GRIDCo

Ghana Grid Company Limited

2010 ELECTRICITY SUPPLY PLAN

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January 2010

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Glossaries and Abbreviations

MW	Units of active power
MVAr	Units of reactive power
GWh	Giga watt hours and units of energy
MVA	Units of the complex power or apparent power
SAPP	Sunon-Asogli Power Plant
SVC	Static VAr Compensator
BPP	Bui Power Plant
WAGP	West African Gas Pipeline
BSP	Bulk Supply Point
LCO	Light Crude Oil
VRA	Volta River Authority
GRIDCo	Ghana Grid Company Limited
GS	Generating Station

EXECUTIVE SUMMARY

Background

In line with the mandate of Ghana Grid Company (GRIDCo) under the Grid Code and the Legislative Instrument to among others, carry out dispatching and transmission of electricity from facilities of wholesale suppliers to bulk customers in a secure, stable and reliable manner, GRIDCo hereby presents its Electricity Supply Plan for the year 2010.

The report addresses the demand outlook and estimated energy consumption for 2010, the corresponding generation scenario and the available network infrastructure to support the forecast demand and supply at the Bulk Supply Point (BSP) level. The report also discusses the risk factors, both generation and transmission, that could affect secure and reliable delivery of power for 2010.

A short-term (2011 and 2012) energy and demand outlook is also presented. The report finally presents the conclusions and the recommendations based on the analyses and the findings.

Demand and Energy Outlook for 2010

The maximum projected demand for 2010 is approximately 1,470 MW, which is about 3.3% or 47 MW increase in growth over the 2009 figure of 1,423 MW. This includes overall estimated peak transmission losses of 5%.

In terms of energy consumption, *the total estimated energy requirement for 2010 is 10,305 GW*h. This includes overall estimated transmission losses of 3.7%, or 368 GWh. Transmission losses as mentioned above are an inevitable part of electricity transmission, since part of the energy to be transferred across the transmission network is dissipated as heat

Hence with the actual 2009 energy consumption of 10,116 GWh, the projected 2010 figure of 10,305 GWh is an increase of about two percent (2%) or 189 GWh over the 2009 figure.

Projected Supply Scenario

The available generation for 2010 is 1,730 MW. Compared with the estimated peak demand of 1,470 MW, the reserve margin for 2010 is estimated as 260 MW corresponding to about 15% of total generation. It must be noted though that this level of reserve margin could be realized only when all the units are available. With the current state of the units where most of the plants are either not available or only one unit is available, the actual reserve margin could be as low as 50 MW 3%. In some instances during the early part of this year, some supply deficits have been encountered resulting in load curtailments.

Estimated Cost of Fuel Required for Thermal Generation

The energy consumption of 10305 GWh in 2010 is projected to be supplied as follows:

- Hydro - 6,360 Gwh
- Thermal - 3,945 Gwh

The generation of the 3,945 GWh thermal complementation would require approximately 19 cargoes of crude oil. With each cargo containing 405,000 barrels and the price of fuel estimated at US$ 87/bbl including incidental charges, the total amount required per cargo is approximately US$ 35 million.

Hence for the total 19 cargoes required for 2010, an amount of about US$ 665 million would be needed by VRA to meet the their thermal generation target for 2010.

Maximum Demand and Total Energy Consumption with VALCO

The purpose of this sub-section is to analyze the security of demand-supply scenario with the commencement of VALCO's operations. With optimal VALCO operations centred around two or more potlines, with each potline rated at 75 MW, overall system demand including losses (with losses still estimated at 5% of peak) would increase to about 1,780 MW when VALCO is assumed to be operating at a minimum of two potlines. At this level of demand, the nominal generation capacity indicated above would fall short of the peak demand by 50 MW or about 2.5%.

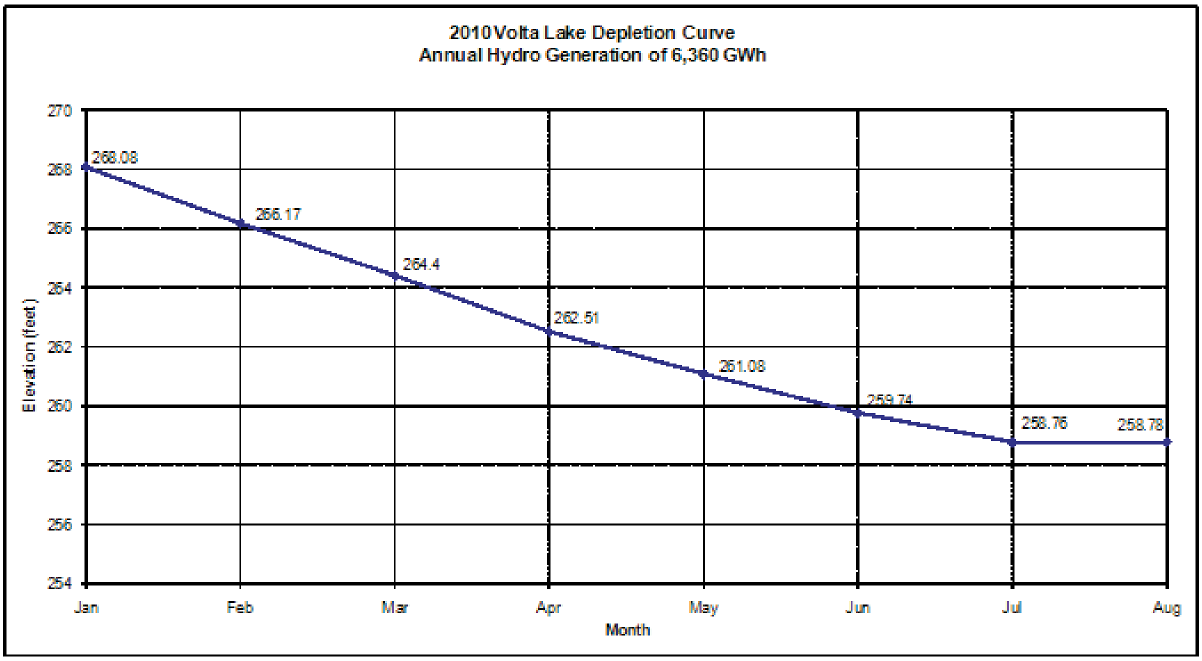
In other words there would be a supply deficit of about 50 MW when VALCO comes on line with two potlines and there is no further boost in generation by way of additional capacity. *The only way this could be averted is when SAPP comes on line to increase the generation supply capacity*. It is worth mentioning that the only way SAPP which is solely for gas fired operation, could come on line is when the WAGP gas is available.

Reservoir Elevation Projection

Based on this level of generation, the projected reservoir trajectory is presented in the following Table and the Depletion Curve.

Table 1: Akosombo Lake Elevations

Level	Height (ft)
Maximum elevation	278.0
Minimum elevation	240.0
Maximum recorded elevation in 2009	270.5 (on Nov 10, 2009)
Elevation at the end of 31st December, 2009	268.08
Projected reservoir elevation at the end of the dry season in 2010.	258.4



The Table 1 shows that at the end of the inflow season in 2009, the registered peak elevation of 270.5 ft was short of the maximum elevation by just 7.5 ft. The Table also shows that between November 10, 2009 when the highest peak was recorded and the end of 2009; the lake had been drawn down by 2.42 ft. Based on the estimated draw down rate in 2010, the reservoir elevation is expected to drop further to 258.76 ft by the end of the dry season.

Effect of Bui's Impoundment on the Akosombo Reservoir

As part of the development of the Bui Power Plant Project, the Black Volta on which the Bui Power Plant (BPP) is being built is expected to be impounded by February 2011. With this river being a major tributary of the Volta reservoir, contributing on the average 18% of the overall inflow to the lake, its impoundment will affect the amount of energy that could be generated from the Akosombo Hydroelectric Plant.

The impoundment is expected to last about 22 months, that is, from February 2011 to December 2012, when the commissioning of the plant is expected to commence. It is therefore imperative that the current water in the reservoir is prudently and optimally utilized. This will avert drawing down the lake to such low levels that has the potential to affect energy generation from the hydro plants, with resultant overall effect on national energy security.

Overview of Short-Term (Two-Year) Load Forecast

The peak demand for 2011 and 2012 is expected to increase to 1,566 MW and 1,667 MW respectively. These include the estimated peak transmission losses of 5%. The corresponding projected energy consumptions are 11,348 GWh and 12,536 GWh respectively which include the estimated energy losses of 4%.

Supply Risk Analyses

This sub-section seeks to analyse the possible risks to meeting the 2010 electricity supply from the perspective of;

- Adequacy in available generation with adequate spinning and reserve capacities to meet the projected demand under all system conditions
- Adequacy in transmission capacity to support the demand-supply scenario under all system conditions
- Adequacy in transformer capacity to meet all substations' load

Adequacy in Supply with adequate Spinning and Reserve Capacities

a) In terms of Capacity

With the current supply situation beset with a number of problems, the supply of 1,470 MW or in energy terms 10,305 GWh in 2010 could encounter a number of challenges; the major ones being:

- Lower plants' availability rates than expected resulting from high units' outage rates and long planned maintenance periods due mostly to unavailability of critical spares.
- Inadequate fuel stocks to run the Thermal Plants. Whenever VRA is not able to secure the required financing to purchase the required quantity of fuel or if for any reason the delivery of fuel is delayed, there would be supply deficit and some load would have to be shed.
- The current overdependence on hydro is also a major risk. This could affect scheduled maintenance of units thereby endangering the integrity of the units with associated dire consequences. Overdependence on hydro also has the tendency of overdrawing the Akosombo reservoir to very low levels that could render the plant inoperable.

Hence considering the very low reserve capacity even with all the plants available, any situation that results in any of the plants going out of service would pose a major risk to supply security in 2010.

b) In terms of Energy

With the projected energy consumption of 10,305 GWh, hydro is expected to contribute 6,360 GWh, with the remaining 3,945 GWh coming from thermal. This implies running almost five thermal plants continuously throughout the year. Hence, with the current low levels of units' availability as alluded to above, a supply deficit of close to 1000 GWh is likely to be experienced.

Adequacy in Transmission Capacity

On the transmission side, the major risks to supply security and reliability are;

1. Inadequacy in transmission capacity which could lead to transmission line overload. This phenomenon which is characteristic of the network mostly during the peak period is due to growth in demand over the years which has not been accompanied by commensurate expansion or reinforcement of the transmission network.

2. Insufficient reactive power compensation which could lead to low substation bus voltages, high voltage drops and poor customer supply voltage. This condition is due to low customer-end power factors, leading to high generator reactive power output and transfer of such reactive power over long distances. The resultant effect is high transmission line losses and higher voltage drops which invariably affect the quality of supply voltage.

3. Inability of the transmission network to withstand any single element contingency. This is as a result of low investment in the transmission network, such that the network does not satisfy what is called n-1 criterion – a measure of a transmission network's ability to withstand an outage of a single network element.

Adequacy in Transformer Capacity

The transmission system currently suffers from inadequate transformer capacity to the extent that most of our substations do not have what is termed a 'Firm Capacity' – a measure of a substation's ability to supply the same amount of total load when the largest transformer at the station is outaged. This transformer inadequacy phenomenon characterises most of our current substations to the extent that in some of the stations, there is only one transformer hence taking out that single transformer would mean all the customers being supplied from that station would be plunged into total “darkness” until the transformer is restored into service.

The criterion for normal operating conditions requires that transformers should not be loaded above 85% of their rated capacities, such that under emergency or contingency conditions, the loading could increase to 100% of the rated. However, as shown in the above Table, this important criterion is not being respected. In fact in Achimota and

Kumasi, an overload condition is already being experienced during the normal operating condition.

This state of affairs cannot be accommodated further since continuous overloading would shorten the life span of these transformers leading to higher failure rates with attendant supply security constraints.

Projects Earmarked for Installation and Commissioning in 2010

In line with the current GRIDCo's objective of implementing strategic and systematic improvement of the National Interconnected Transmission System (NITS), the following projects have been earmarked for installation and commissioning in 2010. The completion of these projects is expected to improve overall system reliability, security and general quality of supply.

Transformers

GRIDCo has taken delivery of the following transformers and would install them as follows:

- Two 50/66 MVA, 161/34.5 kV transformers have been procured and would be installed at Takoradi
- Two 25/33 MVA, 161/34.5 kV transformers would installed at Winneba
- One 25/33 MVA, 161/34.5 kV transformer would be installed at Asawinso
- One 33/33/20 MVA, 161/34.5/11.5 kV transformer would be installed at Cape Coast, whilst a similar capacity transformer would be commissioned at Akwatia.

Shunt Capacitor Banks

A total of 138.9 MVAr shunt capacitor banks are due for installation as follows:

- Achimota - 80 MVArs
- New Tema - 40 MVArs
- Sunyani - 10.8 MVArs
- Kumasi - 8.1 MVArs

Disconnect Switches

Disconnect switches at the following critical substations would be replaced;

- Kumasi – Two defective ones
- Tafo – One defective
- Two defective ones and one at Dunkwa and Nkawkaw respectively
- All the old disconnect switches at Akosombo Switchyard and Volta substation at Tema are being replaced under a contract funded by the World Bank.

Transmission Lines

A fourth line from Volta Switchyard in Tema to Achimota Substation in Accra would also be constructed and commissioned at a total cost of $5million.

FIRST QUARTER 2010 PERFORMANCE

SYSTEM DEMAND

The first quarter of 2010 recorded a maximum coincident system peak load of 1,435MW. This system peak occurred on 28th January, 2010 at 20:00hrs GMT, on this day Ghana's domestic peak load was 1308MW. As compared with the first quarter of 2009, the first quarter peak indicates a 9% increase.

Table 1: System Peak Demand for first quarter 2010

Major Customers	S. Peak (MW) 1ST Qtr 2010	S. Peak (MW) 1ST Qtr 2009	Change(MW)
ECG	1,049.21	916.77	132.44
NED	103.52	91.8	11.72
MINES	181.44	171.22	10.22
EXPORT	127	137	10
SYSTEM PEAK (coincident)	1435	1309	126

GENERATION

Energy Generation

Total energy generated during the first quarter of 2010 is 2,558.3GWh; this is made up of 1,885.64GWh from Akosombo and Kpong hydro generation plants and 702.66GWh of energy from TICO, TTPP, MRPP and TT1PP thermal generation plants. Generation mix at the end of the first quarter is 72.9% and 27.1% for hydro and thermal respectively. The generation breakdown for first quarter 2010 is shown in table 2 below.

Table 2: Total energy generated from hydro and thermal plants-first quarter 2010

	HYDRO GENERATION(GWH)				THERMAL GENERATION (GWH)				
MONTH	AKOSOMBO GS (GWH)	Dis/Cfs	KPONG GS (GWH)	Dis/Cfs	TTPP	TICO	MRPP	TT1PP	TT2PP
JAN.	583.76	1486236	98.19	1405328.	58.94	119.65	14.08	7.58	-
FEB.	486.25	1260065	83.74	1195355	56.66	98.57	1.6	60.45	5.7
MAR.	539.99	1415165	93.71	1329508	65.19	139.43	2.44	66.97	5.4
TOTAL	**1610**	**4161466**	**275.64**	**3930191**	**180.79**	**357.65**	**18.12**	**135**	**11.1**

Table 3: Hydro and Thermal Power Generation Mix for first quarter 2010

Months	Total Hydro (GWH)	Total Thermal (GWH)	Total	Hydro (%)	Thermal (%)
January	681.95	200.25	882.2	77.3	22.7
February	569.99	222.98	792.97	71.9	28.1
March	633.7	279.43	913.13	69.4	30.6
Total	**1885.64**	**702.66**	**2588.3**	**72.9**	**27.1**

Generation Availability

Hydro power plants recorded high percentages of generation availability in the first quarter of 2010.Table 4 shows the availability of the generation stations during the period under review. At Takoradi Thermal Power Station, one generator's (32G2) availability was 80.15%. However the TTPS recorded a low value of 27.71% as presented in the table below.

Table 4: Generating Plants and their first quarter 2010 availabilities

Plant	Percentage (%) Availability
Akosombo Hydroelectric Plant	98.97
Kpong Hydroelectric Plant	99.01
Takoradi Thermal Power Plant-T1 (TAPCO)	27.71
Takoradi Thermal Power Plant-T2 (TICO)	90.5
Tema Thermal Power Plant-T1 (TT1PP)	98.25
Mines Reserve Plant (MRP)	76

Power Supply Risk (Fuel)

Due to the inability of VRA to purchase Light Crude Oil to run the Tema Thermal Station one (TT1PP) about 30MW of electric power had to be shed in January 2010.

Load Shedding

The period under review recorded a number of insufficient generation incidences which resulted in the shedding of 10 MW and 30 MW of power in the NED and ECG's operational areas respectively.

There were however planned 60 MW week day off peak and 90 MW weekday peak period load reduction incidences in Accra. This was to enable a contractor to remove and re-string some portions of the existing Volta-Achimota transmission lines to allow for the stringing of the new Aboadze-Volta 330kV line to the Volta switchyard.

Power supply to Accra is normally served through three lines from the Volta substation at Tema. An outage on any of these lines results in transmission capacity constraints from Tema to Accra. The load shedding was therefore a necessary measure to prevent the overloading of the two remaining lines during the outage period in order to ensure the stability and security of the national grid.

POWER SUPPLY AVAILABILITY

Low Voltage Feeders

The GRIDCo network registered a 99.21%, 99.53% and 99.28% feeder availability for the months of January, February and March respectively. The first quarter average performance was 99.35% which exceeded the PURC target of 95.0%.

The table below shows the availability of low voltage feeders for the first quarter of the year.

Table 5: Feeder Availability from GRIDCo's five operational areas-first quarter 2010

	Feeder Availability (%) per operational area					
Months	**Volta**	**Kumasi**	**Akosombo**	**Takoradi**	**Tamale**	**Average**
January	99.96	99.96	99.38	99.64	99.79	99.74
February	99.41	9910	99.10	99.28	98.26	99.03
March	99.87	99.10	98.98	99.1	99.33	99.28
1st Qtr Average						**99.35**

Transmission Lines

Transmission lines consisting of 69, 161 and 225kV recorded an average impressive performance of 99.54% availability, this was as a result of the ongoing substation obsolete equipment replacement and upgrade started last two years.

The table below shows first quarter 2010 performance of the transmission lines.

Month	Transmission Lines availability (%)
January	99.86
February	99.21
March	99.52
Average	**99.54**

Conclusions

1. The projected 2010 peak demand and energy consumption of 1,470 MW and 10,305 GWh respectively are to be supplied as follows:
   - Hydro - 6,360 GWh representing 62% of the total energy required
   - Thermal - 3,945 GWh representing the remaining 38%

   The generation of 3,945 GWh or 38%, would require higher stock levels of fuel (LCO and Diesel) than is currently the case. In fact about 19 cargoes of crude oil estimated at **US$ 665 Million** would be required to meet the projected energy needs for 2010. Also higher units' availability than is currently the case, would be required to meet this planned generation target.
2. The current (i.e. average of 21.93 GWh/day from hydro since the beginning of 2010) would be detrimental to the operation of the Akosombo plant, especially considering the Black Volta's imminent impoundment at Bui.
3. Until the commissioning of the 330 kV Aboadze-Volta line, 4th Volta-Achimota line and the compensation devices earmarked for 2010, the transmission network would continue to experience low voltages at most substations. Overall transmission would also exceed 5% at peak.
4. The commissioning of the 330 kV Aboadze-Volta and the 4th Volta-Achimota lines eliminates the current bottlenecks associated with the Takoradi-Tarkwa and the Volta-Achimota lines respectively.
5. Impoundment of the black Volta at Bui would decrease the inflow into the Akosombo reservoir and by implication the amount of energy that could be generated from Akosombo plant by about 18%

6. Installing an SVC at Kumasi would significantly improve substation voltages and overall transmission network performance.

7. The current inadequacies in transformer capacity are affecting supply delivery.

Recommendations

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

1. In 2010, a total amount of about **US$ 665 million** would be required by VRA to meet their thermal generation target. Considering the current low levels of tariff and the precarious financial conditions of the utilities, some financial support from the government would be required to ensure energy security for 2010. Alternatively, the PURC could increase the tariff charged by the utilities to their real economic levels to ensure that the utilities could generate enough revenue to run their operations.

2. Additionally, the almost 4,000 GWh thermal complementation which is equivalent to the output of about five 100 MW units running continuously throughout the year, means higher units availability and utilization than is currently the case. This means

   a. planned maintenance of units should be strictly adhered to

   b. Critical spares required for maintenance should be stocked at all times to reduce unit's outage time due to unavailability of spares

   c. Higher stock levels of fuel should be maintained at all times.

   Failure to adhere to the above recommendations could result in energy deficit in the order of about 1,000 GWh if the status quo remains.

3. GRIDCo should be well resourced and assisted to procure additional transformers, disconnect switches, breakers, etc to augment substations' transformation capacity and improve overall system security and reliability.

4. System Operations Department should try as much as possible to coordinate the maintenance programmes of the transmission lines and other infrastructure as well as the generators to achieve optimal despatch of units.

5. In view of the anticipated long period of impoundment of the black Volta at Bui, the drawdown of the Akosombo reservoir should be closely monitored to avert a situation that could render the Akosombo plant inoperable due to extreme low elevation.

6. The Engineering Department supported by the Finance Department should make all effort to ensure that the following network additions are realized and on time.

a. Commissioning of the 330 kV Aboadze-Volta transmission line
b. The construction and commissioning of the 4th Volta-Achimota line
c. The installation and commissioning of the reactive power compensation devices earmarked for 2010.

7. The 13.2 km Prestea-Bogoso line should also be re-constructed to eliminate the limiting link in that segment of the transmission network.

8. Operators particularly those at the System Control Centre should be extra vigilant to ensure that the recommended load reductions are followed under the indicated contingencies to reduce incidents of total collapse situations attributable to these critical lines outages.

9. SVC installation as a means of boosting dynamic voltage support is strongly recommended.

1.0 Introduction

In line with the mandate of Ghana Grid Company (GRIDCo) under the Grid Code and the Legislative Instrument (LI) to among others, carry out dispatching and transmission of electricity from facilities of wholesale suppliers to bulk customers in a secure, stable and reliable manner, GRIDCo hereby presents its Electricity Supply Plan for the year 2010.

The report addresses the demand outlook and estimated energy consumption for 2010, the corresponding generation scenario and the available network infrastructure to support the forecast demand and supply at the Bulk Supply Point (BSP) level. The report also discusses the risk factors, both generation and transmission, that could affect secure and reliable delivery of power for 2010.

A short-term (2011 and 2012) energy and demand outlook is also presented. The report finally presents the conclusions and recommendations based on the analyses carried out and their findings.

1.1 Demand Outlook

The maximum projected demand for 2010 is approximately 1,470 MW, which is approximately 3.3% or 47 MW increase over the 2009 figure of 1,423 MW. This maximum demand includes overall estimated peak transmission losses of about 5%. The summary of the 2010 projected peak demand and the actual peak recorded for 2009 is presented in the Table 2 below:

The detailed breakdown of the 2010 maximum demand is included in the appendix 4.

Table 2: Summary of 2010 and 2009 Demand

2010 - Estimated Peak Demand: 1,470MW	**2009- Actual maximum Peak: 1,423 MW**
MW	MW
Domestic Load - 1,383	Domestic Load - 1,263
Export - 86	Export - 120
VALCO - 1	VALCO - 1
	Inadvertent Exchange to CIE - 39

The 1 MW demand for VALCO is utilized for the running of some essential services at the plant.

1.1 Average Day Load (ADL)

The purpose of this average day load is to discuss the average system demand which is indicative of the system's load factor which in this case, is computed as 80%. The expected average day load for 2010 is about 1,235 MW. This is based on the assumption that for domestic load, the average day demand is about 80% of its value at peak, whilst for mining and other industrial loads they are kept at 100% of their values at peak.

1.2 Expected Energy Consumption

The total expected energy consumption for 2010 is 9,937 GWh. With overall transmission losses estimated at 3.7% of total energy to be consumed, or 368 GWh, *the total estimated energy requirement for 2010 is 10,305 GWh*. Transmission losses as mentioned above are an inevitable part of electricity transmission, since part of the energy to be transferred across the transmission network is dissipated as heat.

With the actual 2009 energy consumption of 10,116 GWh, the projected 2010 figure of 10,305 GWh is an increase of about two percent (1.9%) over the 2009 figure and in absolute terms, a growth of 189 Gwh.

The summary of the 2010 estimated energy consumption is presented in the Table 3 below:

Table 3: Summary of projected 2010 Energy Consumption

Load	Estimated Consumption (GWh)
Domestic	8,927
Export	1,005
VALCO	5
Losses	368

1.3 Projected Monthly Energy Consumption

The annual projected energy consumption is further broken down into monthly time steps. The monthly energy breakdown would assist in the weekly and daily energy planning and supply scheduling in accordance with generating plants maintenance schedules.

A summary of the monthly energy consumption is indicated in the Table 4 below.

Table 4: Summary of Monthly Energy Consumption (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VALCO	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
ECG	544.9	524.5	569.2	528.0	548.0	511.9	518.4	522.7	538.6	588.8	573.3	597.2
NED	58.10	56.68	63.76	58.18	58.18	55.41	55.29	57.83	58.97	62.34	62.60	62.04
MINES	123.7	112.2	124.5	119.8	122.5	118.4	122.4	124.1	123.6	124.4	121.9	123.4
Direct	12.63	12.77	12.42	12.18	12.88	12.81	10.81	13.69	13.15	13.77	14.25	13.76
Exports	88.40	83.40	89.60	83.50	82.50	83.30	88.50	88.50	83.50	83.50	90.50	93.50
Losses	30.67	29.26	31.85	29.71	30.54	28.98	29.48	29.90	30.31	32.34	31.97	32.98
Totals	**859.0**	**819.5**	**892.0**	**831.9**	**855.2**	**811.4**	**825.5**	**837.3**	**848.7**	**905.7**	**895.2**	**923.5**

The detailed monthly energy consumption breakdown is included in the appendix 3.

1.4 Projected Supply Scenario

In 2010, Generating Plants with their capacities and available generation levels indicated in the Table below are expected to provide the needed supply to match the projected demand:

Table 5: Installed Capacity and Available Generation Levels of Existing Plants

Plant	Total Installed Capacity (MW)	Nominal Generation (MW)
Akosombo Hydroelectric Plant	1020	900
Kpong Hydroelectric Plant	160	140
Takoradi Thermal Power Plant-T1 (TAPCO)	330	300
Takoradi Thermal Power Plant-T2 (TICO)	220	200
Tema Thermal Power Plant-T1 (TT1PP)	126	100
Mines Reserve Plant (MRP)	80	45
Tema Thermal Power Plant-T2 (TT2PP)	50	45

Based on the above figures, the total available generation capacity for 2010 is 1,730 MW. Compared with the estimated peak demand including losses of 1,470 MW, the reserve margin at peak period for 2010 is estimated as 260 MW corresponding to about 15% of total generation.

1.5 Monthly Energy Generation

In accordance with the projected monthly energy consumption indicated in Table 4 above, the projected monthly energy generation based on the estimated availability factors of the generating plants is presented in the Table 6 below.

Table 6: Summary of Monthly Energy Generation (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Akosomb	445.7	424.2	462.8	431.2	431.5	470.8	407.1	412.4	417.8	446.1	432.8	515.0
Kpong	89.34	84.85	92.77	86.44	86.11	93.78	81.23	82.30	83.17	89.03	86.57	103.4
T1	171.8	164.5	178.4	166.0	170.2	100.4	164.3	166.5	169.3	180.1	178.4	109.7
T2	83.45	80.71	86.65	81.53	98.84	80.38	128.4	109.0	110.2	118.0	126.6	145.6
TT1PP	68.72	65.19	71.36	66.79	68.50	66.03	44.40	66.99	68.14	72.46	70.73	49.61
Totals	**859.0**	**819.5**	**892.0**	**831.9**	**855.2**	**811.4**	**825.5**	**837.3**	**848.7**	**905.7**	**895.2**	**923.5**

Estimated Cost of Fuel Required for Thermal Generation

The total energy consumption of 10305 GWh in 2010 is projected to be supplied as follows:

- Hydro - 6,360 GWh
- Thermal - 3,945 Gwh

The generation of the 3,945 GWh thermal complementation would require approximately 19 cargoes of crude oil. With each cargo containing 405,000 barrels and the price of fuel estimated at US$ 87/bbl including incidental charges, the total amount required per cargo is approximately US$ 35 million.

Hence for the total 19 cargoes required for 2010, an amount of about US$ 665 million would be needed by VRA to meet the their thermal generation target for 2010.

1.6 Maximum Demand and Total Energy Consumption with VALCO

The purpose of this sub-section is to analyze the security of demand-supply scenario with the commencement of VALCO's operations. With optimal VALCO operations centred around two or more potlines, and each potline rated at 75 MW, overall system demand including losses would increase to about 1,703 MW when VALCO is assumed to be operating at a minimum of two potlines.

With this level of demand, the reserve capacity would decrease to just about 27 MW or just 1.6%.

1.7 Total Energy Supply

For the supply scenario indicated above, the two hydroelectric plants are expected to produce a total of 6,360 GWh. This level of generation is about 1,060 GWh or 17% higher than the long-term average of 5,300 GWh. The implication for this level of generation is that the Akosombo reservoir would be drawn down far below the recommended by about 17%.

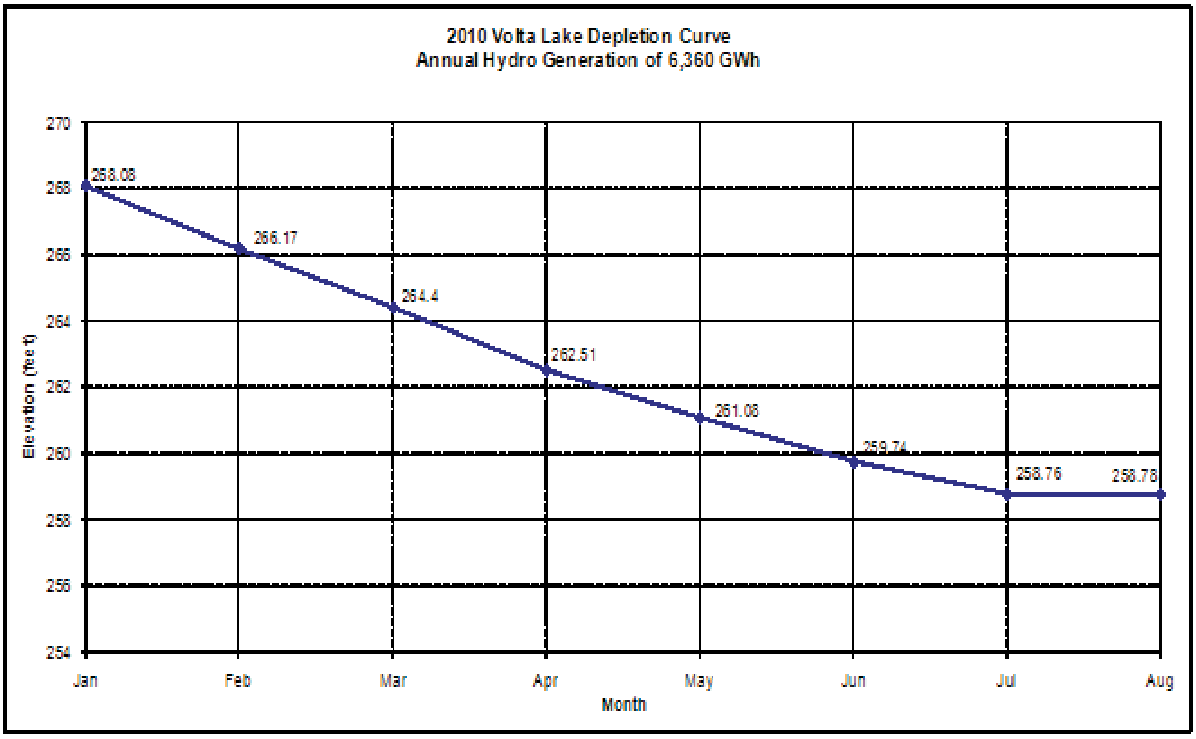
Based on the total hydro generation as indicated above, and the projected energy consumption of 10,305 GWh for 2010, the thermal plants are required to produce a total of 3,948 GWh to complement the hydro generation. This is equivalent to almost continuous operation of five (5) 110 MW thermal units throughout the year. Hence, considering the current availability rates of the generating plants, supply deficits of about 1000 GWh could occur if nothing is done to improve upon units' availability and fuel stock levels.

1.8 Reservoir Elevation Projection

Based on planned hydro generation for 2010, the projected reservoir trajectory is presented in the following Table 7 and the Depletion Curve.

Table 7: Akosombo Lake Elevations

Level	Height (ft)
Maximum elevation	278.0
Minimum elevation	240.0
Maximum recorded elevation in 2009	270.5 (on Nov 10, 2009)
Elevation at the end of 31st December, 2009	268.08
Projected draw down elevation at the end of the dry season in 2010.	258.76



The Table shows that at the end of the inflow season in 2009, the registered peak elevation of 270.5 ft fell short of the maximum elevation by just 7.5 ft. The Table also shows that between November 10, 2009 when the highest peak was recorded and the end of 2009, the lake was drawn down by 2.42 ft. Based on the estimated draw down rate in 2010, the reservoir elevation is expected to reach 258.76 ft by the end of the dry season.

1.9 Effect of Bui's Impoundment on the Akosombo Reservoir

As part of the development of the Bui Power Plant Project, the Black Volta on which the Bui Power Plant (BPP) is being built is expected to be impounded by February 2011. With this river being a major tributary of the Volta reservoir, contributing on the average 18% of the overall inflow to the lake, its impoundment is likely to affect the amount of energy that could be generated from the Akosombo Hydroelectric Plant.

The impoundment is expected to last for 22 months, i.e., from February 2011 to December 2012, when the commissioning of the plant is expected to commence. It is therefore imperative for the current water in the reservoir to be prudently and optimally utilized. This is to avert drawing down the lake to such low levels that has the potential to affect energy generation from the hydro plants with resultant effect on overall national energy security.

1.10 Plant Availability

The following Table presents the plant availability for 2010 based on the planned maintenance schedule of the generating units as presented by the current supplier – VRA. It is noted that the projected energy generation by the various plants takes into consideration the planned maintenance schedules and the corresponding percentage availability values of the various plants.

Table 8: Generating Plants and their estimated availabilities.

Plant	Percentage (%) Availability
Akosombo Hydroelectric Plant	96
Kpong Hydroelectric Plant	96
Takoradi Thermal Power Plant-T1 (TAPCO)	70
Takoradi Thermal Power Plant-T2 (TICO)	85
Tema Thermal Power Plant-T1 (TT1PP)	85
Mines Reserve Plant (MRP)	75
Tema Thermal Power Plant-T2 (TT2PP)	85

Import

No import is expected in 2010 apart from the usual inadvertent exchanges.

The detailed 2010 energy supply plan is presented included in the appendix 2 of the report.

1.11 Sensitivity Analysis with Gas from WAGP

The purpose of this sensitivity analysis is to evaluate the supply possibilities when gas from the West African Gas Pipeline (WAGP) becomes available. It is assumed that the flow of gas from the pipeline will be initially limited to the agreed amount for the foundation customer, in this case VRA. The volume of gas under this agreement is expected to be able to power only two gas turbines at Aboadze.

The completion and commissioning of Sunon-Asogli Power Plant (SAPP), is expected to add a further 180 MW to the existing thermal capacity. However, with SAPP designed to run on gas only, the overall generating capacity in 2010 could be boosted by a further 180 MW to 1,910 MW if an agreement could be reached between VRA and SAPP to allow SAPP to utilize the initial volume of gas. It is our understanding that there is currently no formal agreement to that effect, though, the two companies had engaged in some discussions in the past.

Operation of SAPP would shore up the slim generation reserve margin to 374 MW or approximately 20% of total generation.

1.12 Overview of Short-Term (Two-Year) Load Forecast

This section discusses the short-term (2011-2012) demand and energy consumption forecast and the purpose is to guide planning in the short-term. The peak demand for 2011 and 2012 is expected to increase to 1,566 MW and 1,667 MW respectively. The corresponding projected energy consumption for 2011 and 2012 are 11,348 GWh and 12,536 GWh respectively.

A summary of the peak demand by the major consumers is as presented in Table 9 below:

Table 9: Summary of projected Demand for 2011 and 2012

	2011		2012	
	Demand (MW)	**Energy (GWh)**	**Demand (MW)**	**Energy (GWh)**
ECG	1,126	6,928	1,199	7,290
NED	124	800	132	832
Mines	208	1,678	222	2,363
Direct Customers	15	181	16	184
VALCO	1	5	1	5
Exports	92	1,319	98	1,380
Losses	78	436	83	482
Total	1,644	11,348	1,750	12,536

1.13 Transmission Network Analyses

To evaluate the overall impact of the demand-supply scenario on the security and reliability of the transmission system, requisite network analyses have been carried out. In particular, the analyses performed sought to investigate the following:

- Possible constraints to secure and reliable power evacuation from the generating stations to the load centres from the perspective of transmission line loadings.
- Substations' bus voltages in relation to overall network stability
- The ability of the entire power system to withstand a contingency (outage) of a single network element (e.g. transmission line, generator, transformer, etc)
- Levels of reactive power generation from the generators

- Adequacy or otherwise of overall reactive power compensation in the transmission network in achieving acceptable system voltages
- The overall transmission system losses both during the peak and the off-peak.

This way, the average annual transmission losses could be estimated.

1.14 Supply Risk Analyses

This sub-section seeks to analyse the possible risks to meeting the supply requirement for 2010 from the perspective of;

- Adequacy in available generation with adequate spinning and reserve capacities to meet the projected demand under all system conditions
- Adequacy in transmission capacity to support the demand-supply scenario under all system conditions
- Adequacy in transformer capacity to meet all substations' load

1.14.1 Adequacy in Supply with adequate Spinning and Reserve Capacities

c) In terms of Capacity

With the current supply situation beset with a number of problems, the supply of 1,470 MW or in energy terms 10,305 GWh in 2010 could encounter a number of challenges; the major ones being:

- Lower plants' availability rates than expected resulting from high units' outage rates and long planned maintenance periods due mostly to unavailability of critical spares.
- Inadequate fuel stocks to run the Thermal Plants. Whenever VRA is not able to secure the required financing to purchase the required quantity of fuel or if for any reason the delivery of fuel is delayed, there would be supply deficit and some load would have to be shed.
- The current overdependence on hydro is also a major risk. This could affect scheduled maintenance of units thereby endangering the integrity of the units with associated dire consequences. Overdependence on hydro also has the tendency of overdrawing the Akosombo reservoir to very low levels that could render the plant inoperable.

Hence considering the very low reserve capacity even with all the plants available, any situation that results in any of the plants going out of service would pose a major risk to supply security in 2010.

b) In terms of Energy

As indicated in section 1.3 above, the total energy requirement for 2010 is 10,305 GWh, including a loss component of 3.7%. With hydro projected to provide a total of 6,360 GWh, the remaining supply deficit of either 3,945 GWh, would have to be produced from the thermal plants. With the thermal plants currently reeling under the pressure of inadequate fuel levels, long maintenance periods than planned, higher forced outage rates and other difficulties, energy supply security in 2010 is likely to suffer some setbacks. In fact, a supply deficit of close to 1000 GWh is likely to be experienced when the status quo continues.

1.14.2 Adequacy in Transmission Capacity

On the transmission network, the major risks to supply security and reliability are;

1. Inadequacy in transmission capacity which could lead to transmission line overload. This phenomenon which is characteristic of the network mostly during the peak period is due to growth in demand over the years, which has not been accompanied by commensurate expansion or reinforcement of the transmission network.

2. Insufficient reactive power compensation which could lead to poor customer supply voltage. This condition is due to low customer-end power factors, leading to high generator reactive power output and transfer of such reactive power over long distances. The resultant effect is high transmission line losses and higher voltage drops which invariably affect the quality of supply voltage.

3. Inability of the transmission network to withstand any single contingency. This is as a result of low investment in the transmission network, such that the network does not satisfy what is called n-1 criterion – a measure of a transmission network's ability to withstand an outage of a single network element.

1.14.3 Adequacy in Transformer Capacity

The transmission system currently suffers from inadequate transformer capacity to the extent that most of our substations do not have what is termed a 'Firm Capacity' – a measure of a substation's ability to supply the same amount of total load when the largest transformer at the station is outaged. This transformer inadequacy phenomenon characterises most of our current substations to the extent that in some of the stations, there is only one transformer hence taking out that single transformer would mean all the customers being supplied from that station would be plunged into total "darkness" until the transformer is restored into service. Below are the characteristics of transformers and their loading levels at some of the major substations within the transmission network.

Table 10: Summary of key Substations Transformers and their Loading Levels

Substation	Transformer	Rating (MVA)	Loading as @ Oct. 2009	% of Rating
Achimota	5T1	50/66	59.90	90.76
	5T2	50/66	61.50	93.18
	5T3	50/66	63.30	95.91
	5T4	50/66	67.90	102.88
	5T5	50/66	68.60	103.94
New Tema	4T1	50/66	58.30	88.33
	4T3	50/66	60.20	91.21
Kumasi	13T1	13.7/18.2	18.70	102.75
	13T2	13.7/18.2	18.41	101.15
	13T3	50/66	69.70	105.61
	13T4	50/66	66.70	101.06

The criterion for normal operating conditions requires that transformers should not be loaded above 85% of their rated capacities, such that under emergency or contingency conditions, the loading could increase to 100% of the rated. However, as shown in the above Table, this important criterion is not being respected. In fact in Achimota and Kumasi, an overload condition is already being experienced during the normal operating conditions.

This state of affairs cannot be accommodated further since continuous overloading would shorten the life span of these transformers, leading to higher failure rates with attendant supply security implications.

2.0 Transmission System

During the last quarter of 2009, the Kumasi-Obuasi Transmission Project was completed and commissioned. The commissioning of the transmission configurations under this project has improved the power transfer capacity in the Obuasi-New Obuasi-Kumasi-Kenyasi transmission corridor.

In 2010 a number of transmission lines currently under construction and others planned for construction are expected to be completed and commissioned into service. These include the 330kV Aboadze-Volta line, fourth Volta-Achimota and the reconstruction of the Prestea-Bogoso line. The completion of these additional lines would further improve the capacity of the transmission network to be able to transfer higher levels of power and this would improve overall supply security in 2010.

A number of reactive power compensation devices are also expected to be installed and commissioned into service during the various quarters of the year. These reactive power additions are expected to improve overall system performance in the coming year. The summary of these network additions is as presented below:

1. Commissioning of 330 kV Aboadze-Volta Transmission Line
2. Construction and commissioning of the Volta-Achimota 4th Line
3. Installation and commissioning of shunt capacitor banks under the Reactive Power Compensation Project at the following key substations
   - Achimota - 80 MVArs
   - New Tema - 40 MVArs
   - Sunyani - 10.8 MVArs
   - Kumasi - 8.1 MVArs

Also planned for addition in 2010 to strengthen and improve network stability is the installation and commissioning of transformers at some substations within the network to augment overall transformation capacity. The substations are Winneba, Tafo, Ho and Tamale.

3.0 Projects Earmarked for Installation and Commissioning in 2010

In line with the current GRIDCo's objective of implementing strategic and systematic improvement of the National Interconnected Transmission System (NITS), the following projects have been earmarked for installation and commissioning in 2010. The completion of these projects is expected to improve overall system reliability, security and general quality of supply.

Transformers

GRIDCo has taken delivery of the following transformers and would install them as follows:

- Two 50/66 MVA, 161/34.5 kV transformers have been procured and would be installed at Takoradi
- Two 25/33 MVA, 161/34.5 kV transformers would installed at Winneba
- One 25/33 MVA, 161/34.5 kV transformer would be installed at Asawinso
- One 33/33/20 MVA, 161/34.5/11.5 kV transformer would be installed at Cape Coast, whilst a similar capacity transformer would be commissioned at Akwatia.

Shunt Capacitor Banks

A total of 138.9 MVAr shunt capacitor banks are due for installation as follows:

- Achimota - 80 MVArs
- New Tema - 40 MVArs
- Sunyani - 10.8 MVArs
- Kumasi - 8.1 MVArs

Disconnect Switches

Disconnect switches at the following critical substations would be replaced;

- Kumasi – Two defective ones
- Tafo – One defective
- Two defective ones and one at Dunkwa and Nkawkaw respectively
- All the old disconnect switches at Akosombo Switchyard and Volta substation at Tema are being replaced under a contract funded by the World Bank.

Transmission Lines

A fourth line from Volta Switchyard in Tema to Achimota Substation in Accra would also be constructed and commissioned at a total cost of .

4.0 System Performance and Analyses

As has been indicated in section 1 above, a number of network analyses were performed to evaluate the ability of the transmission network to support the forecast demand for 2010 and the corresponding supply plan under various system conditions. The analyses were mostly of the steady state nature to determine transmission line loadings, substation bus voltages and losses across the transmission network. Key transmission system constraints are also identified.

4.1 Planning Criteria

This section presents the planning criteria employed in assessing the results of the system analyses. The criteria consider the state of the transmission system under both normal and contingency (n-1) conditions

Normal condition is considered as the system state when all power system facilities are in service with no bus voltage and equipment loading violation registered. The detailed criteria for the normal system operating condition are presented below:

4.2 Normal System Operating Conditions

The normal system operating condition is defined as the operating condition with all the power system components in service. Under this operating condition the following criteria must be met:

a. Voltages at all HV substation buses should remain within 95% and 105% of their nominal values.

b. Power flow on all power transformers and transmission lines should not exceed 85% of their thermal ratings and transfer limits, respectively.

c. Loading of all generators should be within their respective generator capability curves.

d. Reactive power generation from all generators should not exceed the maximum ratings as determined by the capability curve.

4.3 Post-contingency System operating conditions

Contingency (n-1) condition is considered as the system state when a single power system element has been outaged with all the remaining facilities in service. The detailed criteria for the contingency system operating condition are presented below:

The post-contingency operating criteria as presented below should be met under this operating condition to ensure that the power system is operated in a secure manner:

a. Voltages at all HV substation buses should be within 90% and 110% of their nominal values.

b. Power flow on all transformers and transmission lines should not exceed their emergency thermal ratings and transfer limits, respectively. Similarly the loading of all generators should be within their emergency ratings.

c. Reactive power generation from generation plants should not exceed their capability limits.

4.4 Assumptions

Based on the demand forecast and the supply scenario, the following assumptions were made:
The following are the available generating facilities:

a) Hydro
- Akosombo Plant-6 Units @ 150MW each
- Kpong Plant - 4 Units @ 35MW each

b) East
- Tema Thermal Power Plant (TT1PP)-100MW

c) West
- Aboadze Thermal Plant – 4 Units @100MW each
- Inadvertent exchanges on the tie-line with CIE

All loads are modelled on the HV side of the power transformers with varying actual power factors as follows:

- Achimota, Kumasi, Takoradi, New Tema and Mallam - 0.87 pu
- Tamale, Techiman, Yendi, Sawla, Bolgatanga - 0.92 pu
- All other loads - 0.90 pu

4.5 Typical System load curve

The system peak period is estimated to cover a four-hour period starting from 6pm to about 10pm. It has also been established that for the rest of the day, the system load averages about 80% of the system peak.

Typical daily load curve for the maximum peak for 2009 and the corresponding generation profile are attached as appendix XI.

In view of the nature of the typical daily load curves as referred to above, the Average Day Load (ADL) was modelled as follows;

- Mines and Industrial loads are maintained at their peak values since they almost have a constant profile

- All other loads reduced to 80% of peak their coincident peak values.

4.6 Classification of Power Flow Cases

All the load flow cases that begin with subscript 1 refer to the peak loading conditions. Those cases with subscript 2 refer to the average day loading conditions.

For example, Case 1 – 0 – depicts the typical peak load system condition. Case 2 – 0 refers to a typical average day loading condition.

4.7 Results of System Analyses

To evaluate the network's ability to support the projected demand and energy consumption for 2010, the load flow analyses were carried in the following order or manner;

- Base Case.
- Base Case with 330 kV Aboadze-Volta in service.
- Base Case with 330 kV Aboadze-Volta and 4th Volta-Achimota in service.
- Base Case with Aboadze-Volta, 4th Volta-Achimota and planned compensation for 2010.
- Base Case with 30 MVAr SVC at Kumasi to assess the possible improvement in system voltage profile with an SVC at Kumasi.
- Maximum East Generation to find out how much maximum generation could be evacuated from the eastern section of the transmission network without any network violation.
- Maximum West Generation to find out how much maximum generation could be evacuated from the eastern section of the transmission network without any network violation.

Summary of Load Flow Results

The summary of the above load flow analyses are indicated in the Table 11 below. The detailed results are presented in the subsequent sections.

Table 11: Summary of Power Flow Analyses

Case	Substation Bus Voltages	Line Loadings	Transmission losses	Machine VAr Generation
Base Case	Most substations especially around Kumasi and the north have less than the required minimum of 152.5 kV with Tamale @ 130 kV or 0.809 pu	No line loading violation is recorded	Total transmission losses are 76.5 MW or about 5% of total generation	Akosombo units are generating on the average 70 MVArs per unit
Base case with 330 kV Abz-Vol	Adding the 330 kV line to the base case results in slight improvement in voltage – generally about 2kV increase in bus voltages are recorded	Loading on the two coastal lines are reduced by about 17 MW and the Takoradi-Tarkwa by 5 Mw	Transmission losses virtually remain unchanged compared with the base case	Machines VArs generation also generally remain unchanged
Base case with 330 kV Abz-Vol & 4th Vol-Ach	Voltage at Achimota and Mallam increases by about 2 kV whilst New Tema and experience 1 kV rise in voltage	The loading on the Vol-Ach lines are reduced by about 11%	Transmission losses are reduced by 2.1 MW, a drop of about 3% compared to the base case	No significant change in units VAr generation is recorded
Base case with 330 kV Abz-Vol, 4th Vol-Ach & Compensation	Compared with the base case, there is about 20 kV increase in voltage in the north whilst for Achimota and its surroundings the increase is about 6 kV	There is generally about 5% drop in line loadings across the network	Compared to the base case, there is about 9 MW or 12% drop in transmission losses	Machine VAr generation is significantly reduced, about 20 MVAr drop at Akosombo.
Base Case with an SVC at Kumasi	Compared to the base case there is about 9 kV and 15 kV improvement in voltage at Kumasi and Tamale respectively	There is slight reduction in line loadings on lines that mostly transport power towards Kumasi	4 MW reduction in losses is recorded	About 7 MVAr reduction in VAr generation is recorded at Aboadze and Akosombo plants

The above Table indicates the following:

1. The base case or the existing transmission network experiences very low voltages at most substations during the peak period. Transmission line losses are also very high, in the order of about 5% of total generation during the peak period. The acceptable level of transmission losses is 3%. Machines also generate a lot of reactive power.

2. The commissioning of the 330 kV Aboadze-Volta 330 kV line would impact positively on system voltages. It would also reduce loadings on lines transporting power from the Aboadze Plant. It would however, increase power flow on the Volta-Achimota lines.
3. Commissioning of the 4th line to Achimota would improve bus voltages at Achimota and its environs. It would also reduce overall transmission losses by about 3%. Loading on the existing Volta-Achimota lines would also reduce by about 11%.
4. With the existing transmission network, installing only a 30 MVAr SVC at Kumasi clears most of the undervoltage conditions with Kumasi and Tamale voltages increased by as much as 9 kV and 15 kV respectively. Transmission losses also reduce by about 5%, with each machine 's VAr generation reduced by 7 MVArs on the average.
5. Complementing the 4th Volta-Achimota line with the scheduled installation of capacitor banks at Achimota – 80 MVArs, New Tema – 40 MVArs, Sunyani - 10.8 MVArs and Kumasi – 8.1 MVArs; improve all substations' voltages to within the acceptable limit of between 152.95 kV to 169.05 kV. Overall transmission losses are also reduced by about 12%. All machines' VAr generation are reduced to within the rated values.

The load flow analyses also indicate that the current power system could evacuate a maximum of 1311 MW from the eastern section of the transmission system. The limiting factor in this case, is the old Akosombo-Tafo Mistletoe line (A7F). The generation comprises the following:

- Akosombo GS - 891 MW
- Kpong GS - 140 MW
- SAPP - 180 MW
- TT1PP - 100 MW

For the maximum western generation, the power flow shows that a maximum of 630 MW could be evacuated, with the limiting factor being the Prestea-Bogoso line.

Detailed Load Flow Results

The detailed results of the load flow analyses are as presented below

It is to be noted that all the single line diagrams of the various load flow cases studied are included in the appendix 6.

4.7.1 Peak Load Steady State Cases

a) Base Case (1 - 0)

Available Generation

- Akosombo Plants – 6 Units, 150 MW each: Total 900 MW
- Kpong Plants – 4 Units , 35 MW each: Total 140 MW
- Aboadze T1-3 Units at 100 MW each: Total 300 MW
- Aboadze T2- 1 Unit at 100 MW each: Total 100 MW
- TT1PP G1 – 100 MW
- TT2PP – 45 MW
- MRPP – 45 MW
- Total Load 1470 MW without losses since actual losses would be calculated.

Summary of Results

The result of this scenario has total online generation of 1,547.5 MW comprising the peak demand of 1470 MW and the overall transmission losses of 76.5 MW. The result indicates that the base case violates the criteria for the normal system operating condition. The violations are mainly in the area of bus voltages in Kumasi and its environs and towards the north being less than 0.95pu.

The overall system losses are 76.5 MW, representing 4.9% of the total power generated.

- Kumasi – 0.855pu
- Tamale – 0.809pu

Machines' reactive power generation is as follows:

- Akosombo machines - averagely 70 MVArs per unit
- Aboadze machines - averagely 53 MVArs per unit

A summary of key substation voltages and Line loadings are included in the appendix 7.

b) Case 1.1: Base case with 330 kV Aboadze-Volta Line in Service

This case analyses the system performance with the 330 kV Aboadze-Volta line in service. It is therefore similar to the base case but with the 330 kV line in service. The result of this case shows on the average about 2 kV improvement in across the network

It also results in reduction of loadings on lines evacuating power from the Aboadze plant as follows:

- Coastal lines - 17 MW
- Takoradi-Tarkwa - 5 MW
- Aboadze-Prestea - 11 MW

Details of the line loadings and substation voltages are included in the appendix 7.

However, no reduction in overall transmission losses is recorded.

c) Case 1.2: Base Case with 330 kV Aboadze-Volta Line and 4th Volta-Achimota Line in Service

With this case, in addition to the 330 kV Aboadze-Volta line, the 4th Volta-Achimota line is in service.

The results show the following:

- Compared to the base case, system losses are reduced by about 2.1 MW
- Compared with the base case the loadings on the existing Volta-Achimota lines are reduced by about 12% (i.e. from 138 MVA to 121 MVA).
- There is about 2 kV improvement in voltage at Achimota and Mallam substations.

The details of the system improvement registered are recorded in the line loading and substation voltages included in the appendix 7.

d) Case 1.3: Base Case with 330kV Aboadze – Volta, Volta-Achimota 4th Line and Compensation

This case involves the following system additions:

- 330 kV Aboadze-Volta Line in Service
- 4th Volta-Achimota Line
- Shunt Capacitors earmarked for commissioning in 2010. The compensation includes Achimota – 80 MVArs, Tema – 40 MVArs, Sunyani – 10.8 MVArs and Kumasi – 8 MVArs.

The result of this case shows the following system improvements:

- About 9 MW 12% reduction in transmission losses compared to the base case.
- There is over 10 kV improvement in voltage at Kumasi and its environs compared to the base case
- Voltage improvement in the north (Tamale, Techiman, Yendi, etc) is about 20 kV.
- All lines are loaded below eighty percent (80%) of their thermal capacities.

The details of line loadings and voltages are included in the appendix 7.

e) Case 1.4: Base Case 30 MVAr SVC at Kumasi

This case analyses the effect of installing a 30 MVAr SVC at Kumasi on the current transmission network.

The result of this case shows the following system improvements:

- About 4 MW reduction in losses compared to the base case.
- There is over 9 kV improvement in voltage at Kumasi and its environs compared to the base case
- Voltage improvement in the north (Tamale, Techiman, Yendi, etc) is about 15 kV.
- Machines reactive power output is on the average, reduced by about 7.5 MVAr.

The details of line loadings and voltages are included in the appendix 1.

f): SAPP (180 MW) Replaces either TT1PP or Akosombo Unit

Analyses to evaluate the impact of the Sunon -Asogli Power Plant (SAPP) on system performance were carried out. It is expected that SAPP would produce a maximum of 180 MW with gas from the West African Gas Pipeline by mid 2010. Hence, commensurate reduction in generation was systematically carried out at Akosombo and Aboadze power stations in turns. The results of these analyses are as presented below:

f1) Case 1-5: *Reduction in Eastern Generation (Hydro-generation) with SAPP in operation*

The result of this case shows that substituting hydro generation with SAPP results in increase in system losses from the base case value of 76.5 MW to 85.5 MW representing 5.5% of total power generated.

The reason for this increase in losses is mostly the heavy loading on the 213 MVA Lilac line linking the Volta substation to the SAPP (i.e. about 85% of line capacity).

However, this scenario improves general voltage profile by about 3 kV. It marginally increases power flow on the Volta-Achimota line by about 2 MVA.

f2) Case 1-6: Reduction in Western Generation (TTPS) with SAPP in operation

The result shows the case with SAPP replacing two units at Aboadze. The result is similar to the previous case with higher transmission losses compared to the base case (i.e. at 96 MW or 6.1% of total generation).

This scenario as expected reduces power flow on the Takoradi-Tarkwa and Prestea - Bogoso lines by 13 MVA. It however, results in lower voltages at most substations with Kumasi and Tamale voltages reducing by about 4 kV and 3 kV respectively.

g) Cases 1.7&8: Maximum Eastern and Western Generation

The purpose of these two cases is to ascertain the maximum generation that the current transmission network could evacuate from the eastern and western sections of the power system. The results indicted the following:

- Maximum limit of eastern evacuation - 1, 311 MW with Akosombo-Tafo line being the bottleneck
- Maximum limit of western evacuation - 630 MW with Prestea-Bogoso line being the bottleneck.

4.7.2 Average Day Case

a) Base Case (2-0)

This case shows the 2010 system average day conditions with total system load of 1,252.MW representing about 80% domestic load of peak load conditions. Mines and other industrial loads are still maintained at 100%.

The following generation units are in service;

- Akosombo Plants – 5 Units, 150MW each
- Kpong Plants – 4 Units , 35MW each
- Aboadze T1-3 Units at 100MW each
- TT1PP – 100MW

The overall system losses are 51.4 MW, representing 3.9% of the total power generated.

Tables showing key substation voltages and major line loadings are included in the appendix VI.

4.7.3 Critical Contingencies

A number of critical lines have been determined based on the amount of power they transmit and their relative power flows above the Surge Impedance Limit (SIL) levels. After a number of lines had been tested, the following line contingencies were identified as having the severest impact on the security and reliability of the power system at peak. They are

1. Akosombo - Kumasi Line
2. Prestea – Bogosu Line
3. Achimota - Volta Line
4. Aboadze – Cape Coast or Aboadze – Winneba Line
5. Akosombo – Tafo line-1

The results of the load flow analyses for these critical line contingencies are as presented below:

a) Case (1-7d): (Akosombo- Kumasi Contingency. peak load condition)

The result of the load flow simulation indicates the following:

- There is heavy reactive power flow from the Akosombo generating units towards the loads.
- The generators are producing over and above their reactive power limits.
- Transmission lines from Akosombo towards Kumasi are heavily overloaded.
- Voltages collapse from Kumasi towards the north which could lead to a system collapse.

Recommended solution to contingency

- ➢ Kumasi load should be reduced to about 100 MW, implying about 60 MW load shedding at Kumasi and its environs during the peak period with majority of the load shed at Kumasi substation until units' reactive power generation and line loadings reduce to acceptable limits.
- ➢ The permanent solution to this problem is the construction of the 330 kV Volta-Kumasi overlay.

b) Case (1-7b): (Prestea-Bogosu cont., peak load condition)

The result of the load flow simulation indicates the following:

- ➢ Partial voltage collapse from Kumasi to the north.
- ➢ Low Voltages recorded in the Western part of the Grid
- ➢ Heavy reactive power generation from all the generating units

Recommended solution to contingency

- ➢ Kumasi load should be reduced to about 100 MW, implying about 60 MW load shedding at Kumasi and its environs during the peak period with majority of the load shed at Kumasi substation until units' reactive power generation and line loadings reduce to acceptable limits.
- ➢ The construction of the 330 kV Aboadze-Prestea-Kumasi transmission lines eliminates this limitation.

c) Case (1-7a): (Achimota-Volta Contingency., peak load condition)

The result of the load flow simulation indicates the following:

- ➢ Low voltages from Kumasi to the north.
- ➢ The two adjacent Achimota-Volta lines get overloaded.

<u>*Recommended solution to contingency*</u>

- Shed about 50 MW load in Achimota substation until units' reactive power generation and line loadings return to acceptable limits
- Commissioning of the 4th Volta-Achimota lines clears this problem

d) Case (1-7) (Aboadze – Winneba Cont., peak load condition)

The result of the load flow simulation indicates the following:

- Slight reduction in system voltages compared to the 2010 base case (1-0).
- Increased units reactive power generation compared to the base case
- The following lines get overloaded as shown in the table below;

<u>*Recommended solution to contingency*</u>

- Shed about 50 MW load at Mallam and 10 MW at Cape Coast substations until units' reactive power generation and line loadings reduce to acceptable limits
- Commissioning of the 330 kV Aboadze-Volta lines eliminates this limitation.

5.0 FIRSTQUARTER 2010 PERFORMANCE

5.1 MAXIMUM SYSTEM DEMAND

The first quarter of 2010 recorded a maximum coincident system peak load of 1,435.9 MW. This system peak occurred on 28th January, 2010 at 20:00hrs GMT, on this day Ghana's domestic peak load was 1308MW. As compared with the first quarter of 2009, the first quarter peak indicates a 9% increase.

Table12: System Peak Demand for first quarter 2010

Major Customers	S. Peak (MW) 1ST Qtr 2010	S. Peak (MW) 1ST Qtr 2009	Change(MW)
ECG	1,049.21	916.77	132.44
NED	103.52	91.8	11.72
MINES	181.44	171.22	10.22
EXPORT	127	137	10
SYSTEM PEAK (coincident)	1435	1309	126

5.2 GENERATION

a) Energy Generation

Total energy generated during the first quarter of 2010 is 2,558.3GWh; this is made up of 1,885.64GWh from Akosombo and Kpong hydro generation plants and 702.66GWh of energy from TICO, TTPP, MRPP and TT1PP thermal generation plants. Generation mix at the end of the first quarter is 72.9% and 27.1% for hydro and thermal respectively.

The generation breakdown for first quarter 2010 is shown in table 2 below.

Table 13: Total energy generated from hydro and thermal plants-first quarter 2010

	HYDRO GENERATION(GWH)				THERMAL GENERATION (GWH)				
MONTH	AKOSOMBO GS (GWH)	Dis/Cfs	KPONG GS (GWH)	Dis/Cfs	TTPP	TICO	MRPP	TT1PP	TT2PP
JAN.	583.76	1486236	98.19	1405328.	58.94	119.65	14.08	7.58	-
FEB.	486.25	1260065	83.74	1195355	56.66	98.57	1.6	60.45	5.7
MAR.	539.99	1415165	93.71	1329508	65.19	139.43	2.44	66.97	5.4
TOTAL	**1610**	**4161466**	**275.64**	**3930191**	**180.79**	**357.65**	**18.12**	**135**	**11.1**

Table 14: Hydro and Thermal Power Generation Mix for first quarter 2010

Months	Total Hydro (GWH)	Total Thermal (GWH)	Total	Hydro (%)	Thermal (%)
January	681.95	200.25	882.2	77.3	22.7
February	569.99	222.98	792.97	71.9	28.1
March	633.7	279.43	913.13	69.4	30.6
Total	**1885.64**	**702.66**	**2588.3**	**72.9**	**27.1**

b) Generation Availability

Hydro power plants recorded high percentages of generation availability in the first quarter of 2010.Table 4 shows the availability of the generation stations during the period under review. At Takoradi Thermal Power Station, one generator's (32G2) availability was 80.15%. However the TTPS recorded a low value of 27.71% as presented in the table below.

Table 15: Generating Plants and their first quarter 2010 availabilities

Plant	Percentage (%) Availability
Akosombo Hydroelectric Plant	98.97
Kpong Hydroelectric Plant	99.01
Takoradi Thermal Power Plant-T1 (TAPCO)	27.71
Takoradi Thermal Power Plant-T2 (TICO)	90.5
Tema Thermal Power Plant-T1 (TT1PP)	98.25
Mines Reserve Plant (MRP)	76

c) Power Supply Risk (Fuel)

Due to the inability of VRA to purchase Light Crude Oil to run the Tema Thermal Station one (TT1PP) about 30MW of electric power had to be shed in January 2010.

d) Load Shedding

The period under review recorded a number of insufficient generation incidences which resulted in the shedding of 10 MW and 30 MW of power in the NED and ECG's operational areas respectively.

There were however planned 60 MW week day off peak and 90 MW weekday peak period load reduction incidences in Accra. This was to enable a contractor to remove and re-string some portions of the existing Volta-Achimota transmission lines to allow for the stringing of the new Aboadze-Volta 330kV line to the Volta switchyard.

Power supply to Accra is normally served through three lines from the Volta substation at Tema. An outage on any of these lines results in transmission capacity constraints from Tema to Accra. The load shedding was therefore a necessary measure to prevent the overloading of the two remaining lines during the outage period in order to ensure the stability and security of the national grid.

5.3 POWER SUPPLY AVAILABILITY

a) Low Voltage Feeders

The GRIDCo network registered a 99.21%, 99.53% and 99.28% feeder availability for the months of January, February and March respectively. The first quarter average performance was 99.35% which exceeded the PURC target of 95.0%.

The table below shows the availability of low voltage feeders for the first quarter of the year.

Table 16: Feeder Availability from GRIDCo's five operational areas-first quarter 2010

	Feeder Availability (%) per operational area					
Months	**Volta**	**Kumasi**	**Akosombo**	**Takoradi**	**Tamale**	**Average**
January	99.96	99.96	99.38	99.64	99.79	99.74
February	99.41	9910	99.10	99.28	98.26	99.03
March	99.87	99.10	98.98	99.1	99.33	99.28
1st Qtr Average						**99.35**

b) Transmission Lines

Transmission lines consisting of 69, 161 and 225kV recorded an average impressive performance of 99.54% availability, this was as a result of the ongoing substation obsolete equipment replacement and upgrade started last two years.

The table below shows first quarter 2010 performance of the transmission lines.

Table 17: Transmission Lines availability for the first quarter 2010

Month	Transmission Lines availability (%)
January	99.86
February	99.21
March	99.52
Average	**99.54**

6.0 Conclusions

6.1 Conclusions

1. The projected 2010 peak demand and energy consumption of 1,470 MW and 10,305 GWh respectively are to be supplied as follows:
   - Hydro - 6,360 GWh representing 62% of the total energy required
   - Thermal - 3,945 GWh representing the remaining 38%

   The generation of 3,945 GWh or 38%, would require higher stock levels of fuel (LCO and Diesel) than is currently the case. In fact about 19 cargoes of crude oil estimated at **US$ 665 million** would be required to meet the projected energy needs for 2010. Also higher units' availability than is currently the case, would be required to meet this planned generation target.
2. The current (i.e. average of 21.93 GWh/day from hydro since the beginning of 2010) would be detrimental to the operation of the Akosombo plant, especially considering the Black Volta's imminent impoundment at Bui.
3. Until the commissioning of the 330 kV Aboadze-Volta line, 4th Volta-Achimota line and the compensation devices earmarked for 2010, the transmission network would continue to experience low voltages at most substations. Overall transmission would also exceed 5% at peak.
4. The commissioning of the 330 kV Aboadze-Volta and the 4th Volta-Achimota lines eliminates the current bottlenecks associated with the Takoradi-Tarkwa and the Volta-Achimota lines respectively.
5. Impoundment of the black Volta at Bui would decrease the inflow into the Akosombo reservoir and by implication the amount of energy that could be generated from Akosombo plant by about 18%
6. Installing an SVC at Kumasi would significantly improve substation voltages and overall transmission network performance.
7. The current inadequacies in transformer capacity are affecting supply delivery.

7.0 Recommendations

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

1. In 2010, a total amount of about **US$ 665 million** would be required by VRA to meet their thermal generation target. Considering the current low levels of tariff and the precarious financial conditions of the utilities, some financial support from the government would be required to ensure energy security for 2010. Alternatively, the PURC could increase the tariff charged by the utilities to their real economic levels to ensure that the utilities could generate enough revenue to run their operations.
2. Additionally, the almost 4,000 GWh thermal complementation which is equivalent to the output of about five 100 MW units running continuously throughout the year, means higher units availability and utilization than is currently the case. This means
    a. planned maintenance of units should be strictly adhered to
    b. Critical spares required for maintenance should be stocked at all times to reduce unit's outage time due to unavailability of spares
    c. Higher stock levels of fuel should be maintained at all times.

Failure to adhere to the above recommendations could result in energy deficit in the order of about 1,000 GWh if the status quo remains.

3. GRIDCo should be well resourced and assisted to procure additional transformers, disconnect switches, breakers, etc to augment substations' transformation capacity and improve overall system security and reliability.
4. System Operations Department should try as much as possible to coordinate the maintenance programmes of the transmission lines and other infrastructure as well as the generators to achieve optimal despatch of units.
5. In view of the anticipated long period of impoundment of the black Volta at Bui, the drawdown of the Akosombo reservoir should be closely monitored to avert a situation that could render the Akosombo plant inoperable due to extreme low elevation.
6. The Engineering Department supported by the Finance Department should make all effort to ensure that the following network additions are realized and on time.
    a. Commissioning of the 330 kV Aboadze-Volta transmission line
    b. The construction and commissioning of the 4th Volta-Achimota line
    c. The installation and commissioning of the reactive power compensation devices earmarked for 2010.
7. The 13.2 km Prestea-Bogoso line should also be re-constructed to eliminate the limiting link in that segment of the transmission network.

8. Operators particularly those at the System Control Centre should be extra vigilant to ensure that the recommended load reductions are followed under the indicated contingencies to reduce incidents of total collapse situations attributable to these critical lines outages.
9. SVC installation as a means of boosting dynamic voltage support is strongly recommended

APPENDIX

Table of Contents (Appendix)

1.0 TRANSFORMER LOADING

AREA: TAKORADI/PRESTEA **MONTH:** OCTOBER 2009

SUBSTATION	INSTALLED CAPACITY		MAX. DEMAND (MVA)		% LOADING THIS MONTH	% LOADING LAST MONTH	% CHANGE
	TRANSFORMER	RATING (MVA)	THIS MONTH	LAST MONTH			
CAPE COAST	7T1	13.3	12.97	9.46	97.52	71.13	26.39
	7T2	33.0	20.10	18.26	60.91	55.33	5.58
TAKORADI	8T1	33.0	26.53	25.53	80.39	77.36	3.03
	8T2	33.0	26.64	25.48	80.73	77.21	3.52
ESIAMA	42T1	33.0	7.94	7.23	24.06	21.91	2.15
PRESTEA	10T2	33.0	7.16	7.23	21.70	21.91	-0.21
BOGOSO	30T1	33.0	13.10	13.40	39.70	40.61	-0.91
	30T2	33.0	27.09	28.36	82.09	85.94	-3.85
TARKWA	9T1	33.0	22.62	31.01	68.55	93.97	-25.42
	9T3	33.0	23.50	37.25	71.21	112.88	-41.67
RELOCATED TARKWA	T1	33.0	14.36	-	-	-	-
	T2	33.0	14.57	-	-	-	-
NEW TARKWA	41T1	33.0	23.30	25.00	70.61	75.76	-5.15
	41T2	33.0	26.70	25.40	80.91	76.97	3.94
AKYEMPIM	42T1	33.0	11.90	11.50	36.06	34.85	1.21

Remarks: About 80 percent of the Tarkwa load has been transferred to the Relocated Tarkwa substation
Some load was transferred from 7T2 to 7T1 during planned maintenance at Cape Coast

Prepared by: V.Y. BOACHIE
FOR: AREA MANAGER

TRANSFORMER LOAD MONITORING SHEET

AREA : VOLTA

DATE: 6/11/09
MONTH: October '09

STATION	INSTALLED CAPACITY		MAXIMUM DEMAND (MVA)		% LOADING	% LOADING	% CHANGE
	Transfor-mers	Rating (MVA)	This month	Last month	This month	Last month	
ACHIMOTA	5T1	66	59.90	58.40	90.76	88.48	2.27
	5T2	66	61.50	62.20	93.18	94.24	-1.06
	5T3	66	63.30	61.80	95.91	93.64	2.27
	5T4	66	67.90	64.00	102.88	96.97	5.91
	5T5	66	68.60	64.10	103.94	97.12	6.82
MALLAM	37T1	66	54.90	52.80	83.18	80.00	3.18
	37T2	66	54.90	52.80	83.18	80.00	3.18
NEW TEMA	4T1	66	54.70	58.30	82.88	88.33	-5.45
	4T2	33	0.00	0.00	0.00	0.00	0.00
	4T3	66	60.20	57.50	91.21	87.12	4.09
	4T4	20	2.61	8.79	13.05	43.95	-30.90
	4T5	66	53.60	56.70	81.21	85.91	-4.70
SMELTER	3T1	20	0.00	0.00	0.00	0.00	0.00
	3T2	20	1.00	1.10	5.00	5.50	-0.50
	3T3	85	0.00	0.00	0.00	0.00	0.00
	3T4	85	0.00	0.00	0.00	0.00	0.00
	3T5	85	0.00	0.00	0.00	0.00	0.00
	3T6	85	0.00	0.00	0.00	0.00	0.00
	3T7	85	0.00	0.00	0.00	0.00	0.00
	3T8	85	0.00	0.00	0.00	0.00	0.00
WINNEBA	6T2	20	13.80	12.65	69.00	63.25	5.75

REMARKS:

Kofi Mensah
AREA MANAGER, VOLTA

TRANSFORMER LOADING MONITORING

AREA: *KUMASI* **MONTH:** *OCTOBER 2009*

SUBSTATION	INSTALLED CAPACITY		MAX. DEMAND (MVA)		%	%	%
	TRANSFORMERS	RATING (MVA)	THIS MONTH	LAST MONTH	LOADING THIS MONTH	LOADING LAST MONTH	CHANGE
KUMASI	13T1	18.2	18.70	19.20	102.75	105.49	-2.75
	13T2	18.2	18.41	17.38	101.15	95.49	5.66
	13T3	66.0	69.70	70.20	105.61	106.36	-0.76
	13T4	66.0	66.70	61.30	101.06	92.88	8.18
	13T5	33.0	0.00	0.00	0.00	0.00	0.00
OBUASI	12T1	20.0	10.04	10.53	50.20	52.65	-2.45
	12T2	20.0	18.68	17.31	93.40	86.55	6.85
	12T3	20.0	0.00	0.00	0.00	0.00	0.00
NEW OBUASI	21T1	33.0	20.23	22.57	61.30	68.39	-7.09
	21T2	33.0	11.97	12.46	36.27	37.76	-1.48
	21T3	33.0	15.74	16.34	47.70	49.52	-1.82
DUNKWA	11T1	7.0	2.53	2.40	36.14	34.29	1.86
ASAWINSO	20T1	13.3	8.81	8.47	66.24	63.68	2.56
	20T2	33.0	19.06	24.91	57.76	75.48	-17.73
KONONGO	18T1	7.0	5.49	4.85	78.43	69.29	9.14
NKAWKAW	14T1	13.3	11.58	11.04	87.07	83.01	4.06
KENYASI	43T1	53	34.80	32.10	65.66	60.57	5.09
	43T2	53	0.00	0.00	0.00	0.00	0.00

Remarks: Replacement bushing for 13T5 transformer is expected to be received from Takoradi Area in November to return 13T5 to service

PREPARED BY:

S. F. KWOFIE
AREA MANAGER

TRANSFORMER LOADING MONITORING SHEET

AREA: TAMALE

DATE: November 1, 2009

MONTH: October 2009

SUBSTATION	INSTALLED CAPACITY		MAXIMUM DEMAND (MVA)		PERCENTAGE LOADING		PERCENTAGE CHANGE
	TRANSFORMERS	RATING (MVA)	THIS MONTH	LAST MONTH	THIS MONTH	LAST MONTH	
TECHIMAN	26T1	20	17.30	17.40	86.50	87.00	-0.50
SUNYANI	27T1	20	16.80	16.80	84.00	84.00	0
	27T2	33	17.70	16.40	53.64	49.70	3.94
TAMALE	28T1	20	13.50	12.90	67.50	64.50	3.00
	28T2	20	12.20	11.90	61.00	59.50	1.50
BOLGA	29T1	20	10.50	15.00	52.50	75.00	-22.50*
YENDI	35T1	13.3	7.70	7.10	57.90	53.38	4.52
SAWLA	38T1	13.3	7.70	7.30	57.90	54.89	3.01
ZEBILLA	53T1	20	11.50	-	57.50	-	-

* The relatively high drop in loading at Bolga Substation was due to the re-energization of the New Zebilla Substation which has taken some load off the Bolga Substation.

Prepared By:

Anthony Godzi
AREA MANAGER

TRANSFORMER LOADING MONITORING SHEET

AREA : AKOSOMBO MONTH : OCTOBER 2009

SUBSTATION	INSTALLED CAPACITY		MAXIMUM DEMAND (MVA)		% LOADING THIS MONTH	% LOADING LAST MONTH	% CHANGE
	TRANSFORMERS	RATING (MVA)	THIS MONTH	LAST MONTH			
TAFO	15T1	13	9.70	8.84	74.62	68.00	6.62
	15T2	33	14.09	16.76	42.70	50.79	-8.09
AKWATIA	16T1	5	3.37	2.94	67.40	58.72	8.68
	16T2	13	11.37	10.63	87.46	81.77	5.69
KPONG	17T1	33	9.98	9.99	30.24	30.27	-0.03
	17T2	33	10.56	10.50	32.00	31.82	0.18
ASIEKPE	22T1	33	28.05	26.54	85.00	80.42	4.58
HO	23T1	7	5.87	5.71	83.86	81.57	2.29
KPEVE	24T1	7	3.35	3.16	47.86	45.14	2.71
KPANDO	25T1	20	8.91	8.65	44.55	43.25	1.30
SOGAKOPE	33T1	15	9.80	9.02	65.33	60.13	5.20
AFLAO	39T1	33	17.00	12.12	51.52	36.73	14.79
AKOSOMBO	1T7	13.3	9.11	9.11	68.50	68.50	0.00

Remarks:

Mark Aryee

Area Manager

1.0

VOLTA RIVER AUTHORITY

2010 Energy Supply Plan - DEMAND

Revised Thermal Maintenance Schedule

PROJECTED DEMAND	Jan (Projected)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Domestic (GWh)													
ECG	543	490	543	525	543	525	543	543	525	543	525	543	6,369
NED	61	55	61	59	61	59	61	61	59	61	59	61	719
Mines													
AngloGold Ashanti	46	42	46	45	46	45	46	46	45	46	45	46	546
PGR/NCM/Sankofa - Prestea	4	4	4	4	4	4	4	4	4	4	4	4	48
Goldfields Ghana Ltd	29	26	29	28	29	28	29	29	28	29	28	29	345
Bogoso Gold Ltd	18	16	18	18	18	18	18	18	18	18	18	18	213
Newmont	20	18	20	20	20	20	20	20	20	20	20	20	240
Wexford	7	6	7	7	7	7	7	7	7	7	7	7	83
Other Mines	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	3
Total Mines	*125*	*113*	*125*	*121*	*125*	*121*	*125*	*125*	*121*	*125*	*121*	*125*	*1,475*
ATL	3.2	2.9	3.2	3.1	3.2	3.1	3.2	3.2	3.1	3.2	3.1	3.2	37
Aluworks	2.4	2.1	2.4	2.3	2.4	2.3	2.4	2.4	2.3	2.4	2.3	2.4	28
Diamond Cement	3.7	3.3	3.7	3.6	3.7	3.6	3.7	3.7	3.6	3.7	3.6	3.7	44
EPZ	1.7	1.5	1.7	1.6	1.7	1.6	1.7	1.7	1.6	1.7	1.6	1.7	20
World Cool Ltd.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
Volta Hotel Ltd.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
Akosombo Township	2.2	2.0	2.2	2.1	2.2	2.1	2.2	2.2	2.1	2.2	2.1	2.2	26
Akuse Township	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	4
Aboadze Township	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2
Total Domestic Demand (GWh)	**743**	**671**	**743**	**719**	**743**	**719**	**743**	**743**	**719**	**743**	**719**	**743**	**6,748**
VALCO (GWh)	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	12
Sonabel (GWh)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	5
CEB Supply (GWh)	85	77	85	82	85	82	85	85	82	85	82	85	1,008
Generation and Substation Usage (GWh)	3	3	3	3	3	3	3	3	3	3	3	3	38
Transmission Losses (GWh)	29	26	29	28	29	28	29	29	28	29	28	29	337
Total Project Demand (GWh)	**861**	**778**	**861**	**833**	**861**	**833**	**861**	**861**	**833**	**861**	**833**	**861**	**10,138**

2010 Energy Supply Plan - SUPPLY

Revised Thermal Maintenance Schedule

Total Hydro Generation of 6,360 GWh

PROJECTED DEMAND AND SUPPLY	Jan (Projected)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
PROJECTED DEMAND	861	778	861	833	861	833	861	861	833	861	833	861	10,138
PROJECTED SUPPLY													
Hydro Supply													
Month Start Elevation (feet)	*268.1*	*266.2*	*264.4*	*262.5*	*261.1*	*259.7*	*258.8*	*258.8*	*260.4*	*264.9*	*267.2*	*266.3*	
Hydro Draft Rate (GWh/day)	*19.3*	*19.7*	*19.7*	*16.3*	*16.4*	*16.4*	*16.5*	*16.4*	*17.4*	*18.0*	*16.5*	*16.7*	*17.4*
Akosombo Generation (GWh)	497	460	508	407	423	410	425	425	435	466	412	430	5,300
Kpong Generation (GWh)	100	92	102	81	85	82	85	85	87	93	82	86	1,060
Total Hydro Generation (GWh)	597	553	610	488	508	492	510	510	522	559	495	516	6,360
Thermal Supply (GWh)													
T1- Steam Turbine (Steam)	0	0	0	54	57	54	56	56	54	56	54	57	497
T1- Gas Turbine (LCO)	71	64	71	108	103	108	112	112	108	112	108	103	1,178
T2 - Simple Cycle (LCO)	126	101	126	122	126	114	116	117	84	113	112	118	1,377
TT1PP - Simple Cycle (LCO)	67	60	54	60	67	65	67	67	65	22	65	67	726
TT2PP (Diesel)	-	-	-	-	-	-	-	-	-	-	-	-	0
MRP (Diesel)	-	-	-	-	-	-	-	-	-	-	-	-	0
Sunon-Asogli Power Plant (Gas)	-	-	-	-	-	-	-	-	-	-	-	-	0
Emergency Diesel Plants (Diesel)	-	-	-	-	-	-	-	-	-	-	-	-	0
Imports from Cote d'Ivoire	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Thermal Supply (GWh)	264	225	251	345	353	341	351	351	311	302	338	345	3,778
Total Supply (GWh)	**861**	**778**	**861**	**833**	**861**	**833**	**861**	**861**	**833**	**861**	**833**	**861**	**10,138**
CEB Wheeled (GWh)	27	24	27	26	27	26	27	27	26	27	26	27	313
Add. Supply Required (GWh)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Assumptions

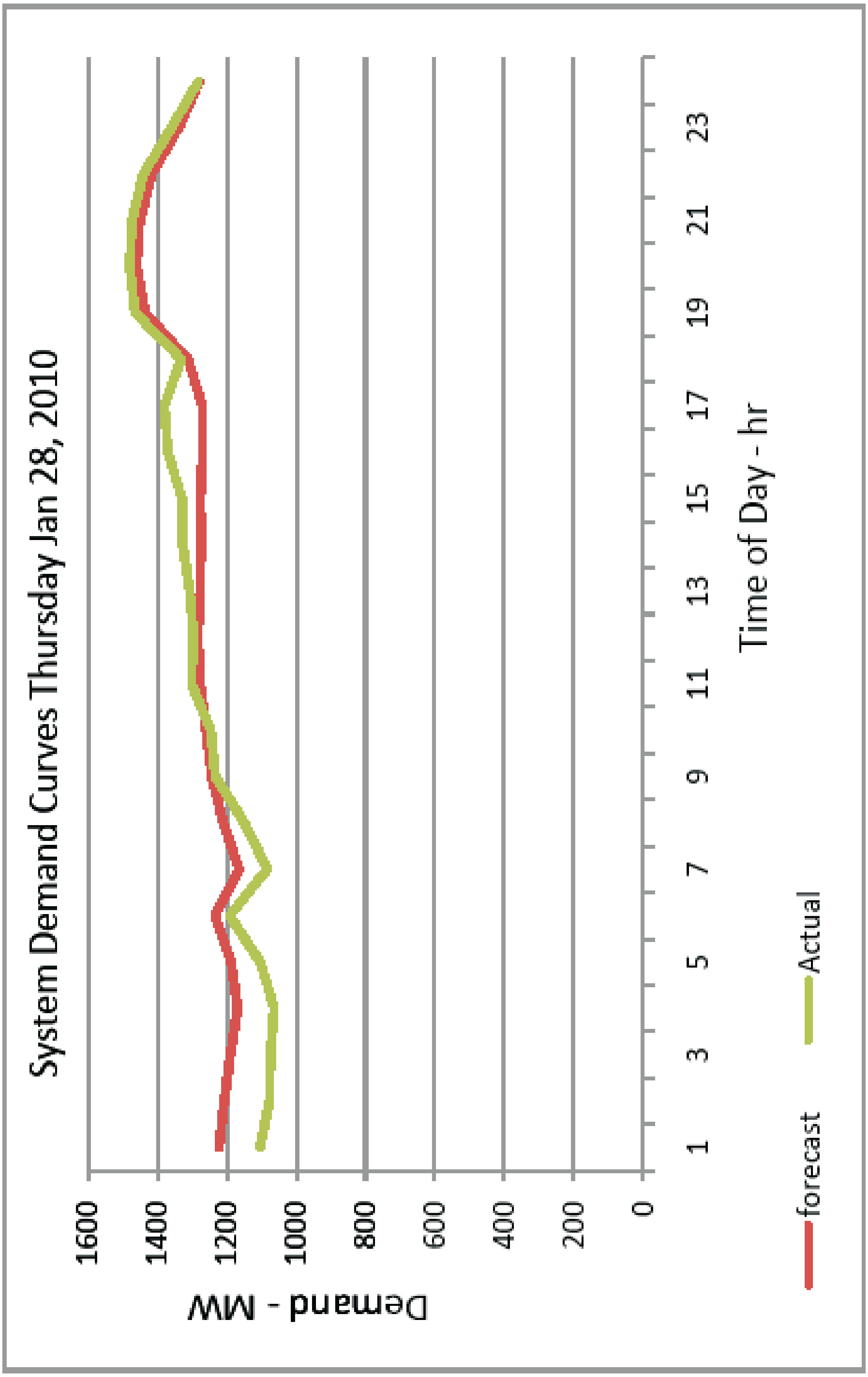
1. T1 to operate at 100 MW Simple Cycle with availability of 95% from January - March 2010
2. T1 to operate at 300 MW Combined Cycle with availability of 70% from April - December 2010
3. T2 available at 200 MW Simple Cycle with availability of 80%
4. TT1PP at 100 MW with availability of 85%
4. MRP at 40 MW with availability of 75%.
5. TT2PP at 45 MW at 85% availability
6. Guaranteed Imports of 100 GWh in 2010. Imports will be used when when available
7. Emergency Diesel Plants at 50 MW with 70% available - on standby
8. Domestic Demand based on 2009 - 2018 load forecast study.

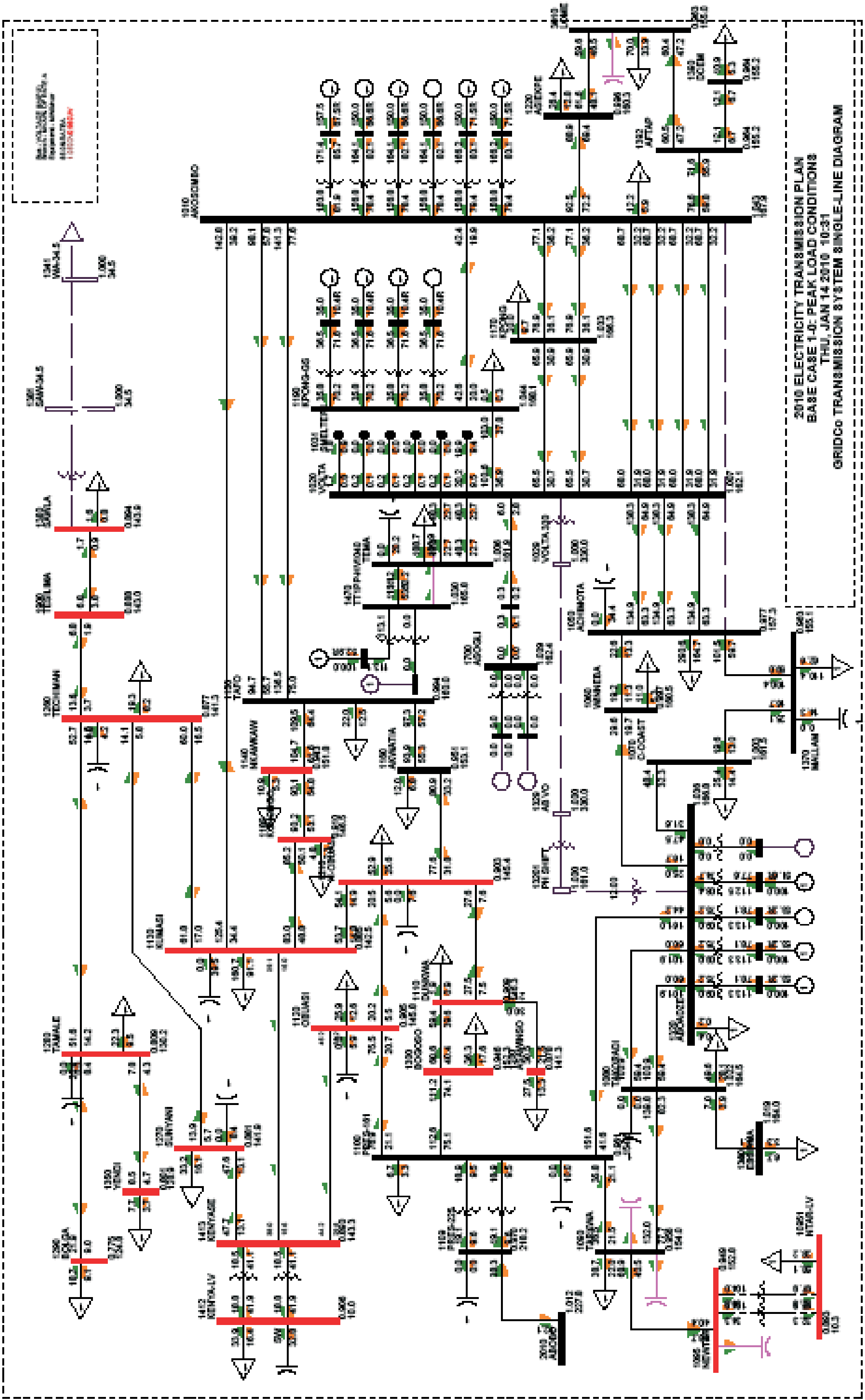
MONTHLY ENERGY FORECAST (GWH) 2010

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
VALCO	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	**6.40**
E.C.G.	544.929	524.567	569.290	528.026	548.080	511.965	518.468	522.751	538.659	588.885	573.374	597.28	**6,566.277**
NED	58.101	56.678	63.758	58.184	58.184	55.407	55.293	57.834	58.973	62.340	62.601	62.038	**709.39**
MINES	123.761	112.292	124.569	119.819	122.562	118.470	122.481	124.135	123.643	124.417	121.992	123.471	**1,461.61**
DIRECT CUSTOMERS													
EPZ	2.966	2.642	2.947	2.509	2.557	2.823	1.276	3.935	3.457	3.434	4.431	4.531	**37.51**
DIAMOND CEMENT	2.936	3.916	3.432	3.778	3.812	4.018	3.564	3.700	3.500	3.80	3.511	3.164	**43.13**
A.T.L.	2.625	2.249	1.977	2.079	2.341	2.103	2.047	2.223	2.514	2.565	2.418	2.084	**27.23**
ALUWORKS	0.900	0.850	0.820	0.700	0.880	0.710	0.840	0.750	0.670	0.750	0.840	0.870	**9.58**
AK'BO. TOWN	2.43	2.350	2.400	2.350	2.400	2.300	2.250	2.250	2.230	2.400	2.300	2.300	**27.96**
VRA AKUSE	0.326	0.326	0.384	0.328	0.373	0.330	0.337	0.323	0.316	0.331	0.311	0.320	**4.01**
ABOADZE (VRA)	0.139	0.129	0.144	0.147	0.172	0.185	0.182	0.177	0.167	0.182	0.184	0.183	**1.99**
WORLD COOL LTD	0.10	0.11	0.11	0.09	0.13	0.14	0.12	0.13	0.10	0.10	0.05	0.100	**1.28**
VOLTA HOTEL LTD	0.07	0.06	0.07	0.07	0.08	0.06	0.06	0.07	0.06	0.07	0.06	0.070	**0.82**
S. ASOGLI PLANT	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**0.135**	**1.62**
EXPORTS													
SONABEL &YOUGA MINES)	3.40	3.40	3.60	3.50	3.50	3.30	3.50	3.50	3.50	3.50	3.50	3.50	41.70
C.E.B.	85.00	80.00	86.00	80.00	79.00	80.00	85.00	85.00	80.00	80.00	87.00	90.00	**997.00**
LOSSES	30.67	29.26	31.85	29.71	30.54	28.98	29.48	29.90	30.31	32.34	31.97	32.98	**367.99**
TOTAL	**859.02**	**819.50**	**892.03**	**831.95**	**855.28**	**811.46**	**825.57**	**837.34**	**848.77**	**905.78**	**895.22**	**923.56**	**10,305.49**

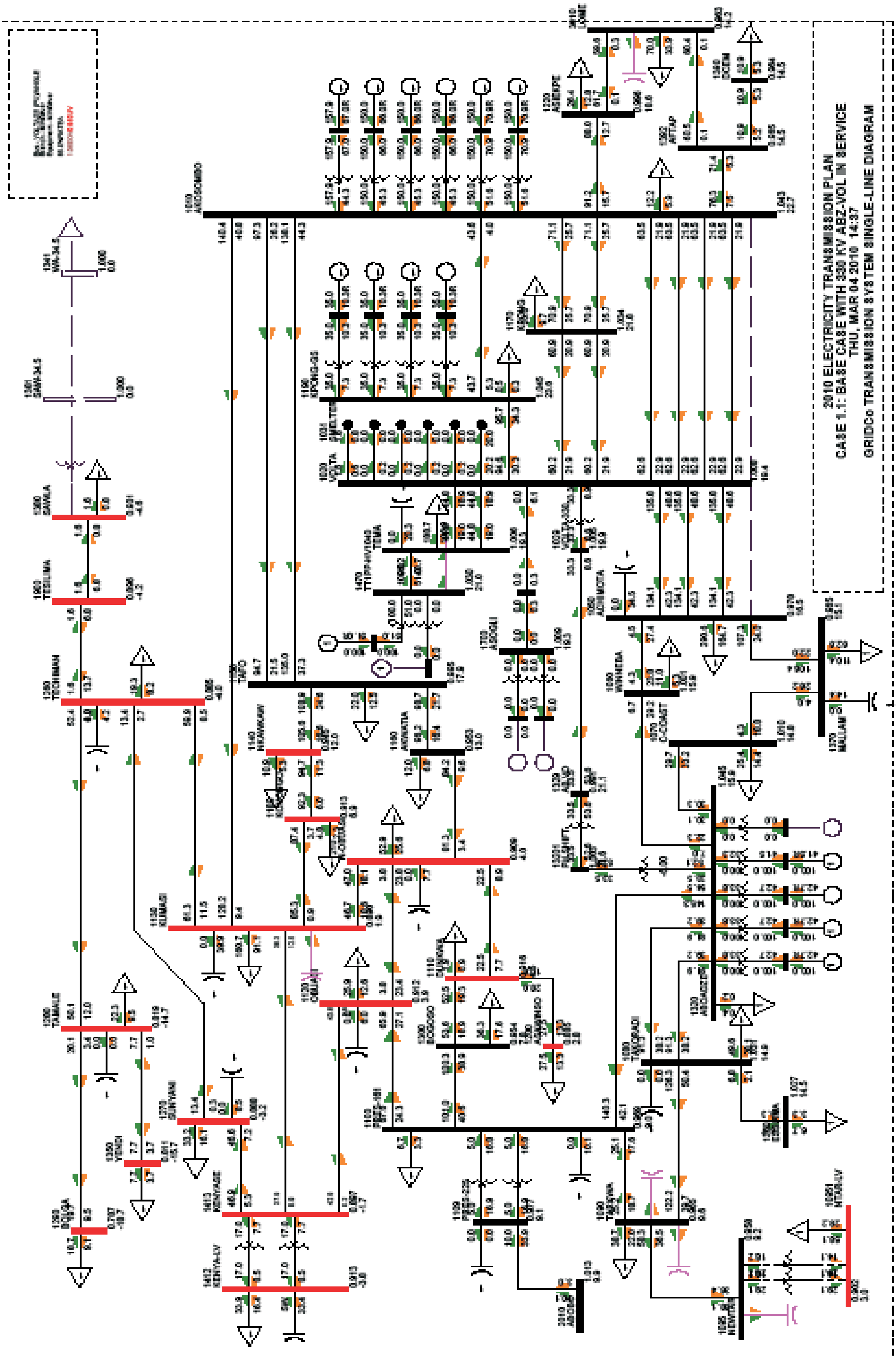
Coincident Peak Demand Forecast by Customer and BSP (MW)

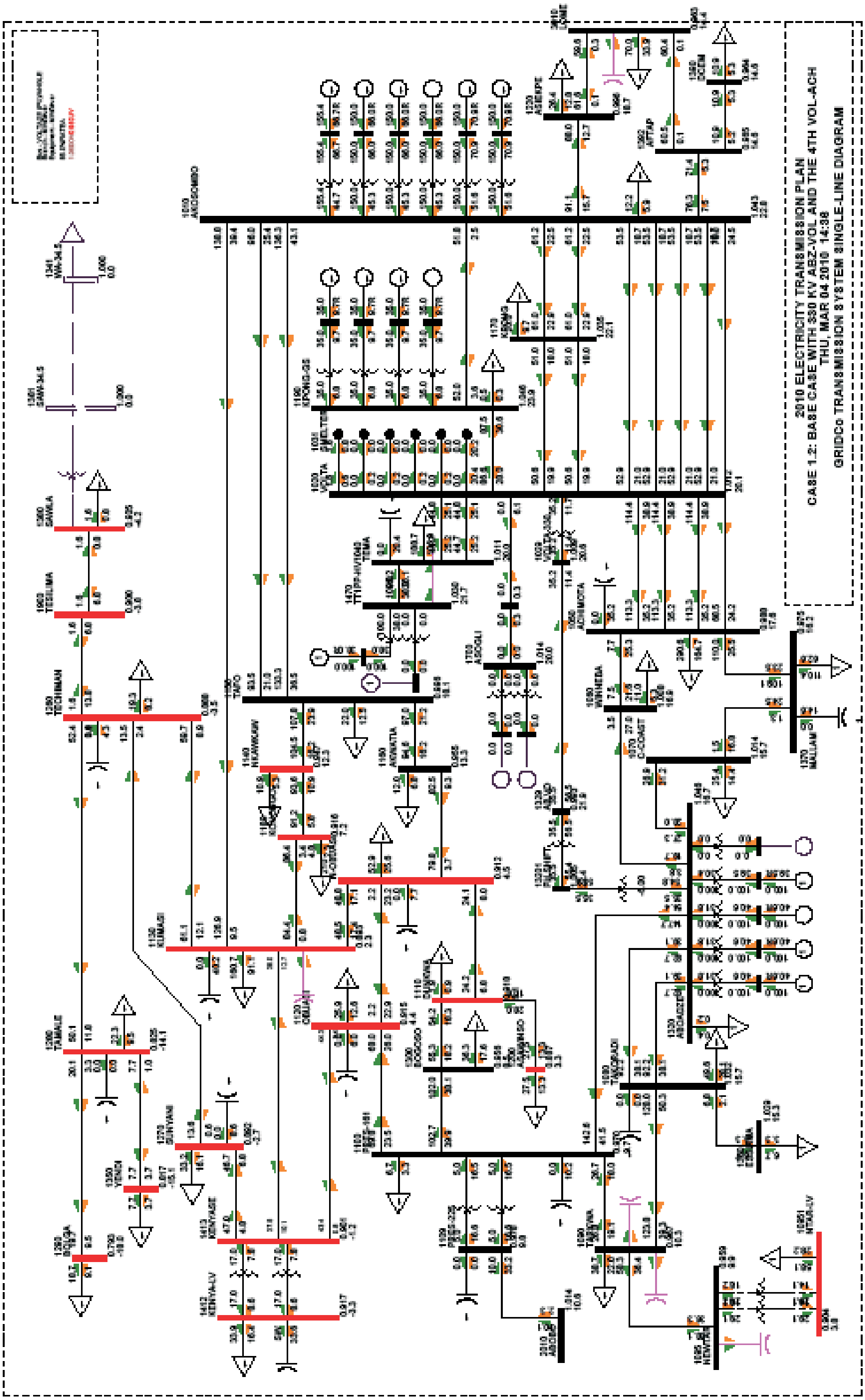
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ECG	922.0	937.3	993.6	1,057.7	1,125.9	1,198.5	1,275.8	1,358.1	1,418.6	1,481.7	1,547.6	1,616.5	1,688.4
NED	**91.9**	**88.4**	**109.7**	**116.8**	**124.3**	**132.3**	**140.9**	**149.9**	**156.6**	**163.6**	**170.9**	**178.5**	**186.4**
Mines													
Obuasi & New Obuasi	53.2	53.1	53.0	56.4	60.0	63.9	68.0	72.4	75.6	79.0	82.5	86.1	90.0
Prestea	5.5	5.5	6.0	6.3	6.7	7.2	7.6	8.1	8.5	8.9	9.3	9.7	10.1
Dunkwa	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tarkwa	23.9	30.7	56.8	60.5	64.3	68.5	72.9	77.6	81.1	84.7	88.5	92.4	96.5
Bogosu	34.2	25.9	27.5	29.2	31.1	33.1	35.3	37.5	39.2	40.9	42.8	44.7	46.7
Konongo	0.04	0.04	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Akwatia	1.3	1.3	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8
Asawinso	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nkawkaw (Newmont)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tafo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ahafo/Kenyase (Newmont)	23.7	30.5	30.2	32.1	34.2	36.4	38.8	41.3	43.1	45.0	47.0	49.1	51.3
Akyempem (Wexford)	7.9	8.2	9.9	10.6	11.3	12.0	12.8	13.6	14.2	14.8	15.5	16.2	16.9
Other Mines	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	149.9	**155.3**	**183.8**	**195.7**	**208.3**	**221.7**	**236.0**	**251.2**	**262.4**	**274.1**	**286.3**	**299.0**	**312.3**
Direct Customers													
Akosombo Textiles	3.5	3.9	3.5	3.7	4.0	4.2	4.5	4.8	5.0	5.2	5.4	5.7	5.9
Aluworks	3.7	2.3	2.1	2.2	2.4	2.5	2.7	2.9	3.0	3.1	3.3	3.4	3.6
Export Processing Zone	1.6	2.0	1.7	1.9	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.8	3.0
Diamond Cement	3.6	3.6	3.2	3.4	3.6	3.8	4.1	4.3	4.5	4.7	5.0	5.2	5.4
WorldCool	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Volta Hotel	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Akuse Township	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Akosombo Township	2.0	2.1	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.9	3.0	3.1
Aboadze Township	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
	15.3	**14.7**	**13.1**	**14.0**	**14.9**	**15.8**	**16.8**	**17.9**	**18.7**	**19.6**	**20.4**	**21.3**	22
Valco	118.0	75.0	68.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Exports													
CEB	37.2	68.9	80.0	85.2	90.7	96.5	102.7	109.3	114.2	119.3	124.6	130.2	135.9
CIE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SONABEL	1.0	0.9	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.6
	38.2	**69.8**	**80.9**	**86.1**	**91.7**	**97.6**	**103.9**	**110.6**	**115.5**	**120.7**	**126.0**	**131.6**	**138**
System Peak (MW)	**1,335.3**	**1,340.4**	**1,449.6**	**1,471.2**	**1,566.1**	**1,667.0**	**1,774.5**	**1,888.9**	**1,972.9**	**2,060.6**	**2,152.3**	**2,248.0**	**2,348.0**

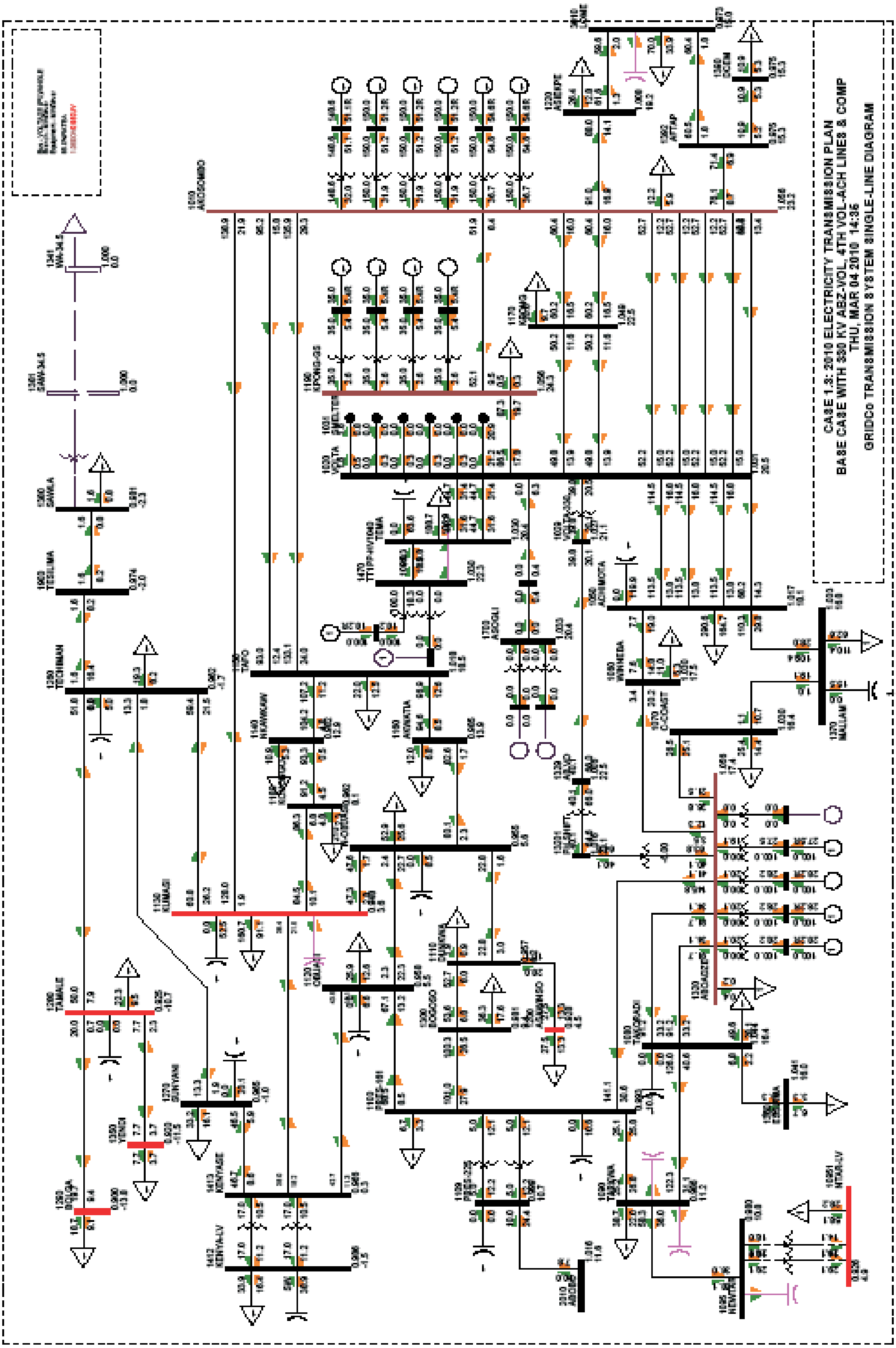

System Demand Curves Thursday Jan 28, 2010
Demand - MW
1600
1400
1200
1000
800
600
400
200
0
1
3
5
7
9
11
13
15
17
19
21
23
Time of Day - hr
forecast
Actual

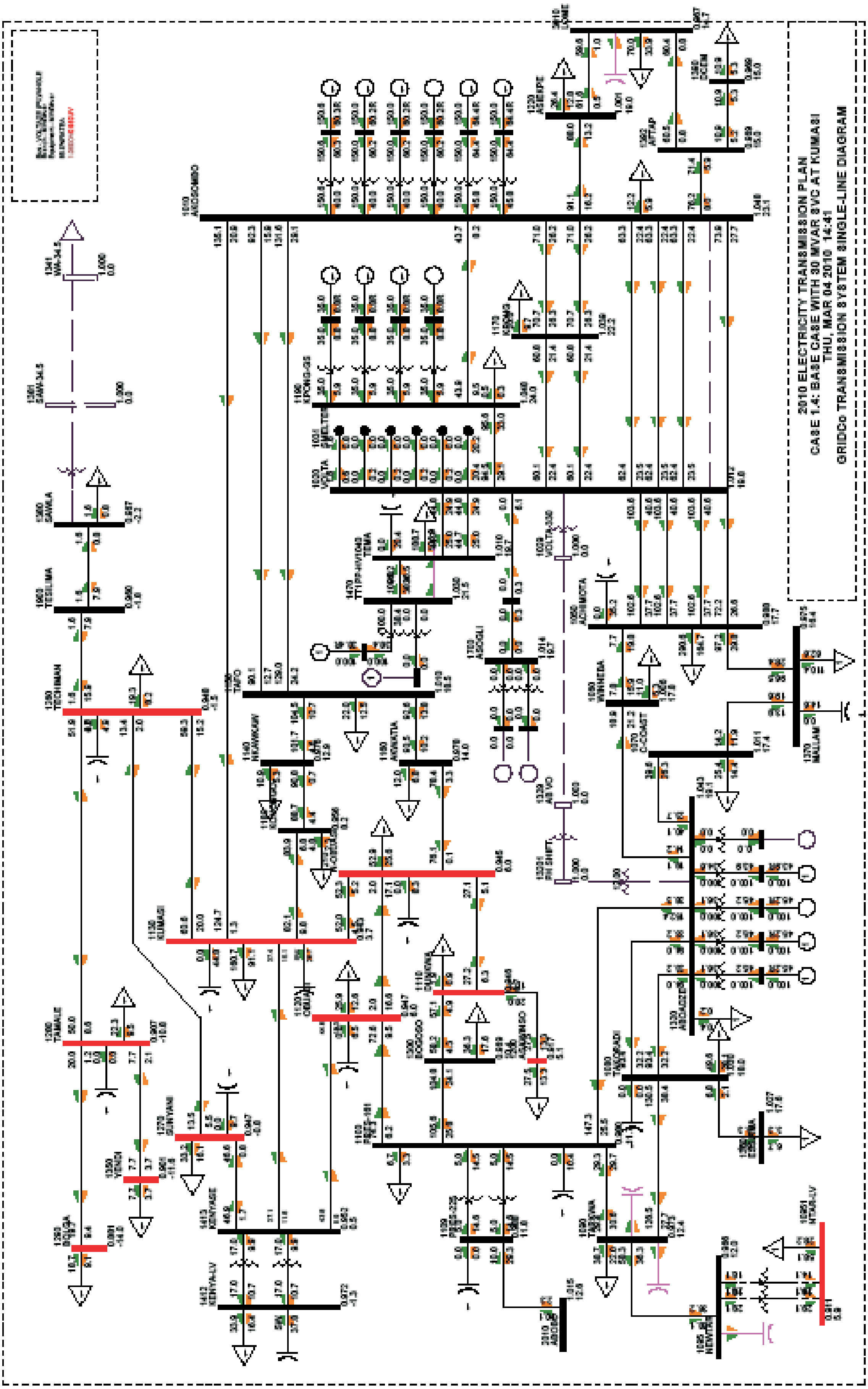


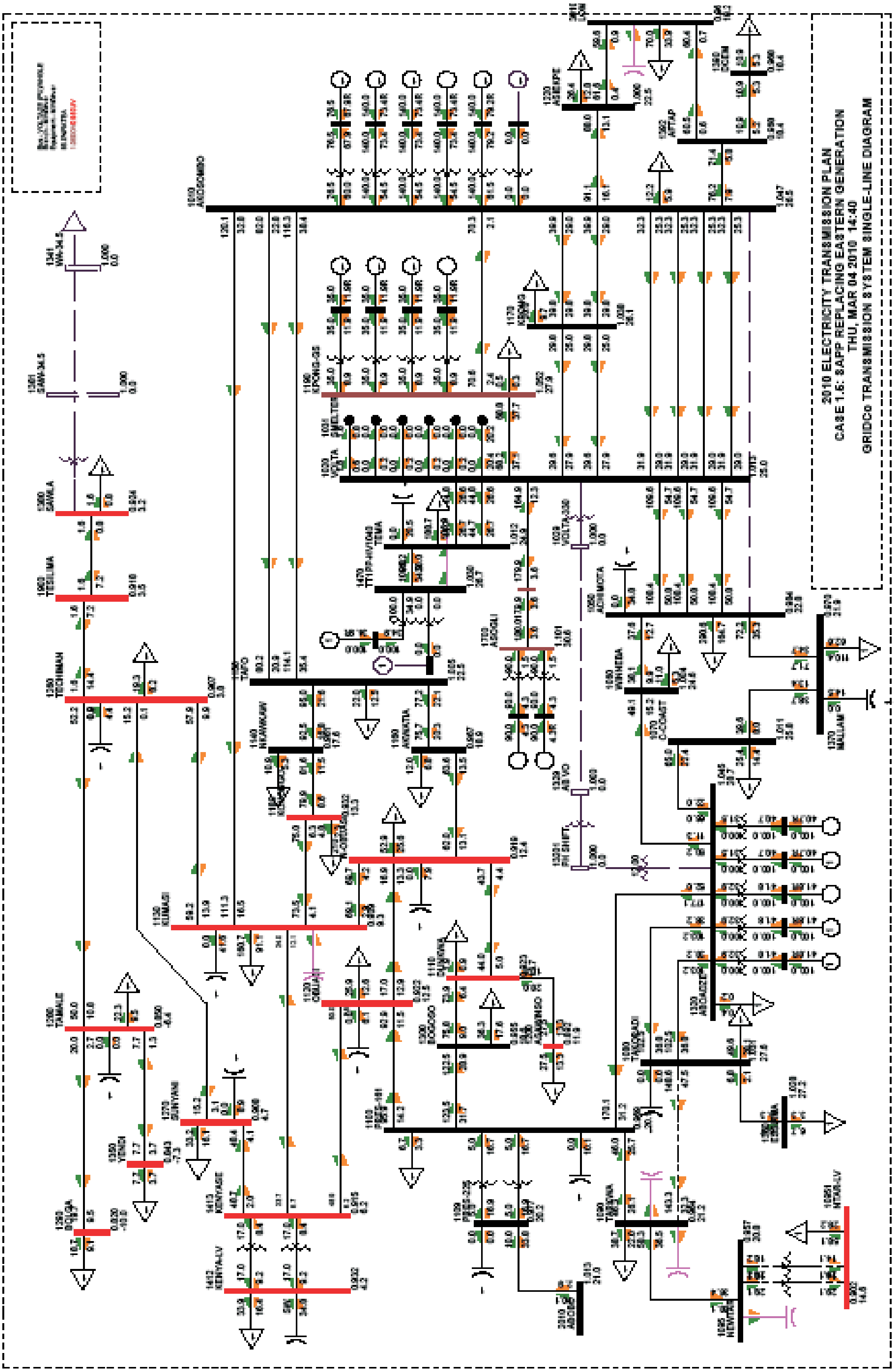
2010 ELECTRICITY TRANSMISSION PLAN
BASE CASE 1-0: PEAK LOAD CONDITIONS
THU, JAN 14 2010 10:31
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM

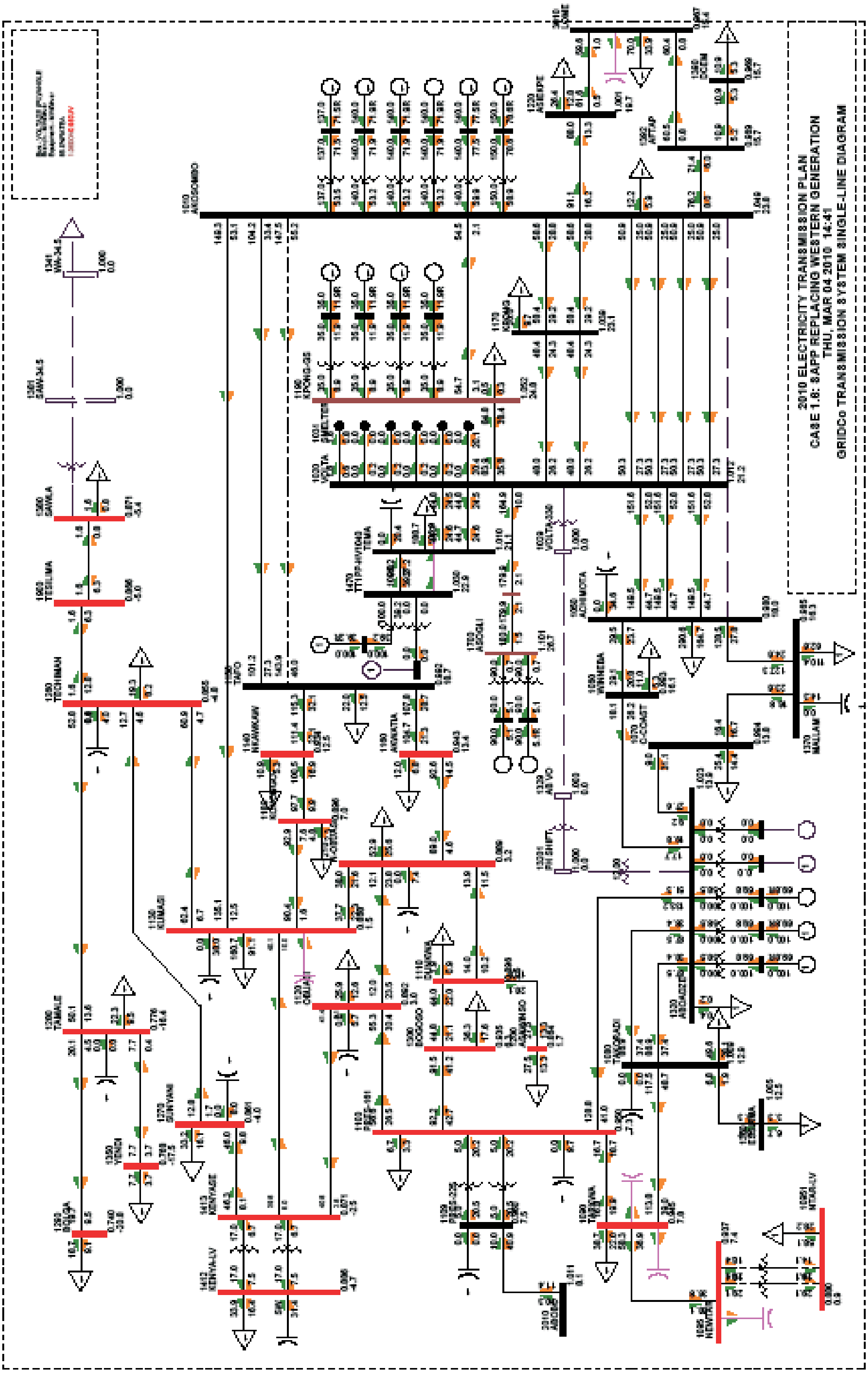

2010 ELECTRICITY TRANSMISSION PLAN
CASE 1.1: BASE CASE WITH 330 KV ABZ-VOL IN SERVICE
THU, MAR 04 2010 14:37
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM

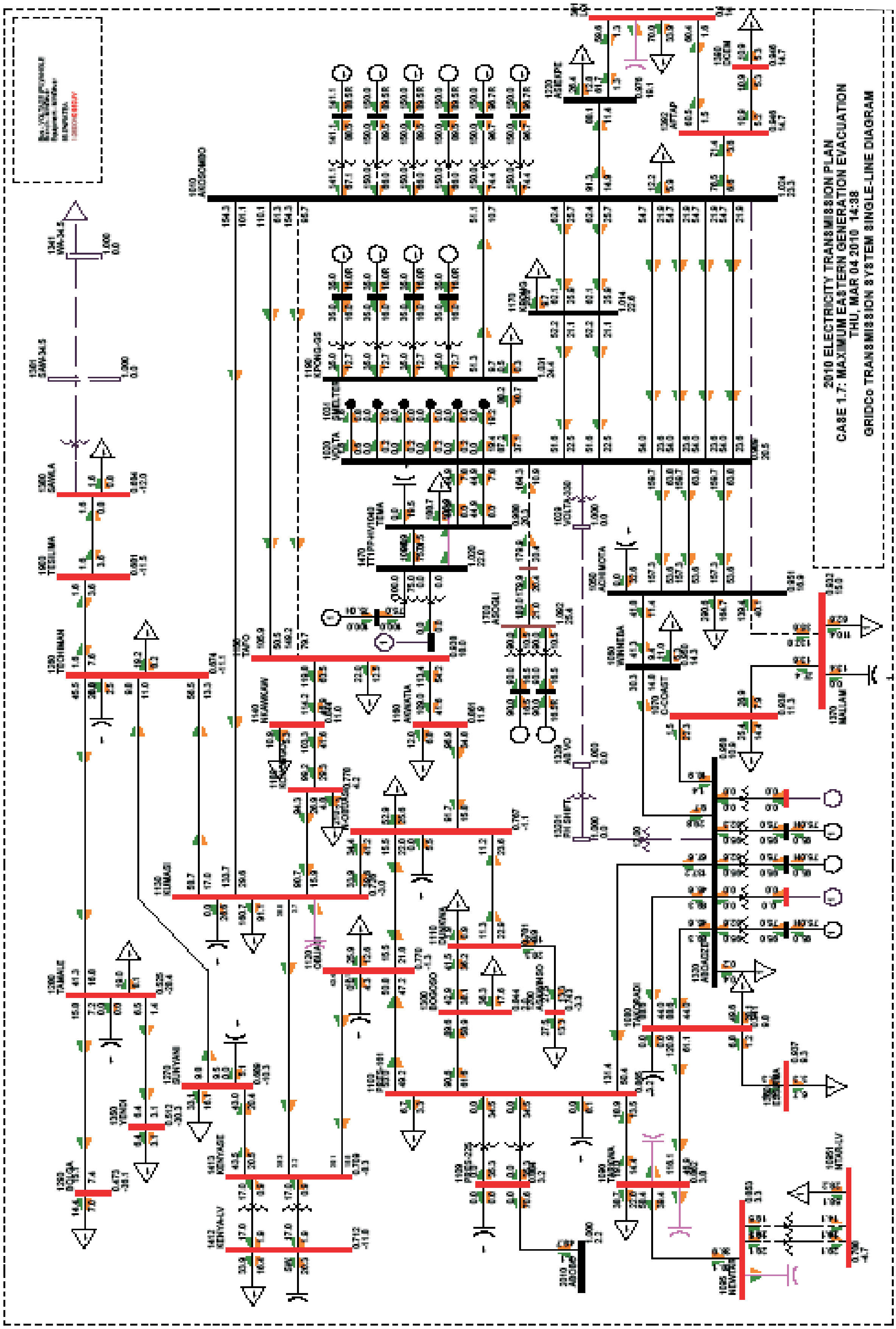

2010 ELECTRICITY TRANSMISSION PLAN
CASE 1.2: BASE CASE WITH 330 KV ABZ-VOL AND THE 4TH VOL-ACH
THU, MAR 04 2010 14:38
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM

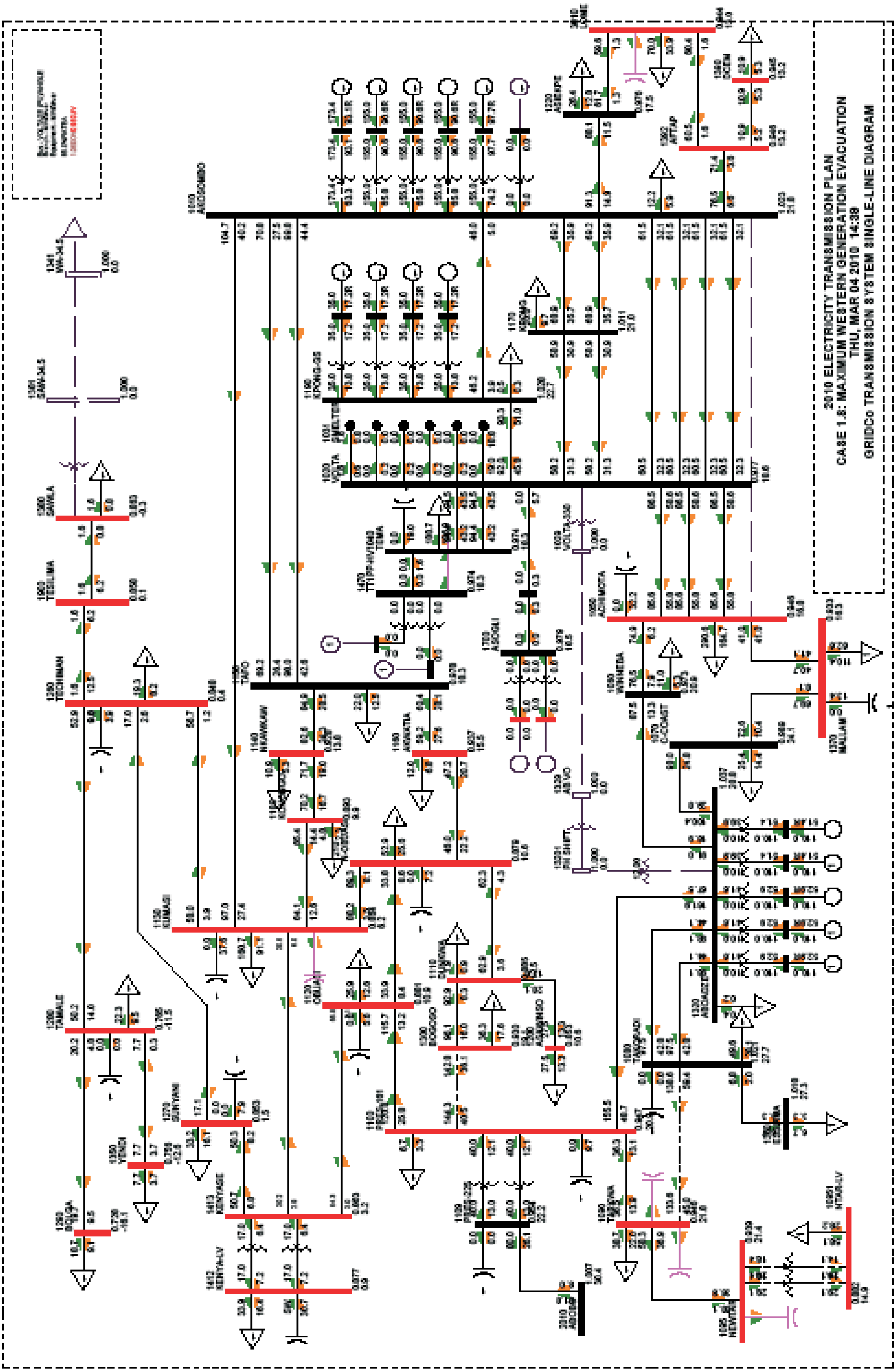

CASE 1.3: 2010 ELECTRICITY TRANSMISSION PLAN
BASE CASE WITH 330 KV ABZ-VOL, 4TH VOL-ACH LINES & COMP
THU, MAR 04 2010 14:36
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM

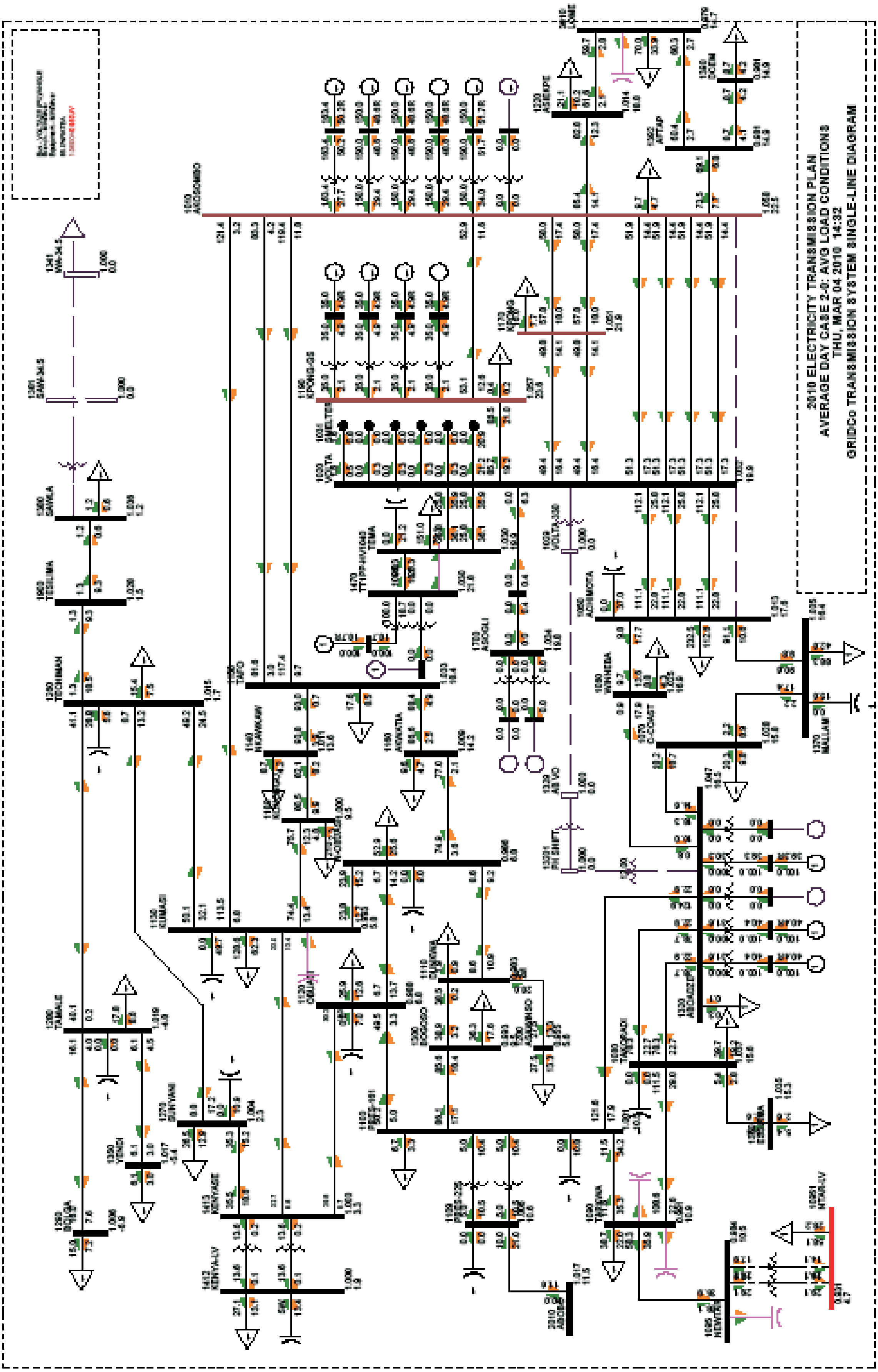

2010 ELECTRICITY TRANSMISSION PLAN
CASE 1.4: BASE CASE WITH 30 MVAR SVC AT KUMASI
THU, MAR 04 2010 14:41
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM


2010 ELECTRICITY TRANSMISSION PLAN
CASE 1.6: SAPP REPLACING EASTERN GENERATION
THU, MAR 04 2010 14:40
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM


2010 ELECTRICITY TRANSMISSION PLAN
CASE 1.6: SAPP REPLACING WESTERN GENERATION
THU, MAR 04 2010 14:41
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM


2010 ELECTRICITY TRANSMISSION PLAN
CASE 1.7: MAXIMUM EASTERN GENERATION EVACUATION
THU, MAR 04 2010 14:38
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM


2010 ELECTRICITY TRANSMISSION PLAN
CASE 1.8: MAXIMUM WESTERN GENERATION EVACUATION
THU, MAR 04 2010 14:38
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM


2010 ELECTRICITY TRANSMISSION PLAN
AVERAGE DAY CASE 2-0: AVG LOAD CONDITIONS
THU, MAR 04 2010 14:32
GRIDCo TRANSMISSION SYSTEM SINGLE-LINE DIAGRAM

1.0 BASE CASE (1- 0)

Table V1-0; Summary of key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Base Case 1- 0	Base Case 1- 0
Akosombo	167.9	1.043
Volta	162.1	1.007
Achimota	157.3	0.977
Aboadze	166.8	1.036
Kumasi	142.5	0.885
Prestea	154.6	0.961
Techiman	141.3	0.877
Tamale	130.2	0.809

Table L1-0; Summary of Major Line Loadings

	Loading MVA	% Loading
Bus Names	Base Case 1- 0	Base Case 1- 0
Volta - Achimota	138.3	64.9
Prestea - Bogosu	112.6	75.1
Takoradi - Tarkwa	139.8	82.3
Akosombo - Kumasi	142.8	39.2
Achimota - Mallam	101.5	59.7
Aboadze – Cape Coast	48.4	32.3
Kenyasi-Obuasi	45.2	30.2
Kumasi-New Obuasi	54.1	14.9
Kumasi – Techiman	61.8	17.0
Aboadze – Prestea	161.0	44.2
Aboadze – Takoradi 1	101.9	60.0
Prestea - Obuasi	76.9	21.1

1.1CASE (1-1); BASE WITH 330KV

Table V1-1; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 1	Case 1- 1
Akosombo	168.0	1.043
Volta	162.2	1.008
Achimota	157.5	0.978
Aboadze	168.2	1.045
Kumasi	143.3	0.890
Prestea	155.9	0.969
Techiman	142.4	0.885
Tamale	131.9	0.819

Table L1-1; Summary of Major Line Loadings

	Loading MVA	% Loading
Bus Names	Case 1- 1	Case 1- 1
Volta - Achimota	144.2	67.7
Prestea - Bogosu	108.9	72.6
Takoradi - Tarkwa	136.0	80.0
Akosombo - Kumasi	146.3	40.1
Achimota - Mallam	109.9	64.7
Aboadze – Cape Coast	44.5	29.7
Kenyasi-Obuasi	43.9	29.3
Kumasi-New Obuasi	50.4	13.9
Kumasi - Techiman	62.4	17.1
Aboadze – Prestea	155.1	42.6
Aboadze – Takoradi 1	99.9	58.8
Prestea - Obuasi	71.9	19.7

1.2CASE (1-2); BASE WITH 330KV AND 4TH LINE

Table V1-2; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 2	Case 1- 2
Akosombo	168.0	1.043
Volta	163.0	1.012
Achimota	159.1	0.988
Aboadze	168.5	1.046
Kumasi	143.8	0.893
Prestea	156.2	0.970
Techiman	143.0	0.888
Tamale	132.8	0.825

Table L1-2; Summary of Major Line Loadings

Bus Names	Loading MVA	% Loading
	Case 1- 2	Case 1- 2
Volta - Achimota	120.9	56.7
Prestea - Bogosu	110.2	73.5
Takoradi - Tarkwa	137.5	80.9
Akosombo - Kumasi	144.3	39.6
Achimota - Mallam	112.9	66.4
Aboadze – Cape Coast	41.2	27.5
Kumasi-New Obuasi	51.7	14.2
Kenyasi- Obuasi	44.4	29.6
Kumasi – Techiman	62.3	17.1
Aboadze – Prestea	157.4	43.2
Aboadze – Takoradi 1	100.6	59.2
Prestea - Obuasi	73.6	20.2

1.3CASE (1-3); BASE WITH 330KV, 4TH LINE AND COMPENSATION

Table V1-3; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 3	Case 1- 3
Akosombo	170.0	1.056
Volta	166.1	1.031
Achimota	163.7	1.017
Aboadze	170.1	1.056
Kumasi	152.7	0.948
Prestea	159.8	0.993
Techiman	154.9	0.962
Tamale	149.0	0.925

Table L1-3; Summary of Major Line Loadings

Bus Names	Loading MVA	% Loading
	Case 1- 3	Case 1- 3
Volta - Achimota	115.7	54.3
Prestea - Bogosu	104.8	69.8
Takoradi - Tarkwa	132.4	77.9
Akosombo - Kumasi	140.6	38.6
Achimota - Mallam	114.2	67.2
Aboadze – Cape Coast	36.5	24.3
Kumasi-New Obuasi	47.6	13.1
Kenyasi- Obuasi	46.0	30.7
Kumasi – Techiman	66.2	18.2
Aboadze – Prestea	151.4	41.6
Aboadze – Takoradi 1	97.8	57.6
Prestea - Obuasi	69.1	19.0

1.4 CASE (1-4); BASE CASE WITH SVC @ KUMASI

Table V1-4; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 4	Case 1- 4
Akosombo	168.8	1.048
Volta	162.0	1.006
Achimota	157.3	0.977
Aboadze	167.6	1.041
Kumasi	151.5	0.941
Prestea	157.7	0.980
Techiman	152.3	0.946
Tamale	145.5	0.904

Table L1-4; Summary of Major Line Loadings

Bus Names	Loading MVA	% Loading
	Case 1- 4	Case 1- 4
Volta – Achimota	136.2	63.9
Prestea – Bogosu	106.5	71.0
Takoradi – Tarkwa	133.8	78.8
Akosombo - Kumasi	139.0	38.1
Achimota – Mallam	98.7	58.1
Aboadze – Cape Coast	51.2	34.1
Kenyasi-Obuasi	45.8	30.5
Kumasi-New Obuasi	50.0	13.7
Kumasi – Techiman	64.0	17.6
Aboadze – Prestea	153.9	42.3
Aboadze – Takoradi 1	98.6	58.0
Prestea – Obuasi	71.7	19.7

1.5 CASE (1-5); SAPP REPLACING EASTERN GENERATION

Table V1-5; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 5	Case 1- 5
Akosombo	168.6	1.047
Volta	163.2	1.013
Achimota	158.3	0.984
Aboadze	168.3	1.045
Kumasi	146.3	0.909
Prestea	156.0	0.969
Techiman	146.0	0.907
Tamale	136.9	0.850

Table L1-5; Summary of Major Line Loadings

Bus Names	Loading MVA	% Loading
	Case 1- 5	Case 1- 5
Volta - Achimota	122.5	57.5
Prestea - Bogosu	127.5	85.0
Takoradi - Tarkwa	156.0	91.8
Akosombo - Kumasi	124.5	34.2
Achimota - Mallam	80.3	47.3
Aboadze – Cape Coast	69.6	46.4
Kumasi-New Obuasi	69.8	19.2
Kenyasi- Obuasi	50.6	33.7
Kumasi – Techiman	60.8	16.7
Aboadze – Prestea	184.6	50.7
Aboadze – Takoradi 1	110.0	64.8
Prestea - Obuasi	96.9	26.6

1.6 CASE (1-6); SAPP REPLACING WESTERN GENERATION

Table V1-6; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 6	Case 1- 6
Akosombo	168.8	1.049
Volta	162.9	1.012
Achimota	157.8	0.980
Aboadze	164.7	1.023
Kumasi	139.8	0.868
Prestea	152.9	0.950
Techiman	137.7	0.855
Tamale	125.0	0.777

Table L1-6; Summary of Major Line Loadings

	Loading MVA	% Loading
Bus Names	Case 1- 6	Case 1- 6
Volta - Achimota	160.5	75.3
Prestea - Bogosu	101.6	67.7
Takoradi - Tarkwa	127.2	74.9
Akosombo - Kumasi	158.5	43.5
Achimota - Mallam	131.4	77.3
Aboadze – Cape Coast	32.4	21.6
Kumasi-New Obuasi	43.8	12.0
Kenyasi- Obuasi	41.4	27.6
Kumasi – Techiman	62.8	17.2
Aboadze – Prestea	142.7	39.2
Aboadze – Takoradi 1	95.5	56.2
Prestea - Obuasi	63.0	17.3

1.7 CASE (1-7); MAXIMUM GENERATION FROM EAST

Table V1-7; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 7	Case 1- 7
Akosombo	164.8	1.024
Volta	159.2	0.989
Achimota	153.2	0.951
Aboadze	154.2	0.958
Kumasi	116.9	0.726
Prestea	139.2	0.865
Techiman	108.5	0.674
Tamale	84.5	0.525

Table L1-7; Summary of Major Line Loadings

Bus Names	Loading MVA	% Loading
	Case 1- 7	Case 1- 7
Volta - Achimota	172.0	80.7
Prestea - Bogosu	109.5	73.0
Takoradi - Tarkwa	135.5	79.7
Akosombo - Kumasi	184.4	50.6
Achimota - Mallam	145.0	85.3
Aboadze – Cape Coast	22.3	14.9
Kumasi-New Obuasi	53.7	14.8
Kenyasi- Obuasi	43.9	29.2
Kumasi – Techiman	61.1	16.8
Aboadze – Prestea	152.9	42.0
Aboadze – Takoradi 1	100.3	59.0
Prestea - Obuasi	72.3	19.9

1.8CASE (1-8); MAXIMUM GENERATION FROM WEST

Table V1-8; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 1- 8	Case 1- 8
Akosombo	164.7	1.023
Volta	157.3	0.977
Achimota	152.3	0.946
Aboadze	167.0	1.037
Kumasi	139.0	0.864
Prestea	152.5	0.947
Techiman	136.5	0.848
Tamale	123.1	0.765

Table L1-8; Summary of Major Line Loadings

	Loading MVA	% Loading
Bus Names	Case 1- 8	Case 1- 8
Volta - Achimota	104.5	49.0
Prestea - Bogosu	149.9	99.9
Takoradi - Tarkwa	150.8	88.8
Akosombo - Kumasi	112.1	30.8
Achimota - Mallam	58.0	34.1
Aboadze – Cape Coast	104.8	69.8
Kumasi-New Obuasi	89.7	24.6
Kenyasi- Obuasi	55.9	37.3
Kumasi – Techiman	58.2	16.0
Aboadze – Prestea	175.4	48.2
Aboadze – Takoradi 1	107.6	63.3
Prestea - Obuasi	123.5	33.9

2.0 CASE (2-0); AVERAGE DAY CASE

Table V2-0; Summary of Key Substation Voltages

Bus Names	Voltages (kV)	Voltages (pu)
	Case 2-0	Case 2-0
Akosombo	170.3	1.058
Volta	166.1	1.032
Achimota	163.2	1.013
Aboadze	168.5	1.047
Kumasi	159.9	0.993
Prestea	161.2	1.001
Techiman	163.4	1.015
Tamale	164.0	1.019

Table L2-0; Summary of Major Line Loadings

	Loading MVA	% Loading
Bus Names	Case 2-0	Case 2-0
Volta - Achimota	115.1	54.0
Prestea - Bogosu	87.7	58.5
Takoradi - Tarkwa	115.2	67.8
Akosombo - Kumasi	121.4	33.3
Achimota - Mallam	91.7	54.0
Aboadze – Cape Coast	26.1	17.4
Kumasi-New Obuasi	28.3	7.8
Kenyasi- Obuasi	34.2	22.8
Kumasi – Techiman	59.5	16.3
Aboadze – Prestea	126.9	34.9
Aboadze – Takoradi 1	81.9	48.2
Prestea - Obuasi	50.5	13.9