17 to 28, 2018
KTPP	• Unit 2 will undergo maintenance for 10 days from April 16 – 25, 2018.
ASOGLI I	• Unit 4 & 6: Will undergo Class A maintenance from July 1 to 31, 2018 • Unit 5 : Class C maintenance[1] from August 5 to 18, 2018 • Unit 2, 3: Class C maintenance from August 18 to 31, 2018 • Unit 1 : Class C maintenance from September 8 to 18, 2018
ASOGLI II	• Unit 7 & Unit 8: Class C Maintenance from March 15 to April 1, 2018 • Unit 7: Class C maintenance from September 1 to 21, 2018 • Unit 9 & 10 : Class C maintenance from November 10 to 27, 2018
CENIT	• Plant to undergo Hot Gas Path Inspection from April 21 to May 12, 2018
AKSA	• One unit will undergo maintenance in January, September, October and November for 12 days.
KarPower Barge	• Units 1 to 24 will undergo maintenance for a total of 336 hrs in February, April and November 2018 and then for 384 hrs in September 2018. • Units 1 to 26 will undergo maintenance for a total of 672 hrs in June 2018. • Units 25 and 26 will undergo maintenance for 48 hrs in March, August and December 2018 and then for 96 hrs in October 2018.

4.5.2 Natural Gas Quantities and Availabilities

Two main supplies of natural gas were considered as follows:

- **Nigeria Gas** – Average supply of 60 mmscf/day is assumed from January to December 2018
- **Ghana Gas**
    - Jubilee Fields- Average of 100 mmscf/day from January to December 2018.
    - TEN Fields – Average of 50 mmscf/day from January to December 2018.
    - Sankofa Fields – Average of 120 mmscf/day from July 2018 (to be used by 450 MW Karpower Barge).

4.5.3 Gas Supply Disruptions

There is a planned three (3) week disruption in gas supply from Ghana Gas in February 2018. A second disruption in gas supply for 19 days is planned for March 2018 during which only 30 mmscf is expected to flow from Ghana Gas.

4.5.4 West to East Reverse Flow

On-going works to facilitate West to East Reverse Flow of gas using the WAPCo Gas Pipeline is expected to be completed by April 2018. This will pave the way for Ghana Gas to supply natural gas to power plants in the Tema Generation Enclave.

4.5.5 Fuel Allocation

Due to the limited quantities of natural gas supply in 2018 as projected above, fuel usage at the Tema and Takoradi Power Enclaves shall be strategically managed as follows:

Tema

- 30 mmscf/day allocated to Sunon-Asogli power plants.
- 30 mmscf/day for VRA plants (TT1PP & KTPP) at Tema
- TT2PP/TT2PP-X operate on natural gas (on standby).
- CENIT and Cenpower to operate on LCO
- Karpower to operate on HFO for the first half of the year and then be relocated to Takoradi to be run on natural gas from Sankofa Fields in the second half of the year .
- AKSA to operate on HFO

Takoradi

- T1 to operate mainly of Gas
- T2 to operate mainly on Gas
- Excess gas to be used by AMERI
- Karpower to operate on Gas from Sakofa fields from July to December 2018.

4.5.6 Fuel Price

The following assumptions on price of fuel delivered made:

- Nigeria Gas – US$ 8.45/mmbtu
- Ghana Gas – US$ 7.6/mmbtu
- Delivered LCO – US$ 70/barrel
- Delivered Diesel – US$ 84/barrel
- Delivered HFO – US$ 405/MT

4.6 Demand - Supply Analysis

This sub-section tries to analyze the demand – supply balance for 2018. The assumptions underpinning the demand - supply projections for 2018 are as described above. The analysis begins with the projected from all the generating plants and is presented in Table 18 below. The analysis of the monthly energy balance shows capacity surplus in 2018.

In view of the supply surplus, some Plants will not be dispatched under normal operating conditions.

Therefore, the following criteria are used to determine which Plants are dispatched on a monthly basis:

a. Merit order dispatch including lower overall system losses.
b. Availability of fuel per Plant
c. Must-run Plants (e.g. Solar)
d. System stability Requirements

Table 18: Projected Monthly Generation in GWh

	2018 Projected Consumption (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	14,478.63	1,246.93	1,129	1,226	1,246	1,257	1,177	1,152	1,173	1,156	1,223	1,220	1,273
VALCO	1,154.19	54	65	86	104	107	104	107	107	104	107	104	107
Export (CEB+SONABEL)	671.97	26	24	26	47	49	47	76	76	74	76	74	76
Projected System Demand	**16,304.79**	**1,327**	**1,218**	**1,337**	**1,396**	**1,413**	**1,328**	**1,335**	**1,356**	**1,334**	**1,407**	**1,398**	**1,456**
Generation Sources	**Projected Supply (GWh)**												
Akosombo	**3,599.99**	326	293	312	302	312	305	269	261	285	315	305	314
Kpong GS	**600.12**	51	45	51	49	51	49	51	51	49	51	49	51
TAPCO	**1,457.06**	89	20	55	58	89	86	179	179	173	179	173	179
TICO	**2,155.05**	174	183	202	196	202	196	202	202	196	101	98	202
TT1PP	**352.98**	60	-	60	-	60	-	60	-	57	-	58	-
KTPP	**369.24**	-	57	-	61	-	61	-	63	-	63	-	63
MRPP	**-**	-	-	-	-	-	-	-	-	-	-	-	-
TT2PP/TT2PPx	**-**	-	-	-	-	-	-	-	-	-	-	-	-
VRA Solar	**4.20**	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.4	0.3	0.4	0.3	0.4
Imports From Cote d'Ivoire	**-**	-	-	-	-	-	-	-	-	-	-	-	-
Total VRA Available Generation	**8,538.63**	**700**	**599**	**680**	**667**	**714**	**698**	**761**	**757**	**761**	**709**	**683**	**809**
AMERI Power Plant	**796.53**	92	-	56	49	76	73	76	76	73	76	73	76
Karpower Barge	**2,708.25**	287	262	229	268	271	218	138	163	147	261	254	210
SAPP	**51.93**	-	52	-	-	-	-	-	-	-	-	-	-
SAPP (Phase 2)	**1,414.18**	118	118	118	118	118	118	118	118	118	118	118	118
CENIT	**380.93**	-	-	-	32	31	45	46	46	45	46	45	46
AKSA	**558.49**	71	133	88	101	35	14	14	14	14	14	48	14
CENPOWER	**1,061.21**	-	-	108	104	108	104	108	108	104	108	104	108
Bui GS	**756.21**	57	52	57	56	57	56	71	71	69	71	69	71
BXC Solar	**25.54**	2.2	1.9	2.2	2.1	2.2	2.1	2.2	2.2	2.1	2.2	2.1	2.2
MEINERGY Solar	**12.90**							2.2	2.2	2.1	2.2	2.1	2.2
Total Available Generation (GWh	**16,304.79**	**1,327**	**1,218**	**1,337**	**1,396**	**1,412**	**1,328**	**1,336**	**1,356**	**1,334**	**1,407**	**1,397**	**1,456**

The Table 19 below on the other hand shows the annual energy and supply balance for 2018. It is seen from the Table that the total generation from the VRA Plants is 8,538.63 GWh, representing 52.36% of the projected total electricity generation in 2018. Total generation from Bui Hydro and other Independent Power Producers (IPPs) total 7,766.17 GWh, accounting for 47.34% of the projected total generation in 2018, out of which total IPP generation is 7,009.96 GWh, representing 42.99% of projected total generation in 2018

Table 19: 2018 Projected energy and Supply Balance in GWh

Projected Demand/Supply	Demand/Supply (GWh)
Total Domestic	14,478.63
VALCO	1,154.19
Exports (CEB+SONABEL+CIE)	671.97
Total Projected Demand	**16,304.79**
Projected Supply	
Total VRA Hydro (Akosombo & Kpong GS)	4,200.11
Bui GS	756.21
VRA Existing Thermal & Solar Generation	
T1	1,457.06
T2	2,155.05
TT1PP	352.98
KTPP	369.24
MRPP	0
TT2PP/TT2PP-X	0
Solar	4.20
Total VRA Thermal & Solar Generation	**4,338.53**
Existing IPP Thermal & Solar Generation	
AMERI Power Plant	796.53
Karpower Barge	2,708.25
SAPP+SAPP Phase 2	1,466.11
CENIT	380.93
AKSA	558.49
CENPOWER	1,061.21
BXC Solar	25.54
MEINERGY Solar	12.90
Total IPP Thermal & Solar Generation	**7,009.96**
Total VRA Supply	**8,538.64**
Total Non-VRA Supply	**7,766.15**
Total Supply	**16,304.79**

A graphical representation of the above energy supply giving the percentage share of each generation type is shown in Figure 10 below. The chart indicates that in 2018 thermal generation will constitute 69.3% of projected total generation whilst hydro generation and generation from Solar PV would constitute 30.4% and 0.3% respectively.

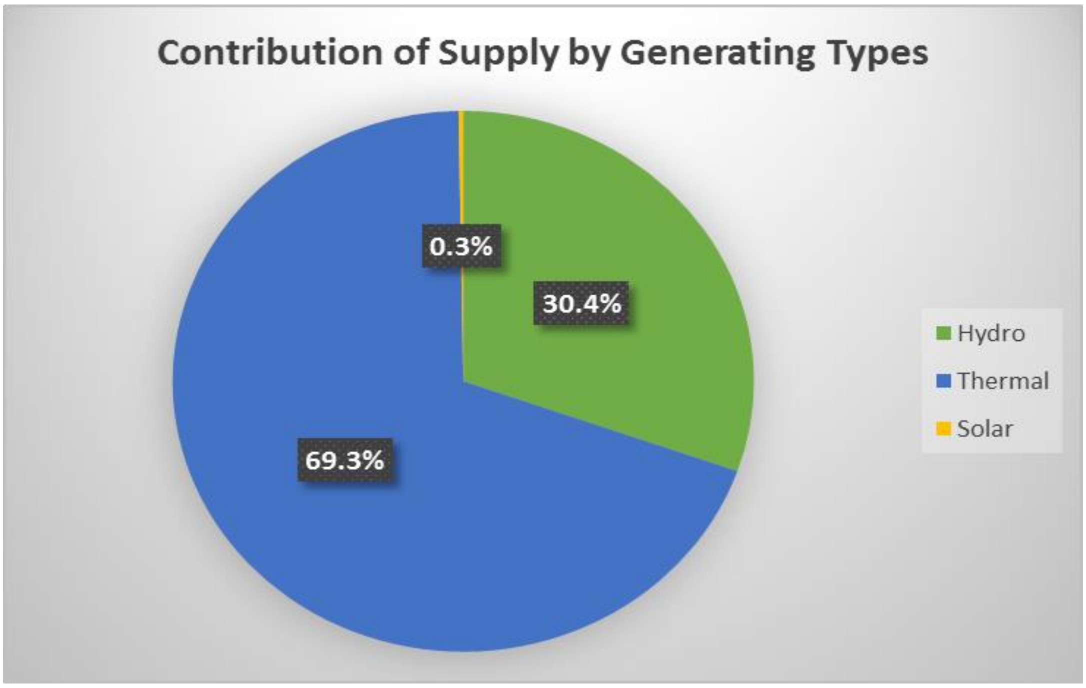
This means that in 2018, generation from thermal sources would be more than twice that from hydro sources.

This high percentage of thermal generation could have serious implications for the sector for the following reasons;

i. It will adversely impact the finances the local power utilities, since their tariffs are cedi denominated, but may require much more forex to purchase fuel and other consumables for their operations, considering the volatility of the cedi.

ii. Since the thermal plants are predominantly gas-based, any disruptions in gas supply would have dire consequences on the power supply situation in the country.

Figure 10: Contribution of Supply by Generation Types



4.7 Projected Capacity Situation

The projected monthly capacity levels, taking planned units' and fuel supply systems' maintenance into consideration is shown in Table 20 below.

Table 20: Projected Monthly Capacity Situation for 2018

Customer Category	2018 Proj. System Peak (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	2,276	2,188	2,195	2,239	2,276	2,264	2,183	2,056	2,059	2,132	2,204	2,230	2,240
VALCO	150	75	100	120	150	150	150	150	150	150	150	150	150
Export (CEB+SONABEL)	133	43	43	43	83	83	83	133	133	133	133	133	133
Projected System Demand	**2,523**	**2,306**	**2,338**	**2,402**	**2,509**	**2,497**	**2,416**	**2,339**	**2,342**	**2,415**	**2,487**	**2,513**	**2,523**
Generation Sources	**Dependable Capacity (MW)**												
Akosombo	900	600	600	600	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	100	150	150	300	300	300	300	300	300
TICO	320	200	320	320	320	320	320	320	320	320	160	160	320
TT1PP	100	100	100	100	100	100	100	100	100	100	100	100	100
KTPP	200	100	100	100	100	100	100	100	100	100	100	100	100
TT2PP	60												
VRA Solar	2.5												
Imports From Cote d'Ivoire	-	-	-	-	-	-	-	-	-	-	-	-	-
Total VRA Available Generation	**1,988**	**1,255**	**1,225**	**1,375**	**1,325**	**1,375**	**1,375**	**1,525**	**1,525**	**1,525**	**1,365**	**1,365**	**1,525**
Bui GS	345	230	230	230	230	230	230	230	230	230	230	230	230
Bui Min Unit	4	4	4	4	4	4	4	4	4	4	4	4	4
SAPP	180	180	180	180	180	180	180	180	180	180	180	180	180
SAPP (Phase 2)	360	180	180	180	180	180	180	360	360	360	360	360	360
CENIT	100	-	-	-	100	-	100	100	100	100	100	100	100
AMERI Power Plant	230	230	-	230	230	230	230	230	230	230	230	230	230
Karpower Barge	450	450	450	450	450	450	450	450	450	450	450	450	450
AKSA	220	220	220	220	220	220	220	220	220	220	220	220	220
CEN Power	340	-	-	340	340	340	340	340	340	340	340	340	340
BXC Solar	20												
Meinergy	20.0												
Total Available Generation (MW	**4,257**	**2,749**	**2,489**	**3,209**	**3,259**	**3,209**	**3,309**	**3,639**	**3,639**	**3,639**	**3,479**	**3,479**	**3,639**
Surplus/deficit (MW)	**1,733**	443	151	807	750	712	893	1300	1297	1224	991	966	1115
Reserve Margin		19%	6%	34%	30%	29%	37%	56%	55%	51%	40%	38%	44%

The analysis of the above monthly demand and supply situation shows monthly positive generation reserve margins of up to 56% in 2018, as such, supply challenges are not anticipated barring any unforeseen fuel supply interruptions. With such a considerable reserve capacity, some of the plants may not be dispatched whilst others may operate below full capacity.

The low capacity reserve margin of about 6% in February is as a result of the planned Sankofa gas pipeline tie-in into the Ghana National Gas Transmission System (NGTS) and a subsequent tie-in into the WAGP Pipeline. These works would result in curtailment of gas supply to the Aboadze Enclave and consequent loss of about 380 MW generation capacity.

4.8 Fuel Requirement

Currently, the main fuels for power generation include Light Crude Oil (LCO), Natural Gas and Heavy Fuel Oil (HFO). The estimates of quantity and cost of fuel require in 2018 is indicated in the Table 21 below:

Table 21: Summary of Annual Fuel Requirements

PLANT	LCO (Barrels)	Natural Gas (MMbtu)	HFO (MT)
T1		11,996,329	
T2	596,986	13,987,551	
TT1PP		4,204,032	
TT2PP			
MRPP			
KTPP		4,393,956	
TOTAL VRA	**596,986**	**34,581,868**	
CENIT	885,658		
AMERI		8,094,557	
Cenpower	1,512,221		
SAPP+ SAPP Phase 2		13,194,441	
Karpower		10,945,185	282,435
AKSA			171,904
TOTAL IPP	**2,397,879**	**32,234,183**	**454,339**
TOTAL (VRA&IPP)	**2,994,865**	**66,816,052**	**454,339**

The summary of fuel requirements for 2018 is as presented below:

- **LCO.** The total LCO requirement for 2018 is about 3 million barrels out of which 597,000 barrels would be required for the VRA and about 2.4 million barrels for non-VRA plants. Based on a cargo size of 405,000 barrels, the annual LCO requirements are about two (2) cargoes and about six (6) cargoes for VRA and non-VRA Plants respectively. Thus, a total of about eight (8) cargoes of LCO would be required.

- **Natural Gas.** Based on the assumed gas supply from Nigeria and Ghana, the total natural gas consumption is projected to be about 67 million mmbtu. VRA plants will use about 35 million mmbtu and IPPs some 32 million mmbtu.

- **HFO.** For the first half of the year, Karpower is expected to operate on HFO. The AKSA Plant is also scheduled to operate on HFO. Therefore, an estimated 455,000 Metric Tonnes would be required by AKSA and Karpower.

- **Diesel.** Diesel would be used mainly for start-ups and stops of all thermal plants. An estimated 100,000 barrels would be required in total for starting and stopping all thermal power plants.

Monthly Fuel Requirement.

The breakdown of **M**onthly fuel requirements and their associated costs are as shown in Figure 11 below.

Figure 11: Monthly fuel requirements and associated costs

Estimated Fuel Requirement & Cost

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Estimated Thermal Fuel Requirement	**Units**													
TAPCO - LCO	barrels	-	-	-	-	-	-	-	-	-	-	-	-	**-**
TAPCO - GAS	mmbtu	734,953	165,957	450,455	474,163	734,953	711,245	1,469,906	1,469,906	1,422,490	1,469,906	1,422,490	1,469,906	**11,996,329**
TICO - LCO	barrels	-	283,315	313,670	-	-	-	-	-	-	-	-	-	**596,986**
TICO - GAS	mmbtu	1,373,605	-	-	1,547,724	1,599,314	1,547,724	1,599,314	1,599,314	1,547,724	799,657	773,862	1,599,314	**13,987,551**
TT1PP - GAS	barrels	708,288	-	708,288	-	708,288	-	708,288	-	685,440	-	685,440	-	**4,204,032**
MRP - GAS	mmbtu	-	-	-	-	-	-	-	-	-	-	-	-	-
KTPP - GAS	mmbtu	-	679,728	-	728,280	-	728,280	-	752,556	-	752,556	-	752,556	**4,393,956**
TT2PP - GAS	mmbtu	-	-	-	-	-	-	-	-	-	-	-	-	**-**
IPP Plants														**-**
AMERI Power Plant - GAS	mmbtu	929,997	-	572,267	497,532	771,174	746,297	771,174	771,174	746,297	771,174	746,297	771,174	**8,094,557**
Karpower Barge - HFO	MT	52,756	48,284	42,063	49,266	49,918	40,148	-	-	-	-	-	-	**282,435**
Karpower Barge - GAS	mmbtu	-	-	-	-	-	-	1,285,678	1,518,010	1,368,952	2,438,143	2,371,795	1,962,607	**10,945,185**
SAPP - GAS	mmbtu	-	484,650	-	-	-	-	-	-	-	-	-	-	**484,650**
SAPP (Phase 2) - GAS	mmbtu	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	1,099,537	**13,194,441**
SAPP (Phase 2) - LCO	barrels	-	-	-	-	-	-	-	-	-	-	-	-	**-**
CENIT - LCO	barrels	-	-	-	74,995	71,424	103,565	107,136	107,136	103,565	107,136	103,565	107,136	**885,658**
AKSA - HFO	MT	21,814	40,955	26,966	31,169	10,885	4,157	4,295	4,295	4,157	4,295	14,622	4,295	**171,904**
CENPOWER - LCO	barrels	-	-	153,199	148,257	153,199	148,257	153,199	153,199	148,257	153,199	148,257	153,199	**1,512,221**
ESTIMATED FUEL COST														
Total VRA LCO - Cost @ US$ 70/bbl	MMUS$	-	19.83	21.96	-	-	-	-	-	-	-	-	-	**42**
Total VRA WAGP Gas - Cost @ US$ 8.45/mmbtu	MMUS$	5.38	5.17	5.38	5.53	5.38	5.53	5.38	5.72	5.21	5.72	5.21	5.72	**65**
Total VRA GHANA Gas - Cost @ US$ 7.6/mmbtu	MMUS$	16.03	1.26	3.42	15.37	17.74	17.17	23.33	23.33	22.57	17.25	16.69	23.33	**197**
Total VRA Fuel Cost	**MMUS$**	**21.41**	**26.26**	**30.76**	**20.90**	**23.12**	**22.70**	**28.71**	**29.05**	**27.78**	**22.97**	**21.90**	**29.05**	**305**
IPP Fuel Cost														
Total IPP LCO - Cost @ US$ 70/bbl	MMUS$	-	-	10.72	15.63	15.72	17.63	18.22	18.22	17.63	18.22	17.63	18.22	**168**
Total IPP WAGP Gas - Cost @ US$ 8.45/mmbtu	MMUS$	9.29	13.39	9.29	9.29	9.29	9.29	9.29	9.29	9.29	9.29	9.29	9.29	**116**
Total IPP GHANA Gas - Cost @ US$ 7.6/mmbtu	MMUS$	7.07	-	4.35	3.78	5.86	5.67	15.63	17.40	16.08	24.39	23.70	20.78	**145**
Total IPP HFO - Cost @ US$ 405/MT	MMUS$	30.20	36.14	27.96	32.58	24.63	17.94	1.74	1.74	1.68	1.74	5.92	1.74	**184**
Total IPP Fuel Cost	**MMUS$**	**46.56**	**49.53**	**52.32**	**61.28**	**55.50**	**50.53**	**44.89**	**46.65**	**44.68**	**53.64**	**56.54**	**50.03**	**612**
Total Cost	**MMUS$**	**67.97**	**75.79**	**83.08**	**82.18**	**78.62**	**73.24**	**73.60**	**75.70**	**72.46**	**76.61**	**78.44**	**79.08**	**917**

4.9 Estimates of Fuel Cost

The breakdown of the estimated cost of fuel for running all the Thermal Plants in 2018 is presented in the Table 22 below. Based on the assumed unit prices, the total estimated fuel cost for the Thermal Plants is US$ 1 Billion. This translates into an approximate monthly average of US$ 83.40 Million.

This total cost comprises US$ 336 Million or approximately US$ 28.02 Million per month for the VRA Plants and US$ 665 Million or monthly average of US$ 55.38 Million for the Non-VRA Plants.

Table 22: Breakdown of Estimated Fuel Cost for 2018

Type of Fuel	Cost (Million USD)
VRA - LCO	42
VRA - GAS	263
VRA - DFO	32
TOTAL VRA FUEL COST	**336**
IPP - LCO	168
IPP - GAS	260
IPP - HFO	184
IPP - DFO	52
TOTAL IPP FUEL COST	**665**
TOTAL VRA & IPP COST	**1,001**

5 TRANSMISSION SYSTEM PERFORMANCE

5.1 Status of Ghana Transmission Grid

In Ghana, the transmission of electricity is done at three main voltage levels, namely; 161 kV, 69 kV network and 330 kV. There is also a 225 kV voltage level transmission but this is only through an interconnection with Ghana's western neighbour Cote d'Ivoire. A similar interconnection with Togo is through two 161 kV lines.

The Ghana transmission network consists approximately of 5,283.8 circuit kilometres of high voltage transmission lines which connect generating plants at Akosombo, Kpong, Tema, Bui and Aboadze to sixty (60) Bulk Supply Points across the nation.

The network has 127 transformers installed at various load centres across the country with a Total Transformation Capacity of **5,609.9** MVA.

The NITS has 600 MVArs of fixed shunts installed at various Substations including Achimota, Mallam, Smelter, Winneba, Takoradi, Kumasi etc. and a 40 MVAr Static Synchronous Compensator (STATCOM) installed at the Tamale substation. The fixed shunts and the STATCOM complement the generating units in providing the reactive power requirements of the NITS, in order to maintain good voltages and minimize overall transmission losses.

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

5.2 Transmission Line, Feeder and Substation Availability

The criteria for transmission Line, Feeder and Substation availability are as presented below;

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

5.3 Steady State Network Analysis

Steady state network analyses are carried out to determine transmission line loadings, substation bus voltages and network loss levels across the transmission network. In particular, the analyses seek to determine:

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

5.3.1 Technical Adequacy Criteria

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

a. Normal Condition

Table 23: Criteria, 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

b. Contingency Conditions

Table 24: Criteria, contingency condition

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

c. Technical Analysis

Load Flow analyses were carried out to determine the transfer capability and assess the level of reliability of the transmission network to evacuate power from the generation centres to the various Bulk Supply Points across the network. Loadings on transmission lines and other power equipment were monitored to determine whether there any limit violations. Also overall transmission system losses were also recorded.

d. Assumptions and Development of a Base Case

The study was carried out on the 2018 network model as highlighted in Section 3 of this report.

e. Generation Additions

The 350 MW Cenpower power plant is expected to come on line during the end of second quarter 2018.

f. Transmission Additions

The following transmission system reinforcements are expected to be commissioned into service in 2018 and thus modeled in the load flow case:

Transmission Lines

- New 330 kV, Kumasi – Kintampo –Tamale – Bolga II.
- 225 kV Bolga II-Ouagadougou (Paga) transmission line.
- Asawinso – Juabeso - Mim 161 kV transmission line Project.
- 330 kV, Double Circuit Aboadze - Dunkwa Transmission line Project.
- 330 kV, Prestea –Kumasi (K2BSP) transmission line Project.
- Upgrade of 161 kV, Volta –A3BSP – Mallam –Achmota Lines.
- 161kV, AKSA – Smelter transmission line Project.

Substations

- A4BSP 330kV (Pokuase).
- Accra Central GIS Station.

5.3.2 Summary of Results for the Steady State Network Analysis

a. **Transmission Losses:** The results of the analysis consider the following scenarios:

- Base Case without exports
- 50MW exports to SONABEL, Burkina Faso in the first half of 2018
- 100MW exports to SONABEL, Burkina Faso from the second half of 2018 when the 330 kV line from Kumasi through Kintampo and Tamale to Bolgatanga is commissioned.

The results of the load flow simulations indicate average transmission losses of 4.7% of system generation for the Base Case when there is no exports. The losses increase to 5.8% when there is an export of 50 MW to SONABEL. The increase in losses can be attributed to the relatively low 161 kV transmission network capacity in the north and the lack of adequate reactive power support.

When the 330 kV line is commissioned and there is an export of 100 MW to Burkina Faso, the transmission losses reduce significantly to 2.9%. This clearly indicates the positive impact of the 330 kV line on system losses.

b. **Voltage Violations:** For the first half of 2018 when 50 MW is being exported to Burkina Faso, the results of the load flow analysis show voltage violations in Kumasi (148 kV) and its surroundings. This could be attributed to the exports, poor customer-end power factors and inadequate reactive power compensation. It has been identified that poor voltages in Kumasi and its environs due to inadequate dynamic voltage support capabilities contribute significantly to higher system losses.

   The analyses indicated a significant improvement in system voltages in Kumasi (i.e. from 148 kV to 163 kV) with the commissioning of the 330 kV transmission expansion projects.

c. **High Generation in the Eastern:** With 1,944 MW of generation connected on the eastern part of the NITS (i.e. Tema, Akosombo and Akuse generation enclaves), the load flow analyses show overloads of 103% on the Volta–Achimota transmission corridor. This results in significant increases in transmission system losses. Furthermore, a contingency on any of the lines in the corridor results in overloads of up to 133% on adjacent circuits and could lead to the cascaded tripping of lines in the corridor. This situation is expected to worsen with the coming into operation of the 350 MW Cenpower Plant in the second quarter of 2018.

d. **High Western Generation and overload on Takoradi-Tarkwa-Prestea Corridor:** The maximum western generation currently is 860 MW made up of TAPCo, TICo and Ameri Power Plants all located in the Aboadze Generation Enclave.

   The power flow 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 overloads on adjacent lines. It also results in low voltages in the Western corridor. However, with the 330 kV Aboadze – Kumasi circuit and the A4BSP Substation in service (second half of 2018), evacuation capacity and overall system reliability increases. In this case, a single contingency does not lead to overloads on adjacent circuits.

e. **Evacuation of Asogli Phase II:** The coming into service of the 330 kV Aboadze – Kumasi lines reduces the loadings on the 330 /161 kV auto transformers at Volta. This is expected to allow for the full evacuation of the 360 MW Asogli Phase II.

f. **System Stability Requirements:** To ensure stability of the NITS in normal operating conditions, the following minimum locational generation requirements are to be met at all times:

- 300 MW power generation from Aboadze, and
- Three (3) units at Akosombo GS
- Two (2) Bui (at peak when there are exports to Sonabel)

5.4 Impact of Transmission Network Expansion Projects – Second half of 2018

There are a number of transmission expansion projects currently ongoing which are expected to be commissioned into service during the second half of 2018. The projects are listed below:

- ✓ **Volta – Achimota – Mallam Transmission Line Upgrade Project:** 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. This is necessary to ensure the evacuation of generation from the new thermal power plants in Tema, namely Karpower (225 MW), Sunon-Asogli Phase II (360 MW) and the Kpone Thermal Power Plant (KTPP - 200 MW). The Project would increase transfer capacity to Accra Central GIS station to enable the injection of high voltage power close to the central business district of Accra. This would also significantly reduce system losses.
- ✓ **Aboadze – Prestea - Kumasi 330 kV Transmission Line Project:** This would improve upon bus voltages in Kumasi and adjacent substations and consequently reduce overall system losses. The project would allow for increase in power export capacity to Northern region as well as Burkina Faso.
- ✓ **Kumasi – Bolgatanga 330 kV transmission line Project**: The project would primarily allow for the export of up to 150 MW of power to Burkina Faso. It would also improve upon the supply capacity and reliability to the northern region of Ghana.

- ✓ **Construction of A4BSP 330 kV substation at Pokuase** 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. It would also allow for the reliable evacuation of the 360 MW Sunon Asogli Phase II Plant.
- ✓ **Construction of 3x125 MVA GIS station at Accra Central:** The station would supply Power to the Central Business District of Accra to meet its growing demand and also clear the overload on the Achimota and Mallam stations which supply power above the station's firm capacity.
- ✓ **Construction of 2x66 MVA Bulk Supply Point at Afienya:** The project is expected to improve upon supply reliability to Ghana Water Company's pumping station at Dodowa. It would also reduce the loading on the New Tema substation and increase supply reliability to Afienya and its environs.

5.5 Load Flow Analyses for Second Half 2018

The load flow analyses seek to analyze the impact the commissioning of the above ongoing project would have on the NITS.

a. Transmission Losses.

The results show significant reduction in transmission system losses from an average of 143.6 MW representing 5.8% of generation to 73.1 MW or 2.9% of scheduled generation.

b. Bus Voltages

Bus voltage across the network improved significantly, no violation is recorded even with increase 100 MW export to Burkina Faso. Table 25 compares critical bus voltages before and after the commissioning of the network expansion projects.

Table 25: Bus Voltage showing voltages for first and second half of 2018

Bus No.	Base kV	Simulated kV	
		Q1-Q2 2018	Q3-Q4 2018
ACHIMOTA	161	155.54	161.95
DUNKWA	161	149.98	162.3
OBUASI	161	150.36	162.99
KUMASI	161	148.09	163.24
ASAWINSO	161	147.29	160.97
NEW OBUASI	161	149.98	162.92
MALLAM	161	152.98	159.61
ANWOMASO	161	147.30	164.59
KADJEBI	69	66.61	69.00

c. Transmission line loadings

The overload situation on the Volta – Achimota transmission lines corridor is eliminated. The loading on the 330/161 kV auto transformers at Volta is significantly reduced due to the consumption of power directly on the 330 kV system at Pokuase (A4BSP). The relief on the auto transformers makes it possible to evacuate the entire 360 MW SAPP Phase II Plant.

d. Contingency Analyses

➢ **Loss of 330 kV Volta –Aboadze Line**

An outage on the 330 kV Volta –Aboadze line results in overloads on the 330/161 kV auto transformers at Volta, however with the Pokuase (A4BSP) station in service the overload situation clears.

➢ **Loss of 330 kV Tamale – Bolgatanga transmission line**

The loss of 330 kV Tamale – Bolgatanga II transmission line with an export of 100MW to Burkina Faso results in the non-convergence of the load flow case due to voltage collapse. Export has to be reduced to 60 MW to stabilize the grid.

➢ **Loss of 161kV Aboadze –Tarkwa transmission line**

Under a high generation from the west, the loss of the Aboadze –Tarkwa line results in an overload on the Takoradi – Tarkwa line (102%) and a high loading on the 330/161 kV Auto transformers (92%).

e. Radial Lines and Single Transformer Stations

The following lines in the NITS are presently radial and therefore the customers served by these lines suffer complete blackout anytime the lines are out-of-service. For the single transformer stations, customers served by these transformers also suffer complete blackout anytime they go out-of-service. The single transformer stations are as indicated in the Table below.

<u>Radial Lines</u>

- 161 kV Takoradi – Esiama Line
- 161 kV Bogoso – Akyempim Line
- 161 kV Bolgatanga – Zebilla – Bawku Line
- 161 kV Tamale –Yendi Line
- 69 kV Asiekpe – Sogakope Line

- 69 kV Asiekpe – Ho – Kpeve – Kpandu Kadjebi Line

<u>Single Transformer Stations</u>

- Sogakope
- Yendi
- Esiama
- Dunkwa
- Konongo
- Ayanfuri
- Obotan
- Mim
- Buipe

5.6 Dynamic Simulations

To determine the stability of the grid under various contingency conditions, dynamic simulations are performed on the contingencies. To assess the impact of the 330 kV Kumasi – Kintampo – Tamale – Bolgatanga line on system stability, the simulations were first performed without and with the 330 kV backbone.

The stability simulations are performed for various likely network contingencies on the grid to observe the impact on the grid and to give an indication of the robustness and stability of the grid. The contingencies considered include;

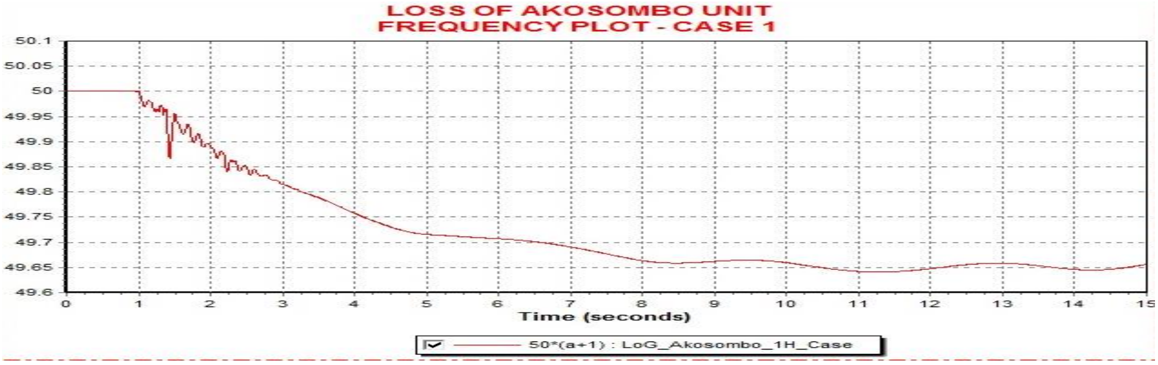
i. Loss of an Akosombo unit for the first and second halves of the year
ii. A three phase fault on one of the Achimota-Accra East lines cleared after 6 cycles by tripping of the same line in both study scenarios.
iii. A three phase fault on the coastal 330kV line which is cleared by tripping of the line after six cycles in both cases.

Loss of an Akosombo unit

Frequency Plots

The loss of one Akosombo unit results in a reduction in system frequency which decays and settles at 49.65 Hz. This does not result in any underfrequency relay trippings. The Plot is as shown in the figure below. The rotor angle plots also show that the resulting oscillations are well-damped.

Figure 12: Case 1 – Frequency plot for loss of an Akosombo unit



- **Three phase fault on one of the Achimota - Accra East lines**

A three phase fault on one of the 161kV Achimota-Accra East lines was simulated and the impact monitored on the machine relative rotor angles and the machine speeds. This fault was cleared after 6 cycles (120ms). The fault caused an instant increase in the speeds of all connected machines with the Akosombo and Bui hydro units registering the greatest speed deviation due to their sizes. The Akosombo machines registered higher speed deviations than Bui due to their proximity to the fault. The deviation in speed continued for more than 15s after fault clearing before settling at speeds lower than the initial speed.

The relative rotor angles plots showed poorly damped oscillations with wider amplitudes. It is noted that the fault occurred in an area of the grid with a lot of generators, heavily loaded lines and higher power demands.

Figure 13: Case 1 – Speed deviation of machines on the grid for 161kV three phase fault

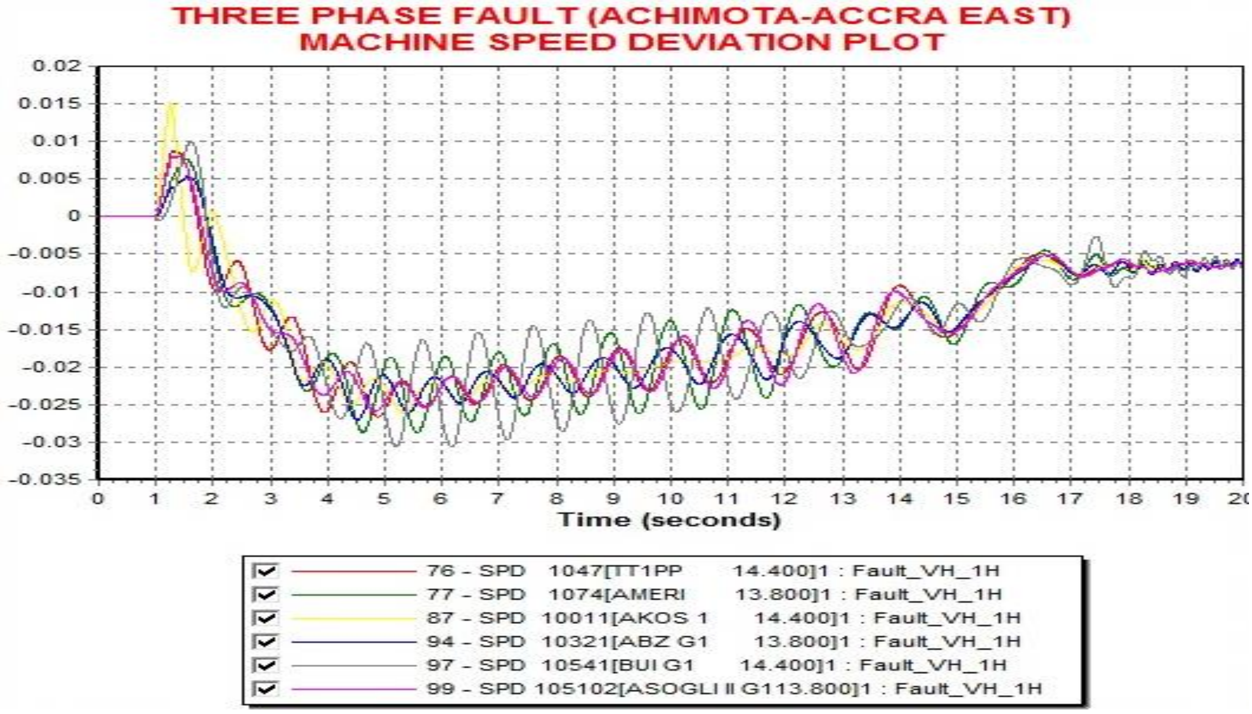
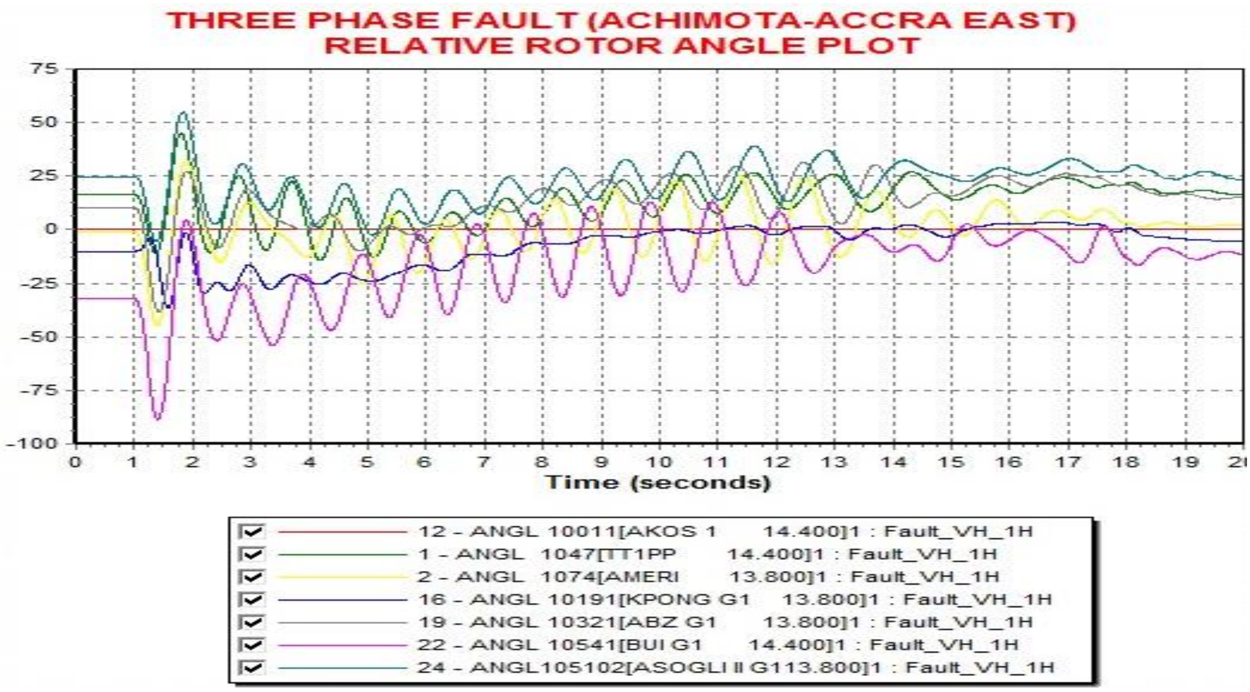


Figure 14: Case 1 – Relative rotor angles of machines on the grid for 161kV three phase fault



➢ ***Three phase fault on the 330kV coastal line from Aboadze to Volta***

Simulation of a three phase fault on the 330kV Aboadze-Volta line cleared after 6 cycles showed a variation in the rotor angles of the machines with adequate damping and a stable operating power system. The impact of the loss of this lightly loaded line does not result in any instability as seen in the relative angle and speed plots below.

Figure 15: Case 1 – Relative rotor angles of machines on the grid for 330kV three phase fault

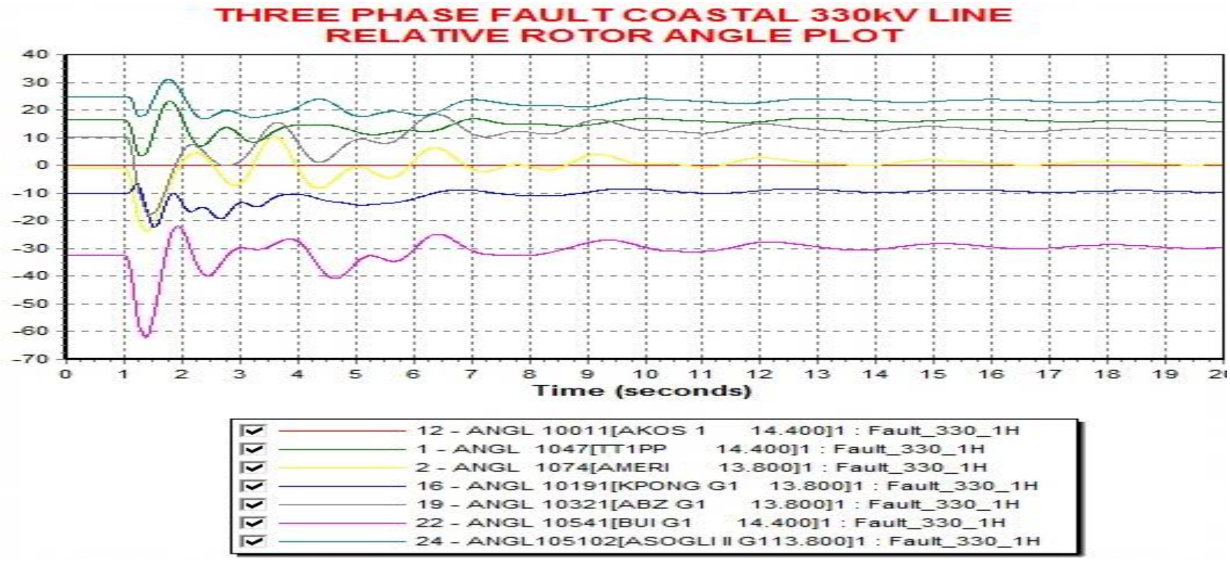
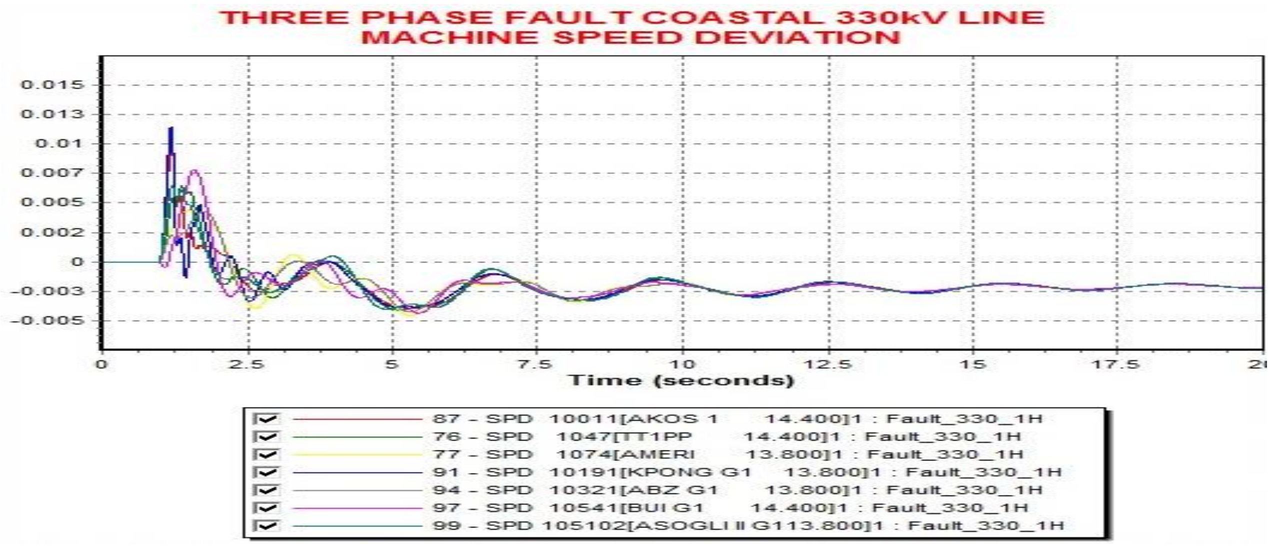


Figure 16: Case 1 – Speed of machines on the grid for 330kV three phase fault



CASE 2: SIMULATIONS FOR SECOND HALF OF THE YEAR

The above simulations were repeated with the 330kV lines in service and an export of 100 MW to SONABEL, in Burkina Faso.

- ***Loss of an Akosombo unit***

Just as simulated in case 1, the Akosombo unit is switched out of service and the impact on the grid frequency and machine rotor angles is monitored.

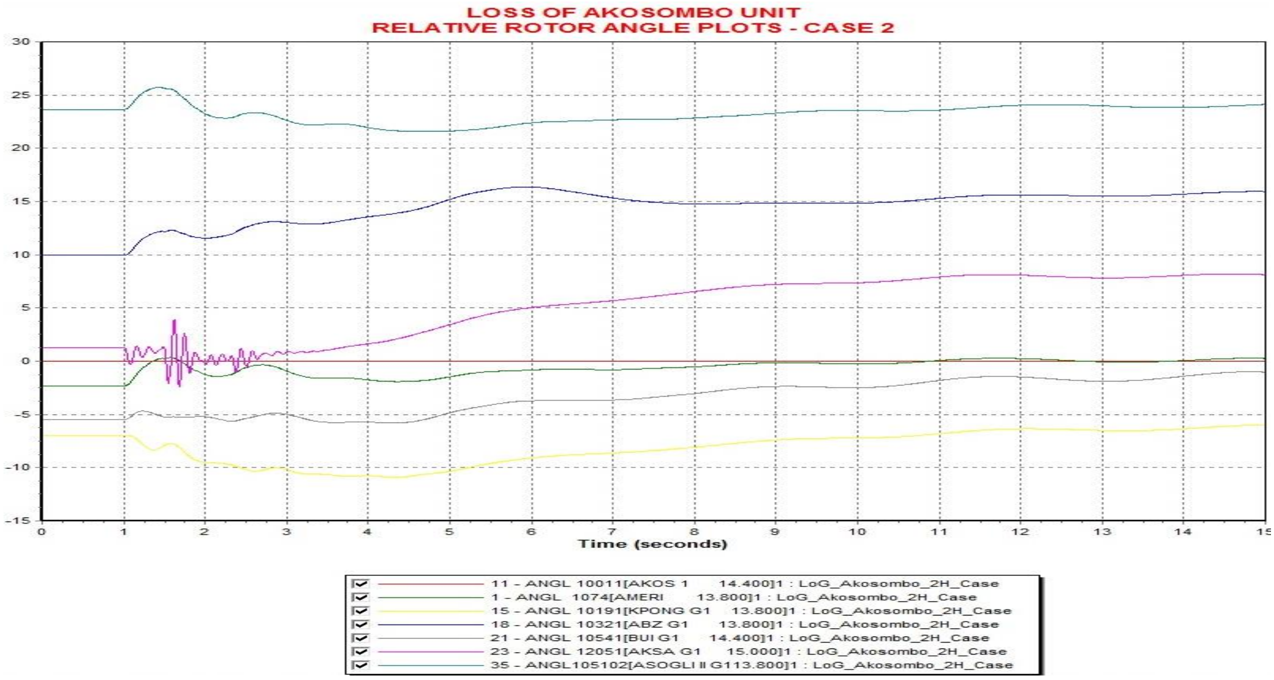
Frequency Plots

The plot below shows an improvement in frequency performnce from 49.65 Hz to 49.68 Hz (higher than in case 1).

Figure 17: Case 2 – Frequency plot for loss of an Akosombo unit

The plot for the rotor angle also shows well-damped oscillations.

Figure 18: Case 2 – Relative rotor angle plots for loss of an Akosombo unit



➢ ***Three phase fault on one of the Achimota-Accra East lines***

Compared to the previous Case, this case shows a significant reduction in the oscillations.

The amplitudes of the oscillations are also smaller as compared to the case 1 attributable to the strengthening of the grid by the 330kV backbone.

Figure 19: Case 2 **–** Speed deviation of machines on the grid for 161kV three phase fault

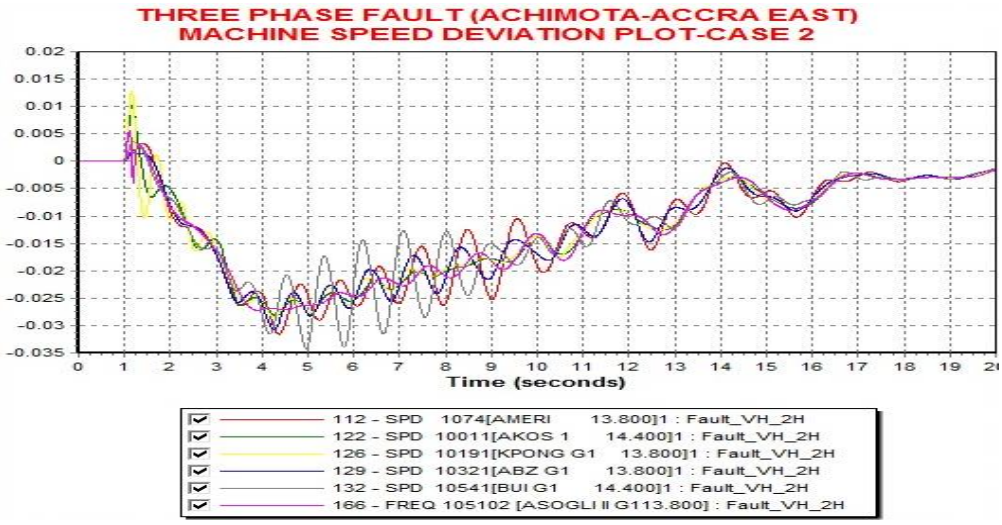
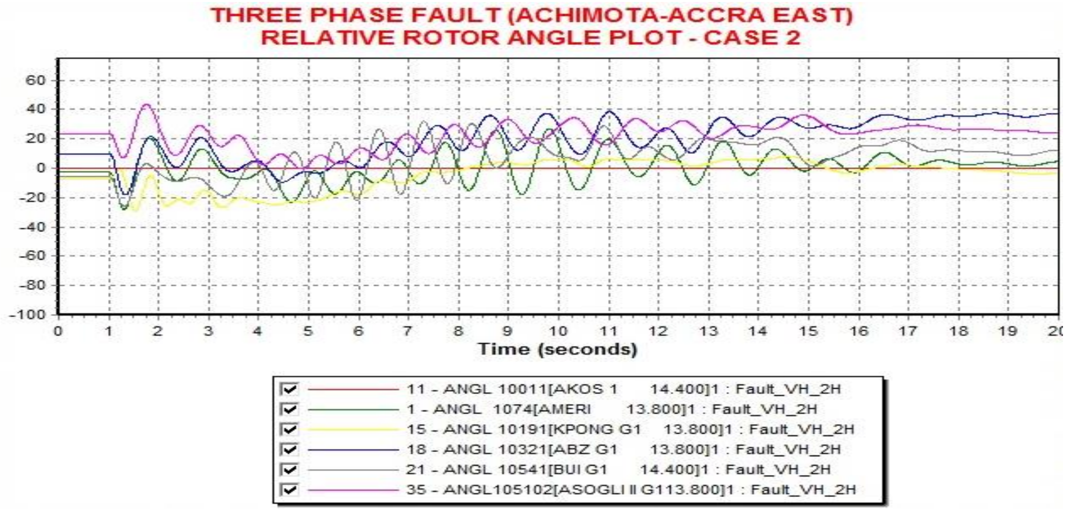


Figure 20: Case 2 – Relative rotor angles of machines on the grid for 161kV three phase fault



- ***Three phase fault on the coastal 330kV line from Aboadze to Volta***

Compared to case 1, the impact of this loss does not affect the network stability. There are no observed oscillations with adequate damping following the observed perturbations.

The final machine speeds are reduced but not as much as in the case 1 with greater oscillations.

Figure 21: Case 2 – Relative rotor angles of machines on the grid for 330kV three phase fault

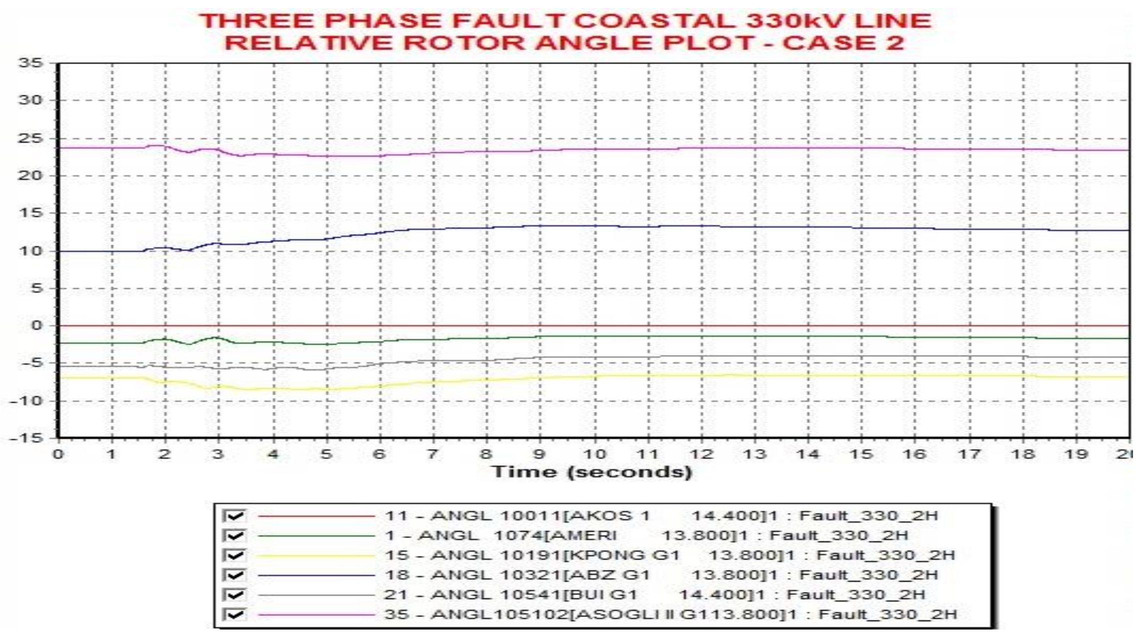
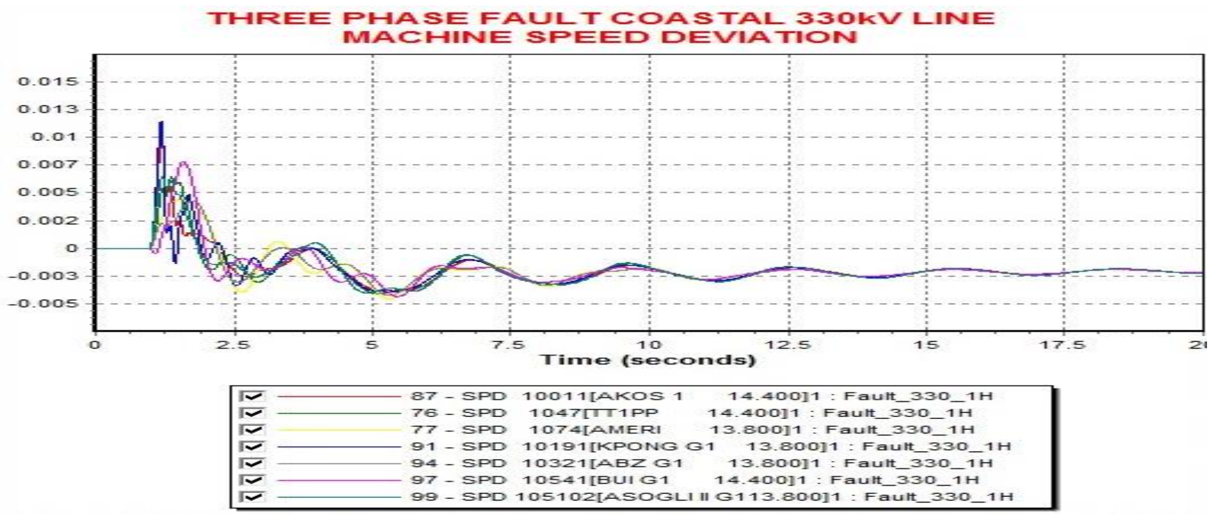


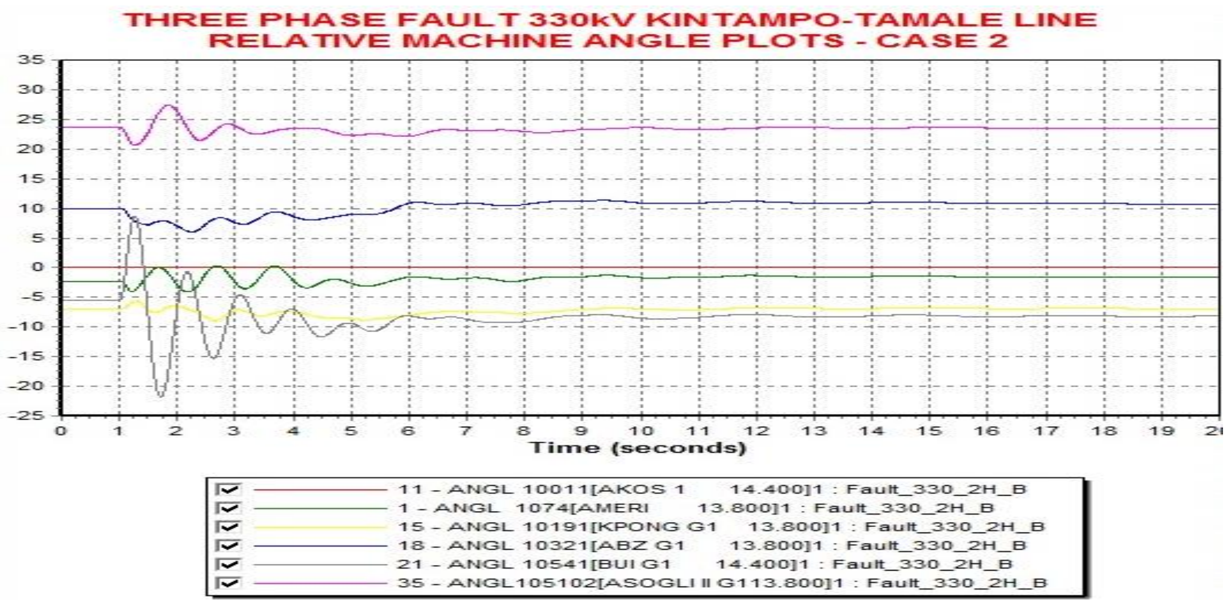
Figure 22: Case 2 – Speed deviation of machines for a 330kV three phase fault



➢ ***Three phase fault on the coastal 330kV line from Kintampo to Tamale***

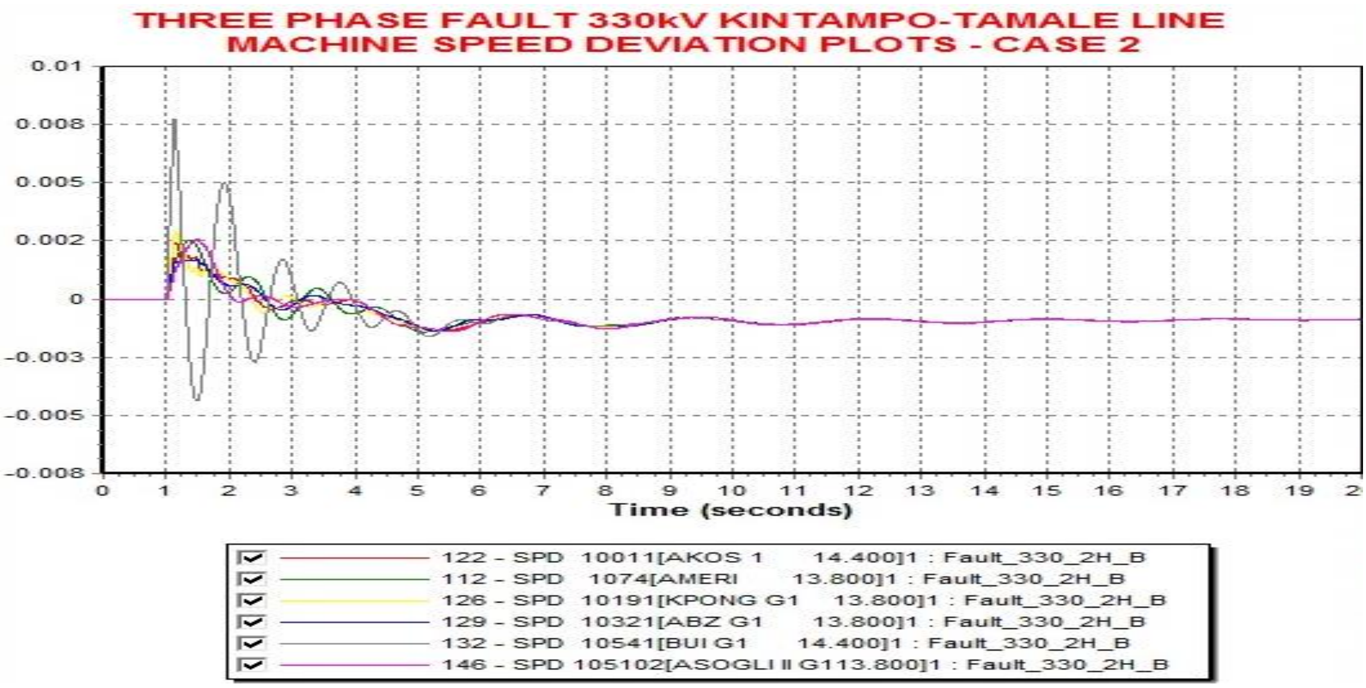
With an export of 100 MW of power to SONABEL, a contigency on the 330kV line from Kintampo to Tamale was performed. A three phase fault was simulated on this line and cleared after 6 cycles. The impact of the loss was greatly seen in the wider amplitude of oscillation observed on the Bui hydro machine. There is however adequate damping which brings the network conditions to normalcy.

Figure 23: Case 2 – Relative rotor angles for a 330kV three phase fault in the north



The machine speed deviation plots below show the fluctuations which settle after a few seconds but at a reduced speed. There are no observed oscillations and the network conditions appear stable.

Figure 24: Case 2 – Speed deviation of machines for a 330kV three phase fault in the north



6 POTENTIAL SUPPLY CHALLENGES IN 2017

Due to the low inflow into the Akosombo and Bui hydro dams in 2017 and the consequent low reservoir elevations, some supply challenges could be experienced in 2018 if adequate fuel supply arrangements are not made in February and March when major works are planned on the domestic gas delivery systems.

6.1 Managing the Hydro Risk

With the current low head water levels in Akosombo and Bui dams, it will be prudent to continue the conservative dispatch of the hydro plants to ensure that the reservoirs are not drawn down below their minimum operating levels to guarantee sustainable operations in the coming years.

6.2 Thermal Fuel Supply Risk

Gas supply inadequacy remains one of the major risks to reliable electricity supply in Ghana. Although, installed generating capacity is high, inadequacy and/or unavailability of fuel to run the thermal units has rendered some thermal plants inoperable.

The Ghana National Gas Company Ltd. and the Tullow Ghana Ltd. have scheduled to carryout planned works between February and July, 2018 as follows:

February 1 – 21, 2018

<u>Ghana National Gas Company and ENI Ghana</u>

- Tie-in of OCTP Sankofa Gas Pipeline to Ghana's National Gas Transmission System (NGTS) at Sanzule;
- Tie-in of NGTS with the West African Gas Pipeline system at Aboadze;

<u>Tullow Ghana Ltd.</u>

- Preparation for turret remediation works on Jubilee FPSO.

A 19-day outage in March 2018

<u>Tullow Ghana Ltd.</u>

- Turret remediation works

To forestall fuel supply deficits and possible electricity supply disruptions to consumers during these maintenance periods, there is the need to make advanced arrangements for adequate LCO storage at both Tema and Takoradi

For the two major maintenance periods in February and March, the estimated fuel quantity and cost are as presented below:

Table 26: Bus Voltage showing voltages for first and second half of 2018

Month	Qty of LCO (bbl)	Total LCO - Cost @ US$ 70/bbl (MUSD)
February	849,945.00	59.5
March	941,011.20	65.9

It is also noted from the 2018 supply scenario and probably for subsequent years that the share of hydro supply has been dwindling with much of the supply coming from thermal plants which are predominantly gas-based. The danger this portends is that, any major disruptions in gas supply, could throw the country into major power crisis. It is therefore imperative that the Companies in the Gas Supply Chain, Tullow, ENI, GNPC, Ghana Gas, BOST and others collaborate strongly with the power supply companies to ensure effective planning and coordination.

6.3 Supply Reliability

6.3.1 Radial lines

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

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

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

6.3.2 Single Transformer Stations

Similar to single circuit radial lines, consumers supplied by single transformer substations also suffer low level of supply reliability. Consumers facing such challenges are those in Akosombo Township, VRA Township at Akuse, Yendi, Sogakope, Esiama etc. since these townships are supplied via single transformer stations.

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

6.4 Power Evacuation

There are also 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 as 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

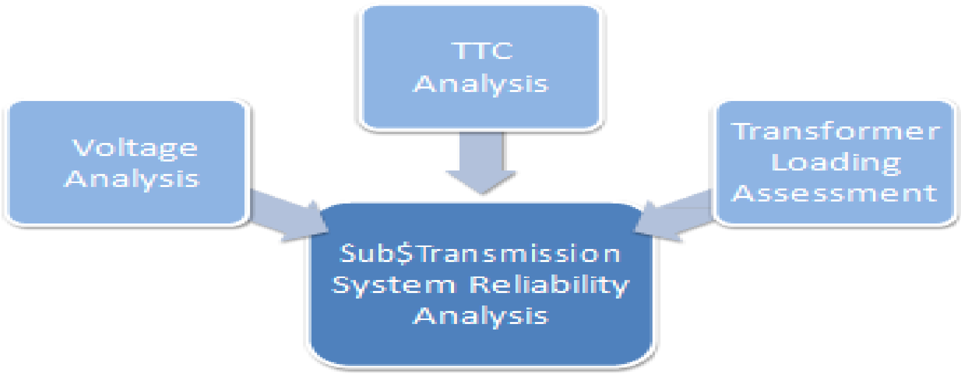
7.1 ECG Network Reliability Assessment

Reliability of supply within the sub – transmission and 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 2017.

7.1.1 Constraints Identified in the 2018 ECG Reliability Study for Selected Areas

ECG, performs three separate analyses to assess the reliability of the sub-transmission system. (See Figure 2.5). First, a Total Transfer Capability (TTC) analysis is carried out to determine the adequacy of uninterruptible sub-transmission capacity to deliver power to the primary substations. The TTC analysis is also used to assess if interruptible sub-transmission capacity will be required to meet any portion of the demand and/or if any demand will be unmet due to inadequate sub-transmission transfer capability.

Figure 25: Aspects of Sub-Transmission System Reliability Analysis



A power flow analysis is then performed to determine voltages at all substations and identify if ECG's reliability criteria are met at each primary substation. As a general rule, if substation voltages deviate significantly from their nominal levels, they can cause instability, and eventually lead to a blackout. Voltage deviations can also damage or destroy customer equipment, and low voltages significantly reduce the ability to transfer power within the sub-transmission network. ECG's reliability criteria require substation voltages at 33 kV to be regulated within a ± 9.10 % tolerance band of their nominal ratings. Therefore, the power flow analysis determines if any substation voltages are outside the tolerance band.

Finally, the adequacy of transformer capacity is assessed at each of the primary substations to support connected peak load. At each primary substation, one or more transformers step down voltage from the 33 kV sub-transmission level to 11 kV for the distribution network. Adequate transformer capacity is important for the reliable operation of the distribution system. ECG reliability criteria specify the loading of transformers under normal operating conditions to 70% of their name plate capacity, therefore under normal operating conditions a transformer loaded at 70% of its rating is considered fully loaded. Under contingency or emergency conditions, transformer loading up to 120% of the nameplate capacity is permissible, but for short duration only until operators can restore the system to normal conditions. These reliability criteria are then used to assess transformer loading at the primary substations.

The sub – transmission reliability analysis have been performed for the four (4no.) major load centers – Accra, Kumasi, Tema and Takoradi to identify constraints of low voltages, overloads on transformers and sub-transmission lines during firm and non – firm assessment for which projects are currently underway to mitigate them.

7.1.2 Sub-Transmission and Distribution Constraints

Although there have been some investments in the Sub-transmission network, the reliability assessment of the network according to ECG shows that these investments are either delayed or will not be enough to ensure uninterruptible sub-transmission service to all and to assure reliable supply at areas identified in this study as not meeting the ECG's Service Standard under N-1 contingency.

To improve upon the existing reliability performance of these areas, a number of interventions and ongoing projects that have either been just completed or expected to be completed within the shortest possible time to meet the ECG 2018 projected demand. The details of these Projects are outlined in Appendix C.

7.2 NEDCo Distribution Network

The Northern Electricity Distribution Company (NEDCo) operates a distribution network that 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, excluding Cross border energy supply was 1,234.05 GWh in 2017 and this has been projected to reach a value of 1,328.97 GWh by the end of 2018, an increase of about 7.7 % over the period.

There are however some pertinent constraints in the NEDCo distribution network which require to be addressed to guarantee reliability and quality of supply to consumers.

7.2.1 NEDCo Distribution Constraints

NEDCo is faced with capacity and voltage constraints within some sections of its distribution infrastructure. These constrains constitute the main bottlenecks to electric power delivery in the NEDCo territory. The main constraints can be classified as below:

Voltage Constraints: Severe voltage drops on heavily loaded and long distribution networks is a limiting factor to electricity supply within NEDCo as customers are unable to use the national grid especially during peak hours. Customers result to alternative sources of supply such as generators during peak periods.

Capacity Constrains: During the extension of electricity to the NEDCo Operational area, the customer density at the time was very low. This influenced the infrastructure capacity design decisions for electricity extension. Currently, significant kilometers of underground cables and conductors are loaded to critical limits thereby impeding the addition of loads to the network.

Reliability constraints: Another limiting factor to electricity supply is reliability constraints as a result of operating long radial lines and frequent breakdown of obsolete distribution infrastructure.

Details of the main constraints at bulk supply points, primary substations, sub-transmission as well as distribution networks are discussed below.

7.2.2 Sub-Transmission and Distribution Lines:

Current status

NEDCo serves a large geographical area mainly by long radial sub-transmission lines and distribution feeders. Due to the ongoing Self-Help Electrification Project (SHEP), these sub transmission and distribution lines have been extended beyond their technically acceptable limits. Feeders from Techiman currently serve Ejura, Atebubu and beyond. Also feeders from Tamale serve Dalun and beyond as well as Yendi feeders serving Bimbilla, Kete-Krachie and beyond are some of the examples of such long radial lines.

Actions

The Ghana GRID Company is currently constructing a new 161/35.4kV BSP at Berekum to improve quality of supply to Berekum and its environs. This project is expected to be completed in 2018. Also, NEDCo has initiated actions to construct a 20MVA, booster station at Bimbilla to improve the supply quality to customers along the Bimbilla- Kete-Krachie line. This project is anticipated to be completed in 2019.

NEDCo is also in dialogue with GRIDCo for the construction of a new BSP at Atebubu in the Techiman operational area to improve the supply quality to the Yaji-Kwame Danso area which is about 200km from the current supply source (Techiman BSP).

NEDCo has over 5,800 distribution transformers in service, some of which are overloaded. In 2018, three hundred and seventy-three (373) distribution transformers are expected to be upgraded or have additional transformers installed to provide relief to existing customers and to enable the connection of additional customers. In the same period, about 150km of low voltage lines are expected to be upgraded.

7.2.3 Primary Substations Constraints

Current status

NEDCo currently has fifteen (15) primary substations including a booster station. All the primary Substations in NEDCo operational area are single transformer substations which poses reliability constraints. The 11kV distribution networks within major cities in NEDCo operational areas like Tamale, Techiman, Sunyani, Bolga and Wa are critically loaded and have been extended beyond their technically acceptable limits. Also, the Bawku and Navrongo primary substations have a number of obsolete switchgear.

Actions

NEDCo is embarking on a project which is aimed at replacing these pieces of obsolete infrastructure. The Contract has already been awarded but this project has delayed due to funding challenges. The new completion date for his project is December 1, 2018.

Also, NEDCo is in the process of securing funding to Construct 6 no. Primary substations as follows:

1. 1X10MVA 34.5/11kV substation at Banvim in Tamale
2. 1X10MVA 34.5/11kV substation at Islamic in Tamale
3. 1X10MVA 34.5/11kV substation at Fuo in Tamale
4. 1X10MVA 34.5/11kV substation at Fiapre in Sunyani
5. 1X10MVA 34.5/11kV substation at Abesim in Sunyani

1X10MVA 34.5/11kV substation at Amangoase in Berekum (Sunyani)

8 OVERVIEW OF MEDIUM-TERM SUPPLY: 2018 - 2022

In this chapter, we present medium-term (2019 - 2023) peak demand and energy consumption forecast to serve as a guide for power system investment planning. Typically, it takes an average of four years for power plant projects to transition from conception through funding arrangements, detail design, construction to commissioning and commencement of commercial operation. This section therefore provides an outlook for generation and transmission system requirements for the next five years (2019 – 2023) to enable adequate and timely measures to be put in place to ensure security of supply in the Ghana Power System over the medium term.

In the past, lack or delays in the implementation of Energy Supply Plan recommendations for generation expansion projects to match forecast growth in demand have culminated in energy crises in the country, which have had adverse impact on economic growth of the country.

8.1 Demand Outlook

Projected demand for electricity over the period is based on GRIDCo's 2018 - 2027 load forecast study. It covers natural growth in domestic demand over the period and some Spot Loads. The expected spot loads for the period are as follows:

- VALCO demand is expected to increase from 2 pot-lines in 2018 and 2019 to 3 pot-lines in 2020 and the entire 5 pot-line operation is assumed from 2021 onwards;
- Mines:
    - Newmont Mines, Ahafo - demand is expected to increase by 10 MW in 2019 and an additional 12.5 MW in 2020.
    - Azuma Mines - 23 MW by 2020 at Yagha (50km North West of Wa);
- Potential Exports:
    - Burkina Faso is expected to be at 150 MW by 2019;
    - Mali is expected to be at 50 MW by 2021, increasing to 100 MW by 2024

Total electricity consumption of the Ghana power system including power exports to Togo, Benin, Burkina Faso and Mali (from 2019) is projected to increase from 19,486 GWh in 2019 to 25,680 GWh in 2023 at a Compound Annual Growth Rate (CAGR) of approximately 7.1 %. The system peak demand is projected to increase from 2,980 MW in 2019 to 3,919 MW in 2023.

The details of the projected demand for 2019 to 2023 are illustrated in Tables 26 and 27.

Table 27: Projected Energy Demand (GWh) (2019- 2023)

	2019	2020	2021	2022	2023
Domestic	14,623	15,531	16,396	17,396	18,425
VALCO	2,909	3,881	4,845	4,845	4,845
Exports	1,235	1,235	1,580	1,580	1,580
Transmission Losses +Network Usage	719	773	727	777	831
TOTAL	**19,486**	**21,420**	**23,548**	**24,598**	**25,680**

Table 28: Projected Peak Demand (MW) (2019- 2023)

	2019	2020	2021	2022	2023
Domestic	2,366	2,511	2,674	2,837	3,005
VALCO	332	443	553	553	553
Exports	183	183	233	233	233
Transmission Losses +Network Usage	100	108	116	122	127
TOTAL	**2,980**	**3,245**	**3,576**	**3,745**	**3,919**

8.2 Projected Supply Outlook

The power supply outlook was prepared considering the existing and committed generation capacity additions. The assessment of generation adequacy is based on ensuring that sufficient generation resources are available to meet the forecast demand plus a 25% required capacity reserve margin.

8.3 Existing Generation

The existing power supply facilities are made up of hydro, thermal and renewable energy sources as shown in Chapter 4. A detailed breakdown of projected demand versus expected supply from the existing generation resources is as shown in table 35.

The following assumptions were made for Hydro Power Generation:

- **Akosombo & Kpong GS.** Provision was made for the recovery of the Akosombo reservoir. A maximum of four (4) units were assumed over the period 2018 - 2020, five (5) units in 2021. From 2022 onwards, all the six (6) units are expected to be available to support peak demand. Akosombo & Kpong are assumed to generate a total of 4,200 GWh per annum over the period 2018-2020 and 4,600 GWh in 2021. It is assumed that from 2022 onwards, the firm generation output of 5,300 GWh per annum would be produced by Akosombo and Kpong Plants.

- **Bui Generating Station.** Bui hydro is assumed to produce about 756 GWh of electricity/year from 2018. Bui GS is assumed to generate an average of 230 MW during peak period to support peak demand.

As indicated under Demand and Supply in Table 28, in order to meet the target of 25% capacity reserve, an additional generation capacity of 209 MW will be required in 2020. This requirement increases to 696 MW by 2023. It is important to note that these additions are only required to meet the reserve margin requirement of 25% since there is still a reserve margin of 6% in 2023 without the addition of new generation capacity.

Table 29: Projected Demand Versus Supply (existing) balance (2019- 2023)

		Projected				
		2019	**2020**	**2021**	**2022**	**2023**
Projected Demand (MW)	**CAPACITY DEMAND(MW)**					
	Domestic	2,366	2,511	2,674	2,837	3,005
	VALCO	332	443	553	553	553
	Export	183	183	233	233	233
	Transmission Losses +Network Usage	100	108	116	122	127
	TOTAL PROJECTED DEMAND	**2,980**	**3,245**	**3,576**	**3,745**	**3,919**
Existing Generation	**TOTAL PROJECTED DEMAND+25% Reserve**	**3,725**	**4,056**	**4,470**	**4,681**	**4,898**
	CAPACITY SUPPLY (MW)					
	Hydro					
	Akosombo	600	600	750	900	900
	Kpong	105	105	140	140	140
	Bui Hydro Plant	230	230	230	230	230
	Total Existing Hydro	**935**	**935**	**1,120**	**1,270**	**1,270**
	Thermal					
	Existing Generation					
	T1	300	300	150	150	320
	T2	320	320	320	320	320
	Takoradi 3 (T3)	-	-	-	-	-
	TT1PP	100	100	100	100	100
	CENIT	100	100	100	100	100
	200 MW Sunon-Asogli (Phase 1)	180	180	180	180	180
	TT2PP	70	70	70	70	70
	KTPP	200	200	200	200	200
	VRA Solar Power Plant Project-Phase 1	2.5	2.5	2.5	2.5	2.5
	AMERI	230	230	230	230	230
	Karpower	450	450	450	450	450
	AKSA	220	220	220	220	220
	Sunon-Asogli (Phase 2)	360	360	360	360	360
	Cenpower	340	340	340	340	340
	BXC Solar	20	20	20	20	20
	Meinergy	20	20	20	20	20
	Total Existing Non Hydro Generation	**2,913**	**2,913**	**2,763**	**2,763**	**2,933**
	TOTAL AVAILABLE GENERATION	**3,848**	**3,848**	**3,883**	**4,033**	**4,203**
	Surplus/Deficit	**122**	**(209)**	**(587)**	**(648)**	**(696)**
	Reserve Margin Less Solar Plants (%)	**28%**	**17%**	**7%**	**7%**	**6%**

8.4 Committed Generation Projects

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

- **AKSA.** AKSA is currently operating at 220 MW and will increase to 340 MW
- **VRA Solar Power Plant.** The VRA has secured funding to construct a 12 MWp Solar power plant in the Upper West Region of Ghana. The plant is expected to be on line by 2019.

- **Marinus Energy.** This is a 26.5 MW thermal plant to be located at Atuabo in the Western Region. The plant is expected to come on line by 2019.
- **Amandi Energy Limited.** This is a 192 MW combined-cycle power plant expected to be commissioned by 2019. The plant will be located in Aboadze.
- **Early Power.** This is a 400 MW power plant to be located at Tema expected to be commissioned in 2019.
- **Jacobson Jelco.** This is a 360 MW combined-cycle power plant to be located at Aboadze and **e**xpected to be commissioned in 2021.
- **Rotan Power Limited.** This is a 634 MW combined-cycle power plant. 300 MW is expected to be commissioned in 2023 and the rest of the 334 MW is expected to be commissioned in 2025.
- **T3**. This is a 132 MW combine cycle plant which is currently out of service due to damage to the gas turbine engines. It is expected that the engines will be refurbished/replaced by 2020.

8.5 Other Potential Generation Projects

A number of other generation projects which are also likely to come on line within the planning period are presented below. These projects are however not considered in the medium-term supply scenario because of some uncertainties about the projects.

- **Bui Solar Power Enclave.** Bui Power Authority is collaborating with a number of investors to develop up to 250 MWp Solar PV. Currently, Feasibility Studies have been completed for 100 MWp of the generation capacity. Further, grid impact study is ongoing to confirm the capability of the grid to evacuate all the 250 MWp. The first 100 MWp is planned for 2019. The remaining 150 MW is expected to come on line by 2020.
- **Upwind Ayitepa Limited.** This is a 225 MW wind power project expected to come on line in 2020. Grid impact study has been completed.
- **APSD Biomas Project.** This is a project that seeks to add 65 MW biomas capacity to the grid and is located in the Brong Ahafo Region. The project is expected to come on line in 2019.
- **Eleqtra.** This is a 50 MW wind power project expected to come on line in 2020.

The demand and supply balance for the existing and committed generation capacity is shown in Table 29.

Table 30: Projected Demand Versus Supply (+committed generation) Balance (2019- 2023)

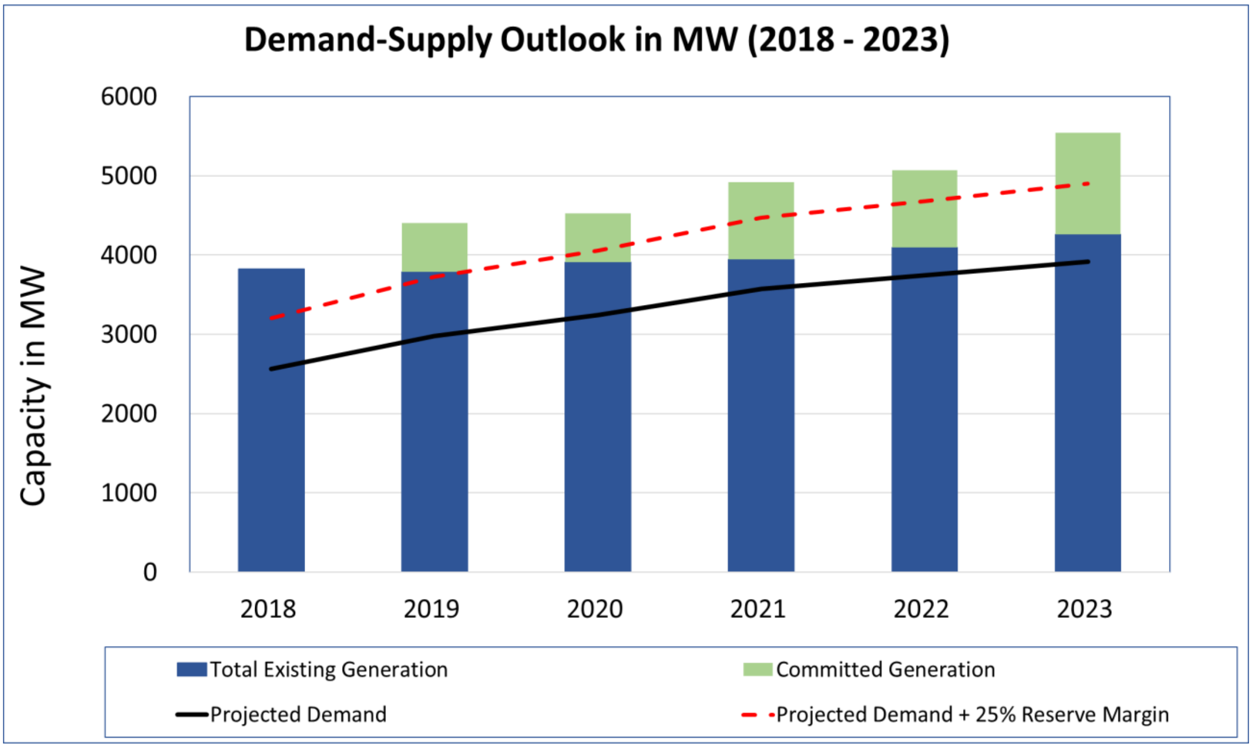
	Projected				
CAPACITY DEMAND(MW)	**2019**	**2020**	**2021**	**2022**	**2023**
Domestic	2,366	2,511	2,674	2,837	3,005
VALCO	332	443	553	553	553
Export	183	183	233	233	233
Transmission Losses +Network Usage	100	108	116	122	127
TOTAL PROJECTED DEMAND	**2,980**	**3,245**	**3,576**	**3,745**	**3,919**
CAPACITY SUPPLY (MW)					
Hydro					
Total Existing Hydro Capacity	**935**	**935**	**1,120**	**1,270**	**1,270**
Total Existing Thermal Generation	**2,853**	**2,973**	**2,823**	**2,823**	**2,993**
Total Existing Renewable Generation	**42.5**	**42.5**	**42.5**	**42.5**	**42.5**
COMMITTED GENERATION					
VRA Solar Power Plant	12	12	12	12	12
Marinus Energy	25	25	25	25	25
Amandi Energy Limited	190	190	190	190	190
Early Power	390	390	390	390	390
Jacobson Jelco			360	360	360
Rotan Power Limited					300
Total Committed Generation	**617**	**617**	**977**	**977**	**1277**
TOTAL (Existing + Committed)	**4,447**	**4,567**	**4,962**	**5,112**	**5,582**
RESERVE CAPACITY EXCLUDING SOLAR (%)	**47%**	**39%**	**37%**	**35%**	**41%**

8.5.1 Additional Generation Requirement

As seen in Table 35 and Figure 46, with the deployment of the committed generation capacity, there is adequate generation capacity to meet projected demand. The highest capacity reserve margin recorded over the period is 47% and the lowest generation capacity reserve margin expected over the period is 35% (the required reserve margin is 25%). Hence barring any delays in the realization of these anticipated generation projects, there should be adequate generation capacity to meet medium-term projected power demand.

Most of the additional thermal generation capacity expected over the period will operate on natural gas. It is therefore important to ensure that efforts are made to achieve adequacy in natural gas supply.

Figure 26: Projected Demand Versus Supply balance (2018 - 2023)



8.6 Medium Term Transmission Network Expansion/Upgrade Requirements

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

- Construction of a second 330 kV Prestea - Dunkwa – Kumasi line
- Construction of a second 330 kV Aboadze – A4 BSP circuit
- Construction of a double circuit 330 kV A4BSP to Kumasi line

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

8.6.1 Impact of Siting Generation at Western Part of Accra.

Power flow analyses indicate that siting a 200 MW generation in the western part of Accra (around Winneba) results in a significant improvement in transmission network voltage reliability. It also reduces congestion on the Volta – Achimota transmission corridor. Furthermore, total transmission system losses reduce to 95.1 MW (3.96%) of generation from 106 MW (4.4 %).

Tables 30 to 33 show the load flow results.

Table 31: Comparison of system losses- Generation at Winneba and No Generation

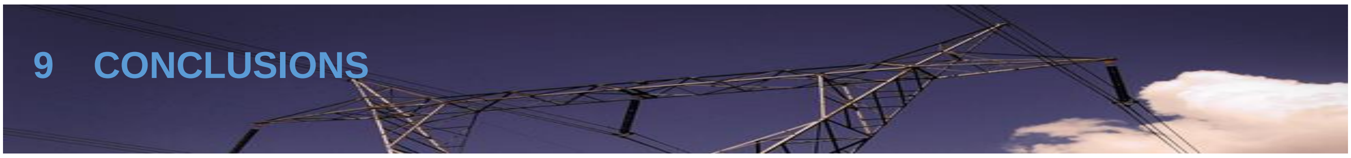
	No Generation	With Generation at Winneba
Losses	106 MW	95.1 MW

Table 32: Comparison of Line Loadings- Generation at Winneba and No Generation

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

Table 33: Comparison of bus Voltages- Generation at Winneba and No Generation

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



9 CONCLUSIONS

.The following conclusions are drawn in respect of the electricity supply and demand plan for 2018:

9.1 Demand and Supply Outlook

a. 2018 total system demand is projected to be 2,523.49 MW, representing a 15.1 % growth over the 2017 peak demand of 2,192.15 MW.

b. The projected energy consumption for 2018 is 16,304.79 GWh of which:

- Hydro supply will be - 4,956.32 GWh representing 30.4% of the total energy supply;
- Thermal supply will be - 11,305.85 GWh representing 69.34% of total energy supply; and
- Renewables supply will be - 42.64 GWh representing 0.23% *of total energy supply.*

c. Total projected energy exports are 671.97GWh for 2018.

d. VALCO is expected to operate on two potlines with projected total consumption of 1,154.19 GWh.

e. There is the need to dispatch Akosombo and Bui Hydro Plants conservatively throughout 2018 to ensure that the two reservoirs are not drawn down below their minimum operating levels to guarantee sustainable operations in the coming years

f. In terms of fuel, the following quantities of the various fuel types are required;

- LCO - 3,000,000 barrels
- Natural Gas - 67,000,000 MMbtu.
- HFO - 455,000 MT
- Diesel - 100,000 barrels

g. In terms of fuel cost, an annual total of approximately 1.0 billion USD is required, averaging a monthly total of some US$ 83.40 Million.

h. To ensure stability of the grid in normal operating conditions, the following minimum generating limits should be observed at all times:

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

9.2 Requirements for Grid Reinforcement

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

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

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

l. Low voltages would be experienced at Kumasi, Accra and surrounding areas due to poor customer-end power factors.

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

9.3 Distribution Systems

n. The Accra Central BSP is expected to be completed within the second quarter of 2018 to increase the level of reliability and meet the growing demand within the ECG network in Accra. This project will resolve loading constraints currently being realized on selected 33 kV feeders and reduce technical losses within the ECG Accra network.

o. A number of substations and interconnected circuits currently under construction are expected to be completed within the first quarter of 2018. These include the Ogbojo 33 kV / 11 kV substation and associated 33 kV lines from GIMPA to Kwabenya 33 kV / 11 kV substations and from Dodowa switching station to Mobole 33 kV bus.

p. NEDCo will continue to experience some challenges in its operational areas. These include the following overload and low voltage conditions;

- Overload on the Shield-Wire transformer at Techiman which serves Abofour and Nkenkansu in the Ashanti Region has capacity constraints.
- Overload on the transformer serving Wa Township and its environs.
- Obsolete switchgear at Bawku and Navrongo Distribution Stations.
- Low voltages at Ejura, Atebubu, Dalung, Bimbilla, Kete-Krachi due to long radial distribution lines.

9.4 Medium Term Supply

With the deployment of the committed generation capacity, there is adequate generation capacity to meet projected demand. Up to about 47% capacity reserve margin is recorded over the period (the required reserve margin is 25%). Barring any delays in the realization of these anticipated generation projects, there should be adequate generation capacity to meet medium-term projected power demand.

q. Over the medium term (2019 – 2023) system demand is expected to grow to 3,191 MW. Hence to meet the reliability requirement of the Ghana power system an additional reserve margin of 25% representing 798 MW is required. This adds up to a total required supply capacity of 4,898 MW.

r. Low voltage challenges could be experienced in Kumasi. The construction of generation resources of up to 200 MW in Kumasi in the medium term addresses this challenge.

10 RECOMMENDATIONS

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

1. The Akosombo and Bui Reservoirs should be prudently managed in 2018 by.
   a. Operating three Units at Akosombo during off-peak and four units at Peak
   b. Operating on the average, two units at Bui
2. In view of the low hydro generation, measures should be put in place to ensure security of fuel for the thermal plants to forestall possible supply disruptions to consumers.
3. The players in gas supply chain, namely; Ghana Gas Company Limited, Tullow, ENI, GNPC should strongly collaborate with the power utilities to ensure effective planning and coordination to avert any possible gas supply curtailments which could have dire consequences for power supply.
4. In view of the huge investments in fuel supply, the Government of Ghana (GoG) should assist the Utilities to raise the necessary financing to procure the required quantities of fuel and on time to avert any possible power supply crisis.
5. The ongoing transmission expansion projects should be expedited and completed on schedule.
   a. Volta – Achimota – Mallam Transmission Line Upgrade Project
   b. Aboadze – Prestea - Kumasi 330 kV Transmission Line Project
   c. Kumasi – Bolgatanga 330 kV transmission line Project
6. 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.
7. A well-coordinated maintenance programme should be pursued by both GRIDCo and the Generating Companies (GENCOs).
8. 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.

9. The following substation projects should be expedited;

    a. The completion of the Afienya BSP.

    b. Construction of 3x125 MVA GIS station at Accra Central.

    c. Construction of A4BSP 330 kV substation at Pokuase.

10. The interventions detailed in Appendix C1 to address constraints on the ECG network in the operational areas should be expeditiously implemented to ensure that they are completed on schedule.

11 APPENDICES

Appendix A –Forecast Peak Demand and Energy Consumption

A1: Medium Term Peak Demand Forecast (MW): 2019 - 2024

A2: Projected Energy Consumption (GWh) -2019 - 2031

Appendix B –Actual Peak Demand and Energy Consumption

B1: 2017 Actual Energy Consumption

B2: 2017 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): 2018 - 2027

Load forecast: Peak demand (MW)-Coincident	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
ECG	1642.72	1809.59	1876.84	2024.77	2166.12	2312.61	2467.81	2634.51	2815.35	2818.93
NEDCo	211.71	222.48	249.92	257.83	274.07	288.75	305.78	323.55	340.23	357.25
MINES	226.71	241.88	265.04	271.12	272.87	274.92	281.11	281.59	283.58	286.43
Other Bulk Customers	74.97	70.00	97.09	98.27	102.27	107.27	112.27	117.27	122.27	127.27
VALCO	150.00	332.00	443.00	553.00	553.00	553.00	553.00	553.00	553.00	553.00
CEB(Togo/Benin)	30.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
SONABEL(Burkina)	100.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00
CIE(Ivory Coast)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
EDM(Mali)	0.00	0.00	0.00	50.00	50.00	50.00	100.00	100.00	100.00	100.00
Transmission Losses +Network Usage	84.37	98.20	107.06	114.81	120.30	125.95	145.74	152.69	160.17	161.21
System Peak MW-Coincident	**2523.48**	**2937.16**	**3201.95**	**3532.81**	**3701.64**	**3875.51**	**4128.71**	**4325.62**	**4537.61**	**4567.09**

A2: Projected Energy Consumption (GWh) -2018-2027

Load forecast: Peak demand (GWh)-Coincident	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
ECG	10588.86	11027.52	11437.26	12145.98	12993.92	13872.66	14803.63	15803.64	16888.39	18070.58
NEDCo	1373.10	1444.88	1620.00	1692.39	1808.52	1917.82	2038.64	2171.41	2294.14	2301.69
MINES	1,495.41	1,656.20	1,834.98	1,909.23	1,923.85	1,938.23	1,991.21	2,010.64	2,019.33	2,013.48
Other Bulk Customers	426.96	226.88	256.78	261.50	265.50	270.50	275.50	282.63	287.63	292.63
VALCO	1,154.19	2,909.00	3,881.00	4,845.00	4,845.00	4,845.00	4,845.00	4,845.00	4,845.00	4,845.00
CEB(Togo/Benin)	230.00	65.70	65.70	65.70	65.70	65.70	65.70	65.70	65.70	65.70
SONABEL(Burkina)	428.76	985.50	985.50	985.50	985.50	985.50	985.50	985.50	985.50	985.50
CIE(Ivory Coast)	13.21	19.71	19.71	19.71	19.71	19.71	19.71	19.71	19.71	19.71
EDM(Mali)	0.00	0.00	0.00	344.50	344.50	344.50	689.00	689.00	689.00	689.00
Transmission Losses +Network Usage	**594.33**	**702.77**	**752.24**	**708.94**	**758.24**	**810.96**	**823.20**	**880.46**	**941.71**	**1,030.85**
Total Energy GWh	**16,304.82**	**19,038.16**	**20,853.18**	**22,978.46**	**24,010.44**	**25,070.58**	**26,537.09**	**27,753.68**	**29,036.11**	**30,314.13**

APPENDIX B - ACTUAL PEAK DEMAND AND ENERGY CONSUMPTION

B1: Electricity Company of Ghana-Monthly Actual Energy Consumption (GWh) by BSP's in 2017

STATIONS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
KPONG	17,013.2	13,478.3	13,930.6	14,285.4	15,060.0	14,725.3	15,696.1	15,461.8	15,105.4	16,857.6	15,881.0	18,202.6	185,697.3
AKUSE	221.1	198.6	228.0	195.2	189.8	167.4	162.7	167.4	189.9	195.5	189.2	217.8	2,322.6
NEW TEMA	89,822.6	80,468.4	92,887.6	83,240.7	90,358.6	85,226.1	88,143.9	86,848.9	84,612.7	92,719.9	81,130.4	75,668.3	1,031,128.0
ACHIMOTA	192,897.0	146,534.0	165,348.3	155,983.7	165,782.0	141,775.3	164,068.9	156,830.1	164,901.7	179,799.3	188,241.4	195,887.2	2,018,048.9
MALLAM	83,283.7	101,945.6	118,175.0	116,702.0	110,090.5	109,004.1	75,784.7	81,837.0	77,746.5	95,455.2	85,461.5	89,005.2	1,144,491.0
WINNEBA	29,977.7	26,241.0	29,240.0	28,286.0	29,689.0	27,658.1	28,451.3	28,747.6	28,420.0	31,701.5	32,167.2	34,326.3	354,905.7
ACCRA EAST	95,803.0	75,723.0	88,792.0	94,215.0	101,718.0	81,323.3	76,636.7	72,687.9	69,743.8	87,664.9	95,814.2	87,431.6	1,027,553.4
SMELTER II	11,877.0	18,300.0	20,612.0	20,009.0	18,847.4	20,140.4	18,296.5	18,677.5	18,248.9	20,690.9	33,287.8	36,232.4	255,219.8
CAPE COAST	23,323.0	20,669.0	24,071.0	22,662.0	22,543.0	20,684.1	20,759.7	20,046.7	21,143.0	23,759.4	23,277.8	24,084.2	267,022.9
TAKORADI	34,222.4	29,368.7	35,820.1	34,426.3	35,089.4	32,650.3	32,001.2	32,261.5	31,149.5	33,943.2	34,877.9	35,502.8	401,313.2
ESSIAMA	6,285.0	5,355.7	6,191.0	5,509.9	5,596.0	5,041.9	4,940.2	5,296.7	5,003.0	5,357.7	5,359.1	6,127.7	66,063.7
BOGOSO	6,558.7	6,103.5	6,505.4	6,158.0	6,542.3	6,387.6	6,363.1	5,893.0	5,779.7	6,558.0	6,354.0	6,950.5	76,153.6
PRESTEA	2,030.5	1,900.8	2,048.9	1,970.1	1,894.8	1,773.9	1,783.3	1,692.2	1,619.1	1,809.8	1,787.9	1,991.7	22,303.0
TARKWA	22,018.7	17,316.2	21,127.9	20,594.0	20,311.4	20,081.4	20,229.2	19,401.3	19,452.1	20,285.6	20,539.8	20,592.6	241,950.1
AKYEMPIM	318.7	270.6	274.7	252.6	268.0	263.7	259.5	188.9	193.2	201.2	214.3	252.2	2,957.6
DUNKWA	3,140.4	2,942.4	3,227.9	3,126.8	3,128.4	2,728.6	2,757.9	2,764.5	2,668.8	2,873.3	2,860.3	3,046.5	35,265.8
ASAWINSO	26,373.3	25,198.7	25,953.1	23,980.7	25,285.3	26,684.4	27,047.4	25,912.2	24,873.8	25,968.6	26,758.0	27,991.9	312,027.2
OBUASI	11,423.2	10,375.3	10,946.5	10,702.4	10,646.9	9,905.3	9,970.9	9,788.8	9,523.1	10,183.7	10,434.6	10,965.8	124,866.4
KUMASI	99,746.0	82,471.0	101,014.0	98,988.0	99,937.0	91,779.0	94,076.6	95,202.5	90,548.1	91,383.8	86,903.3	103,956.7	1,136,006.0
ANWOMASO	30,542.0	35,870.0	33,524.0	33,042.0	30,817.0	30,142.0	30,758.1	28,045.5	30,358.0	38,462.3	38,261.6	29,292.4	389,114.9
KONONGO	5,669.5	5,192.1	5,490.4	5,454.9	5,677.0	5,102.0	5,355.2	4,933.5	4,913.5	5,824.6	5,603.5	6,118.0	65,334.1
NKAWKAW	6,869.6	6,149.0	6,981.5	6,957.8	7,048.1	6,300.4	6,409.3	6,101.8	6,002.3	6,692.3	6,612.2	7,011.9	79,136.2
AKWATIA	12,415.4	12,014.9	12,887.0	12,342.4	12,603.8	12,081.1	11,635.7	11,667.8	10,843.1	11,133.3	11,813.6	12,280.3	143,718.4
TAFO	18,365.0	17,187.8	18,950.8	18,105.4	18,348.3	17,316.1	16,945.9	16,495.5	16,175.5	17,757.7	17,829.7	18,665.0	212,142.5
HO	5,385.5	5,481.2	5,914.3	5,855.0	5,697.0	5,184.9	5,317.6	5,283.2	5,267.8	5,970.3	5,743.3	6,077.7	67,177.7
KPEVE	3,043.9	2,328.4	2,735.2	2,488.6	2,425.0	2,307.4	2,538.2	2,535.4	2,567.8	2,533.5	2,516.6	2,653.7	30,673.8
KPANDU	7,167.8	6,631.0	7,680.5	6,990.1	7,100.5	6,799.3	7,352.4	7,216.7	7,066.9	7,691.5	7,545.6	7,959.2	87,201.4
ASIEKPE	511.6	471.7	493.7	463.8	464.1	402.1	361.5	381.3	364.6	385.9	455.5	442.4	5,198.0
SOGAKOPE	6,748.6	6,137.9	5,817.0	5,955.2	6,632.4	6,036.2	6,107.8	6,043.8	5,627.0	6,270.3	6,730.4	7,137.7	75,244.3
AFLAO	5,280.0	4,515.0	5,390.0	5,868.0	4,932.7	4,599.7	4,840.6	4,801.6	5,236.2	5,900.7	5,297.0	5,708.4	62,369.9
TOTAL	858,334.1	766,839.6	872,258.4	844,810.9	864,723.7	794,271.1	785,052.0	773,212.3	765,344.9	856,031.2	859,948.5	881,780.5	9,922,607.3

B2: Electricity Company of Ghana-Actual Peak Demand – 2017

STATIONS	January	February	March	April	May	June	July	August	September	October	November	December	HIGHEST
AKUSE	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3		0.31
NEW TEMA	205.34	200.13	236.55	187.34	195.7	193.65	193.52	168.79	194.43	201.25		185.79	236.55
ACHIMOTA	299	304.8	283.8	380.1	257.8	308.6	268.5	267.6	252.8	297.3	300.3	300.7	380.10
MALLAM	198.9	230.5	228.5	258.7	215.8	215.7	207.6	226.5	163	198.3	210.8	161.4	258.70
ACCRA EAST	160.7	214.3	218.2	176.9	195.2	178.2	159.1	159.3	152.5	187.3	194.3	176.3	218.20
WINNEBA	62.5	78.2	59.3	65	71.5	65.5	59.2	62	61.7	72.5	68	68.3	78.20
SMELTER II	35.2	36.3	35.6	39	41.6	36.3	59	33.5	17.1	36.8		71.3	71.30
CAPE COAST	46.6	46.5	49	48.3	46.2	47.6	41	42.8	45.6	47.6	48.7	48.3	49.00
TAKORADI	99.13	121.79	69.99	122.99	82.9	85.24	75.63	61.37	63.48	71.53	69.76	68.8	122.99
ESSIAMA	15.95	13.03	13.23	12.57	13.39	11.88	10.62	10.76	11.2	12.15	12.06	12.77	15.95
BOGOSO	13.97	14.78	14.52	14.11	14.2	13.66	12.7	12.03	12.53	13.98	14.09	14.81	14.81
TARKWA	45.05	49.26	57.95	50.43	49.37	48.15	47.55	49.26	35.03	44.86	44.72	51.51	57.95
AKYEMPIM	0.71	0.73	0.71	0.71	0.74	0.69	0.63	0.47	0.63	0.62	0.62	0.65	0.74
DUNKWA	6.08	6.14	6.07	5.98	5.93	5.66	5.25	5.34	5.43	5.67	5.57	5.81	6.14
PRESTEA	3.56	3.53	3.63	3.56	3.37	3.29	19.63	2.99	2.99	3.3	3.32	3.49	19.63
ASAWINSO	49.3	49.49	54.31	51.96	55.56	47.13	46.98	45.14	46.36	48.7	48.29	49.19	55.56
OBUASI	25.65	27.15	23.11	27.79	21.31	20.35	19.63	18.76	19.53	22.63	24.09	20.79	27.79
ANWOMASO	88.5	99.2	104.2	49.7	94.8	94	91.5	71.3	96.3	102.7	107	73.2	107.00
KUMASI	239.4	219.6	221.6	206.5	232.4	199.7	193	190.3	223.3	228.3	229.5	232.4	239.40
KONONGO	10.52	10.82	10.7	10.67	10.52	10.23	10.36	9.65	10.16	10.44	10.81	10.54	10.82
NKAWKAW	15	20.45	25.83	18.83	30.54	13.69	13.64	12.82	17.79	16.35	14.15	15.23	30.54
AKWATIA	27.66	29.21	28.1	25.444	29.55	26.98	25.87	27.51	25.66	30.73	26.38	25.68	30.73
TAFO	35.08	30.473	36.02	35.85	38.06	34.95	32.92	33.56	33.3	35.57	35.36	35.83	38.06
HO	9.75	12.01	15.79	10.53	10.11	10.32	9.97	10.07	10.06	10.59	10.4	15.93	15.93
KPONG	26.05	28.56	27.92	45.86	42.2	27.45	39.6	26.2	34	89.1	28.94	32.1	89.10
KPEVE	5.14	5.39	5.3	4.58	4.63	4.58	4.03	5.37	5.29	4.87	4.61	4.67	5.39
KPANDU	14.77	15.12	14.64	22.68	17.8	14.52	14.3	14.26	14.48	14.68	14.59	14.53	22.68
ASIEKPE	1.24	1.24	1.17	1.18	11.9	1.09	0.85	0.8	0.85	0.85	1.11	0.98	11.90
SOGAKOPE	13.26	13.69	13.28	13.77	13.5	13.7	12.71	11.93	12.5	13.37	13.68	13.63	13.77
AFLAO	11.3	9.7		12.5	10.8	10.5	9.7	9.5	14.4	13.6	10.7	10.7	14.40
TOTAL	1,765.607	1,892.389	1,859.326	1,903.805	1,817.635	1,743.542	1,685.209	1,590.105	1,582.664	1,835.903	1,552.113	1,725.330	1,903.805

APPENDIX C – DISTRIBUTION NETWORK INTERVENTIONS

C1: Selected Interventions being carried out by ECG to resolve network constraints in 2018

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Load Center	Timeline
1	Construction of the Accra Central BSP on the Graphic Road	High demand growth in Accra. Distribution reliability threat of lines supplying Accra central load.	1. Increased level of reliability especially during contingent conditions. 2. Improved voltages within Accra central load. 3. Reduction in loading of existing feeders supplying Accra Central Demand	1. Severe loading constraints on feeders supplying Accra central load. 2. Improved level of reliability of supply during contingent situations 3. Technical Loss Reduction	Accra	Second Quarter of 2018
2	Construction of BSP Mobole and creation of 33 kV offloading circuits for the newly constructed Mobole Bulk	1. The Dodowa switching station and Mampong substation are currently supplied through a single circuit 26 MVA	1. Increase flexibility of supply within the Tema network 2. Improve voltages at load centers within Mobole catchment area 3. Support and provide	1. Severe low voltages at Dodowa 2. Potential power outages to customers supplied from the Dodowa switching	Tema	Complete

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Load Center	Timeline
	Supply Point	distribution line about 27 km from Adenta. 2. This results in severe voltage levels at Dodowa and beyond. Afienya BSP will serve as a alternative supply to Dodowa, Mampong and possibly Aburi	alternative supply to neighbouring sub-transmission Accra networks 4. Improve power supply reliability to Dodowa, Mampong and possibly Aburi 5. Reduce technical losses	station 3. High suppressed demand		
3	Upgrade of existing Sogakope substation from 10/13 MVA 69/11 kV to 25/33 MVA 69/11 kV	Potential overloading of the substation based on projected demand for 2018 in Sogakope	1. Reduction in technical losses. 2. Increased capacity to meet projected demand for 2018	1. Likely outages resulting from overloads 2. High level of Technical losses	Volta	Planned
4	Construction of a	New load centers	1. Reduction in Technical	1. Low voltages	Accra	First Quarter of

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Load Center	Timeline
	2x20/26 MVA 33/11 kV Primary Substation at Ogbojo complete with associated 33kV circuits and 11 kV offloading circuits for the Ogbojo substation	developing within the Ogbojo catchment area	Losses 2. Increased reliability and flexibility of supply to loads within the Ogbojo catchment area 3. Improved economic loading of neighbouring substations as the Ogbojo substation will off - load a percentage of existing loading on the neighbouring substations	2. Poor level of reliability of supply		2018
5	Construction of a 33kV double circuit tower lines from Gimpa to Kwabenya and Dodowa to Mobole substations	Currently the Kwabenya substation is a terminal substation either when it is supplied from the Achimota BSP	1. Improved reliable power supply to Kwabenya with alternatives 2. Improved voltage levels at Kwabenya	1. Low voltages at Kwabenya 2. High level of reliability of supply to the Kwabenya substation	Accra	First Quarter of 2018

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Load Center	Timeline
		through Adenta or A3BSP through Adenta. Severe voltages are anticipated when supplied from A3BSP and loading constraint on the H - Adenta when supplied from Achimota BSP				
6	Construction of Primary S/S. at Meridian Tema. Construction of the Tema "A" to Meridian portion of the looping of the 2x60 MVA 33 kV	To off - load projected overloading on the Tema A and Tema D substations	1. Improved economic loading of Tema A and Tema D substations. 2. Reduce technical losses 3. Improved reliability of supply to load centers within the Meridian catchment area	1. High level of Technical losses 2. Low level of reliability	Tema	Complete

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Load Center	Timeline
	double circuit tower line from Tema "A" to "D" through the Meridian substation					
7	Creation of 33 kV & 11 kV offloading circuits from the newly constructed Hohoe Primary Substation	Reduce potential overload on neighboring primary substations	1. Reduce Technical Losses 2. Improved economic loading	1. Likely outages resulting from overloads 2. High level of Technical losses	Volta/Hoho e	Complete
8	Creation of 33kV & 11kV offloading circuits for the reconstructed Denu/Aflao Primary Substation	Reduce potential overload on neighboring primary substations	1. Reduce Technical Losses 2. Improved economic loading	1. Likely outages resulting from overloads 2. High level of Technical losses	Denu	Complete
9	Construction of permanent	Reduce potential overload on	1. Reduce Technical Losses 2. Improved economic	1. Likely outages resulting from	Tema	Complete

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Load Center	Timeline
	substation at the existing Kpone industrial area (OLAM) in Tema	neighboring primary substations	loading	overloads 2. High level of Technical losses		
10	Construction of a 9.9km line from Otokrom to James Adomkrom to link the Juabeso & Asankragwa/Enchi 33kV lines	No alternative line to supply load centers during outages	1. Improved level of reliability	Longer duration of outages resulting in high levels of SAIDI	Western	Complete

C2 a: Northern Electricity Distribution Company –Actual Energy Consumption (GWh) -2017

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) -2017

STATIONS	January	February	March	April	May	June	July	August	September	October	November	December	Maximum
SUNYANI	43.1	43.6	43.4	41.8	41.9	41.8	39.6	38.4	40.9	41.3	40.7	41.4	43.62
TECHIMAN	39.7	43.9	39.6	37.4	34.1	35.9	46.1	31.8	37.3	34.8	35.2	29.9	46.1
TAMALE	49.6	51.5	52.5	53.5	53.0	52.6	49.7	49.2	51.8	63.5	57.6	50.2	63.5
BOL'TANGA	15.9	17.1	19.1	19.0	18.3	18.0	17.1	17.3	15.3	21.0	10.6	18.8	21.0
YENDI	18.9	18.9	19.4	20.2	19.8	19.7	19.3	19.2	19.8	20.6	19.8	19.4	20.6
SAWLA	6.3	6.7	7.0	7.0	7.0	6.8	6.2	6.4	6.9	7.5	7.0	7.1	7.5
BUIPE (PBC)	1.2	1.3	1.3	1.3	1.4	1.2	1.2	1.4	1.4	1.5	1.6	1.6	1.6
ZEBILLA	1.3	1.3	1.4	1.4	1.5	1.4	1.4	1.4	1.4	1.5	1.4	1.6	1.6
MIM	11.1	12.4	12.7	12.9	12.9	12.7	11.1	11.0	11.5	12.1	12.5	12.6	12.9
KINTAMPO	2.9	3.6	3.2	3.1	3.3	3.1	3.0	3.7	3.1	6.9	6.8	7.9	7.9
TUMU	3.4	3.6	3.7	3.7	2.9	2.9	2.7	2.6	2.7	2.9	3.6	8.6	8.6
WA	12.4	13.4	13.8	14.5	13.5	13.8	12.1	12.2	13.6	14.9	13.4	12.8	14.9
BAWKU	10.1	10.7	11.2	11.1	12.0	10.9	10.0	10.8	10.4	12.8	12.0	11.9	12.8
TOTAL	215.9	228.0	228.2	227.0	221.5	220.8	219.4	205.3	216.1	241.4	222.2	223.7	241.4

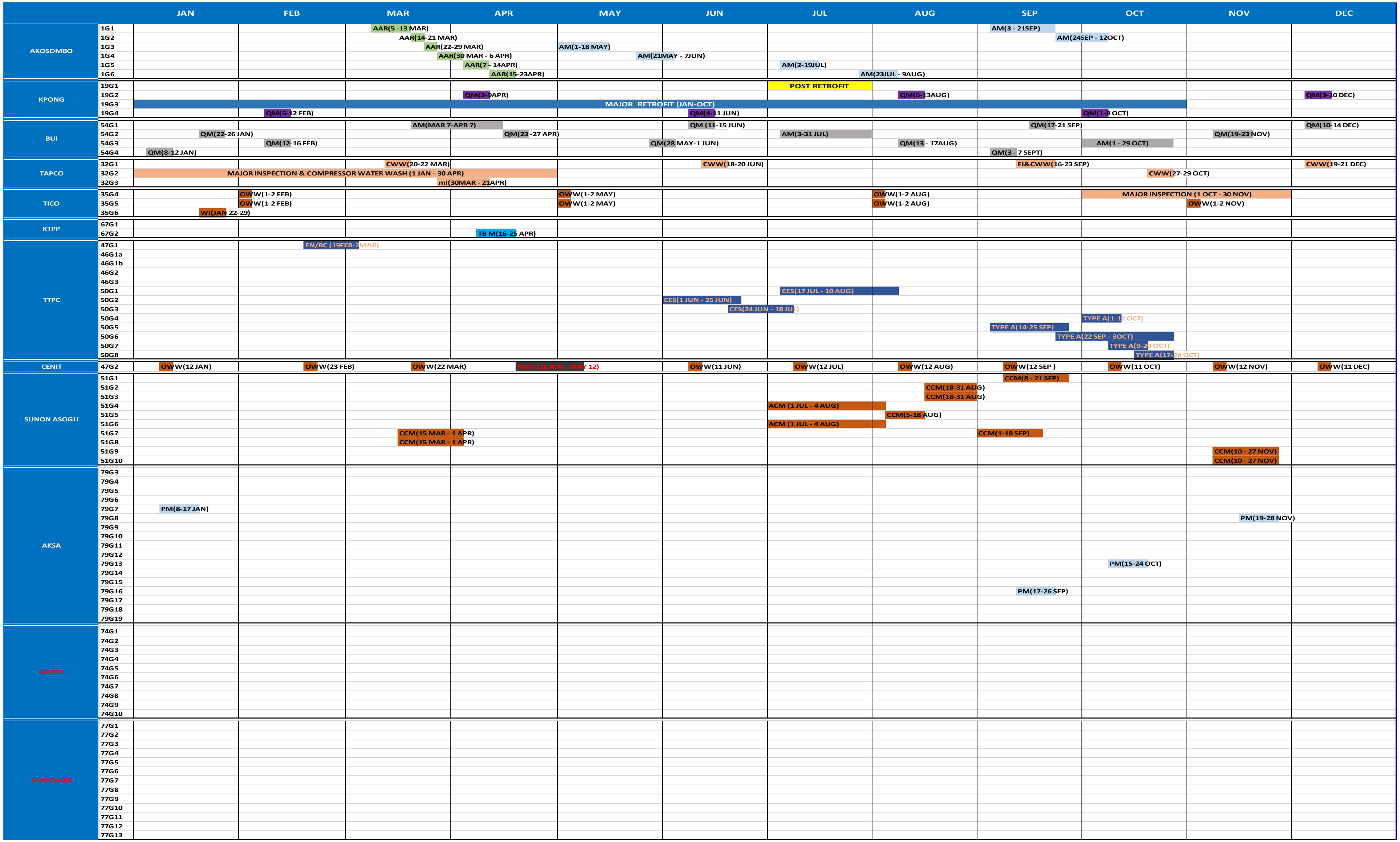
C2 c: Mines-Energy Consumption (GWh)-2017

CUSTOMERS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
G.F.G. NEW TARKWA	13.4	12.9	15.3	16.3	14.2	15.1	11.5	8.2	9.4	9.7	8.8	10.6	145.5
NCM PRESTEA	1.2	1.2		1.2	1.4	1.6	1.8	1.9	1.6	1.6	1.8	1.9	17.1
SANKOFA PRESTEA	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0					0.4
OWERE KONONGO	0.1	0.1	0.1	0.1	0.1	0.0							0.3
ANGLOGOLD OBUASI	1.3	1.4	1.5	1.4	1.5	1.6	1.8	2.0	1.9	1.7	2.0	1.7	19.9
ANGLOGOLD NEW OBUASI	5.1	4.1	4.8	4.7	4.7	4.8	5.2	5.1	4.3	4.4	4.4	4.5	56.1
G.C.D. AKWATIA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	1.1
GOLDEN STAR BOGOSO	4.4	4.0	4.5	4.1	4.3	4.2	4.3	4.3	4.2	4.2	4.3	4.5	51.2
GOLDEN STAR WASSA	7.3	7.0	7.7	6.6	6.9	5.7	5.4	7.6	7.6	7.3	7.9	7.9	85.0
ADAMUS GOLD ESSIAMA	3.7	3.1	3.4	3.4	3.6	3.5	3.8	3.7	3.4	3.7	3.4	3.7	42.4
PERSEUS GOLD AYANFURI	10.8	9.8	11.2	9.3	11.3	12.5	11.3	10.1	10.9	12.1	12.7	10.6	132.5
NEWMONT NEW ABERIM	19.9	18.8	15.7	18.2	18.5	17.8	17.8	18.6	18.7	19.1	18.8	19.1	220.9
NEWMONT KENYASE	22.3	19.3	22.6	20.6	22.6	21.6	23.4	22.4	23.3	22.9	24.0	22.2	267.2
ADANSI GOLD OBOTAN	8.9	8.8	9.4	8.9	9.4	9.0	8.0	8.6	9.2	9.4	9.6	10.0	109.3
DRILLWORX KONONGO							0.0	0.1	0.1	0.1	0.1	0.1	0.6
TOTAL	98.56	90.46	96.23	94.93	98.60	97.52	94.44	92.64	94.67	96.37	97.95	97.02	1,149.39

C2 d: - Consumption (GWh)-2017

CUSTOMERS	January	February	March	April	May	June	July	August	September	October	November	December	Maximum
G.F.G. NEW TARKWA	35.4	28.4	39.3	39.2	39.0	39.4	38.9	37.8	39.3	37.3	38.3	38.2	39.4
NCM PRESTEA	2.9	2.9	2.9	2.9	2.9	3.4	8.4	3.6	3.7	3.5	3.7	3.7	8.4
SANKOFA PRESTEA	0.8	0.3	0.1	0.4	0.1	0.3	0.1	0.3					0.8
OWERE KONONGO	0.1	0.1	0.1	0.1	0.1	0.1							0.1
ANGLOGOLD. OBUASI	3.7	4.1	3.2	3.6	3.6	3.9	4.2	4.3	4.1	3.7	4.2	4.0	4.3
ANGLOGOLD NEW OBUASI	9.1	9.1	17.1	17.9	8.7	15.7	9.9	9.2	7.2	14.3	7.3	7.8	17.9
G.C.D. AKWATIA	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2		0.2
GOLDEN STAR BOGOSO	6.9	7.0	7.0	6.9	7.3	7.1	7.0	6.5	6.9	6.9	7.2	7.3	7.3
GOLDEN STAR WASSA	11.7	11.8	11.9	11.7	11.7	11.7	11.8	12.2	12.2	12.4	12.5	12.2	12.5
ADAMUS GOLD ESSIAMA	5.6	5.4	5.6	5.5	5.5	5.6	5.6		5.4	5.4	5.4	5.5	5.6
PERCEUS GOLD AYANFURI	18.2	17.9	18.3	17.8	18.6	19.4	19.1	18.9	18.2	19.5	19.3	18.8	19.5
NEWMONT NEW ABERIM	30.7	15.6	30.0	29.3	29.3	23.7	29.8	37.6	57.3	56.3	29.0	42.6	57.3
NEWMONT KENYASI	36.5	32.6	33.0	69.8	66.0	65.8	35.8	67.3	69.7	36.2	71.9	45.1	71.9
ADANSI GOLD LTD OBOTAN	14.3	14.4	14.7	14.6	14.6	14.4	14.1	14.5	15.8	15.7	15.1	15.3	15.8
DRILLWORX KONONGO							240.00	250.00	320.00	330.00	330.00	320.00	330.0
TOTAL	176.0	149.8	183.4	219.9	207.6	210.6	385.9	212.2	240.0	211.3	214.1	200.5	386

Appendix D – 2017 PLANNED GENERATING UNITS MAINTENANCE



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