No.

Republic of Ghana
Ministry of Energy
Electricity Company of Ghana
Northern Electricity Department of Volta River Authority

Power Distribution System Master Plan Study for Ghana

Final Report
Supplemental Volume 3
Master Plan & Implementation Plan

September 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

Chubu Electric Power Co., Inc.

IL
JR
08-033

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Chapter 1 Master Plan for distribution network renewal, reinforcement, and extension

1.1 Results of preparation of plans for primary substations and subtransmission lines

1.1.1 Plans for ECG primary substations and subtransmission lines

(1) Plans for existing primary substations and subtransmission lines

Attachment 1 presents the plans for existing ECG primary substations and subtransmission lines. The ECG has plans for 28 substation projects at a total cost of about USD58 million and 39 subtransmission line projects at one of about USD32 million by 2012. Funding sources (e.g., the GEDAP and Ghanaian government) have already been determined for most of these projects, but this is not the case for some.

(2) Results for the major cities (Accra, Tema, Kumasi, and Takoradi)

Sections (a) through (d) present the results for the four major urban areas in the ECG supply area, i.e., Accra, Tema, Kumasi, and Takoradi, respectively.

(a) Planning results for the Accra system

Figure 1 shows a diagram for the current 33-kV system in the Accra area. In 2008, the maximum demand was 458 MVA. The Accra system has two BSPs (Achimota and Mallam). About 65 percent of the power demand at peak times is supplied from the Achimota BSP. There is a large power flow in supply from the Achimota BSP to central Accra (on the Achimota-Airport section and between the K and D points, for example; the combined power flow value is 219 MVA). A total of 10 circuits of subtransmission lines (with a combined thermal capacity of 310 MVA) are used in these sections.

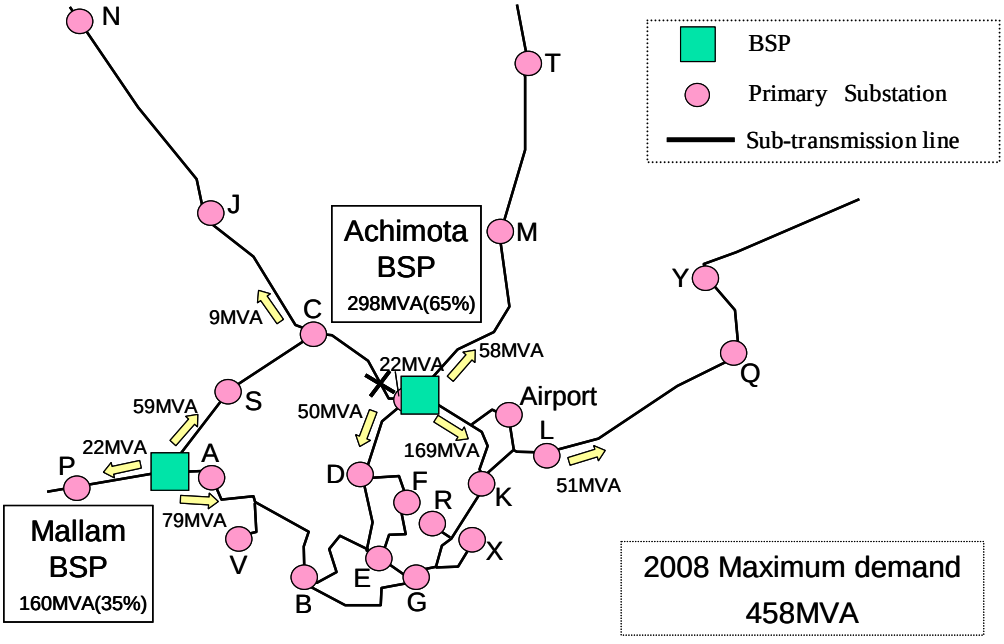


Figure 1 Diagram of the current Accra 33-kV system

Figure 2 presents a diagram of the system as of 2012 upon implementation of the Ghana Energy Development and Access Project (GEDAP) and other existing projects in their entirety. In that year, the maximum peak demand would reach 516 MVA. Attachment 1 lists the existing projects in the Accra area. By 2012, GEDAP, the national government project, and other projects are anticipated to add a total of 480 MVA in transformer capacity and 334 km of subtransmission lines (through extensions). Furthermore, under the national government project, a third BSP is to be constructed in the eastern part of the Accra area.

Analysis of the system as of 2012 found that there would not be any overload or voltage problems for the primary substations and subtransmission lines in the Accra area. The existing future plans for primary substations and sub-transmission lines are enough for the maximum demand in 2012.

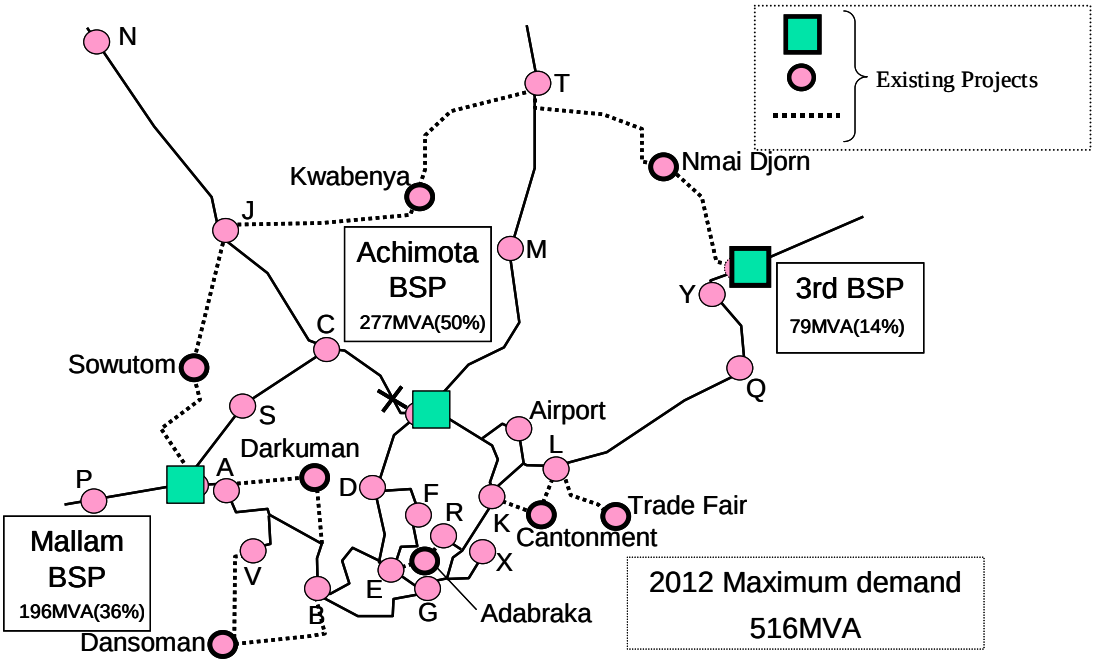


Figure 2 Diagram of the Accra 33-kV system in 2012

Although there are no additional plans for the years following 2012, an analysis was made of the system over the years 2013 - 2017 to check for bottlenecks. This analysis found overload on the subtransmission line between the H (Achimota) and E points in the system diagram for 2016 shown in Figure 3.

As shown in Table 1, the installation of an additional subtransmission line at the overload point was selected as the solution for the aforementioned bottleneck. Besides resolving the bottleneck in 2016, this step would prevent the occurrence of a bottleneck in 2017 (when the maximum peak demand would reach 609 MVA).

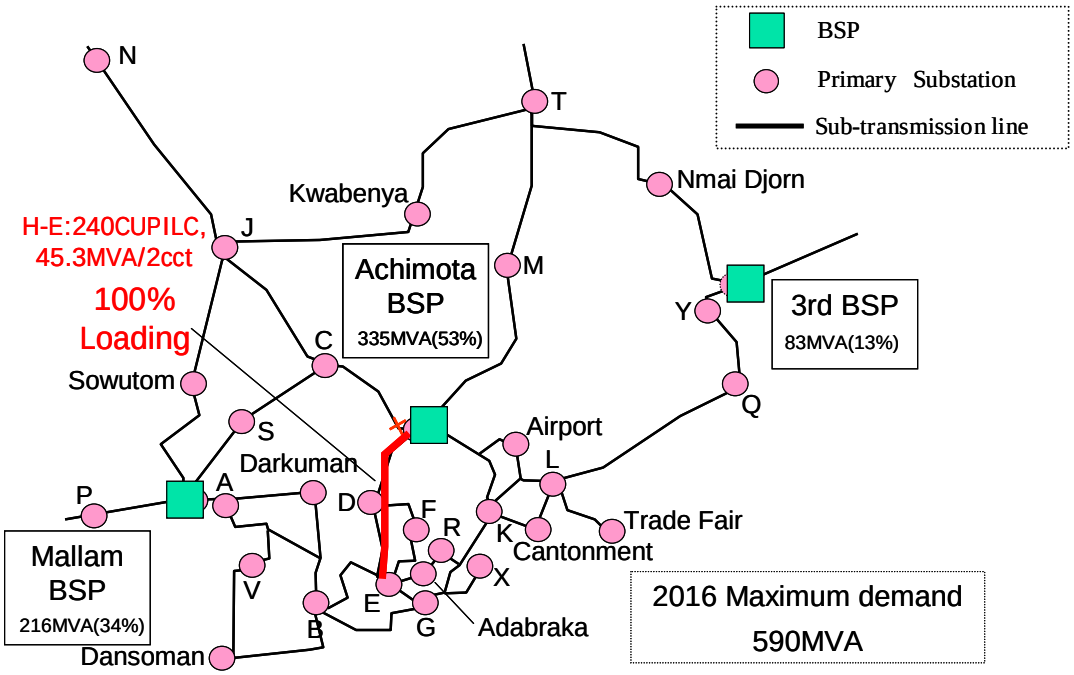


Figure 3 Diagram of the Accra 33-kV system in 2016

Table 1 Proposed project for the Accra system

Facility name	Bottleneck	Countermeasure	Cost (USD1,000)	Year of impleme ntation
H(Achimota)-E	- Subtransmission line overload	- Installation of two new 630 ALXLPE circuits between H and E (2 circuits x 6.3 km)	1,323	2016

(b) Planning results for the Tema system

Figure 4 shows a diagram for the current 33-kV system in the Tema area. In 2008, the maximum peak demand was 160 MVA. The Tema 33-kV system is supplied from the Tema BSP.

Figure 5 presents a diagram of the system as of 2012 upon implementation of the GEDAP and other existing projects in their entirety. In that year, the maximum peak demand would reach 190 MVA. Attachment 1 lists the existing projects in the Tema area. By 2012, GEDAP, the national government project, and other projects are anticipated to add a total of 200 MVA in transformer capacity and 140 km of subtransmission lines (through extensions). The system will be connected to the BSP built in the Accra area.

Analysis of the system as of 2012 found that there would not be any overload or voltage problems for the primary substations and subtransmission lines in the Tema area. The existing future plans for primary substations and sub-transmission lines are enough for the maximum demand in 2012.

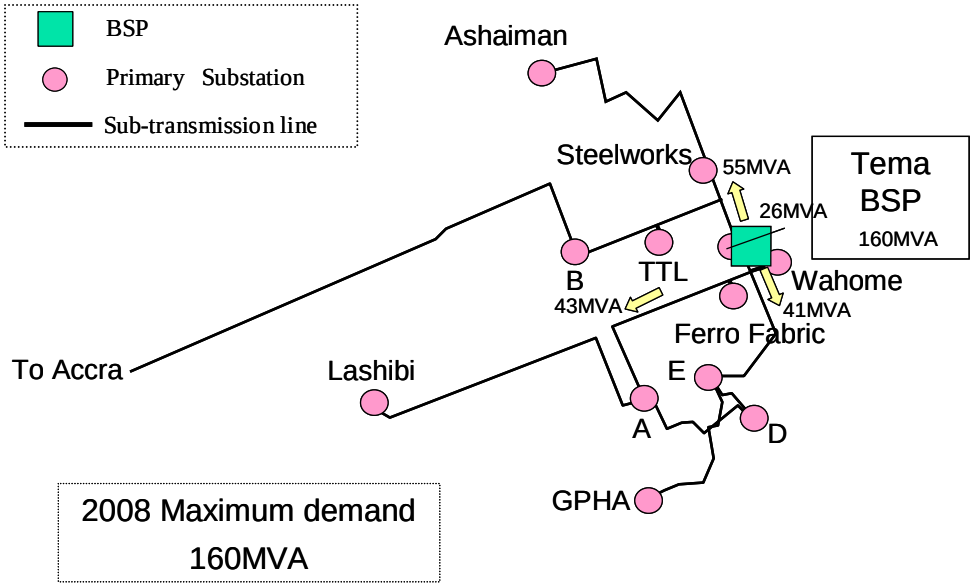


Figure 4 Diagram of the current Tema 33-kV system

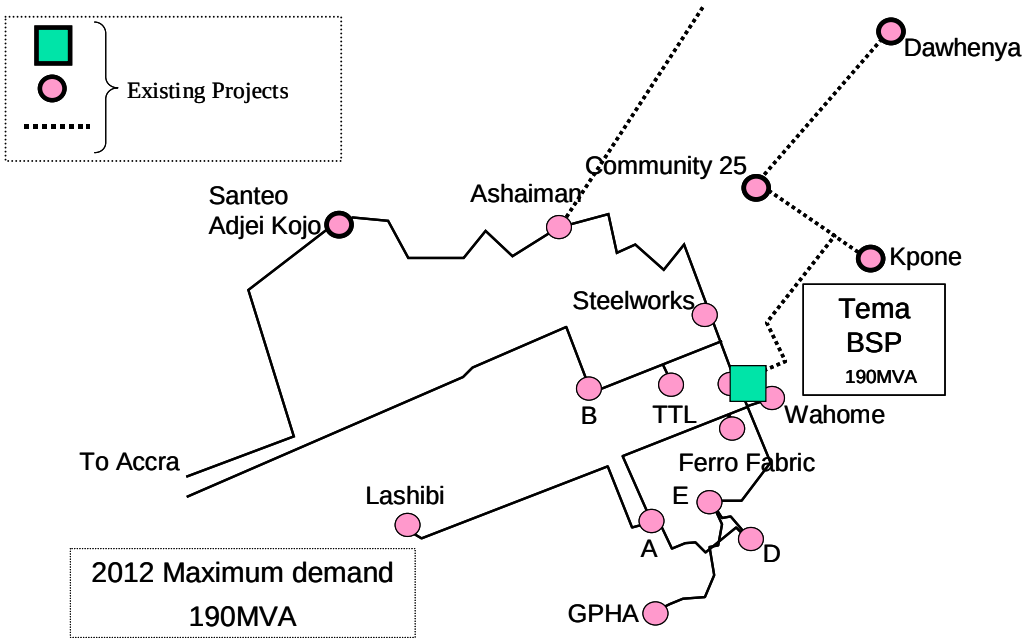


Figure 5 Diagram of the Tema 33-kV system in 2012

Although there are no additional plans for the years following 2012 in the Tema area either, an analysis was made of the system over the years 2013 - 2017 to check for bottlenecks. This analysis found overload on the subtransmission line between the H (Tema) and E points in the system diagram for 2016 shown in Figure 6.

As shown in Table 2, the installation of an additional subtransmission line at the overload point was selected as the solution for the aforementioned bottleneck. Besides resolving the bottleneck in 2016, this step would prevent the occurrence of a bottleneck in 2017 (when the maximum peak demand would reach

240 MVA).

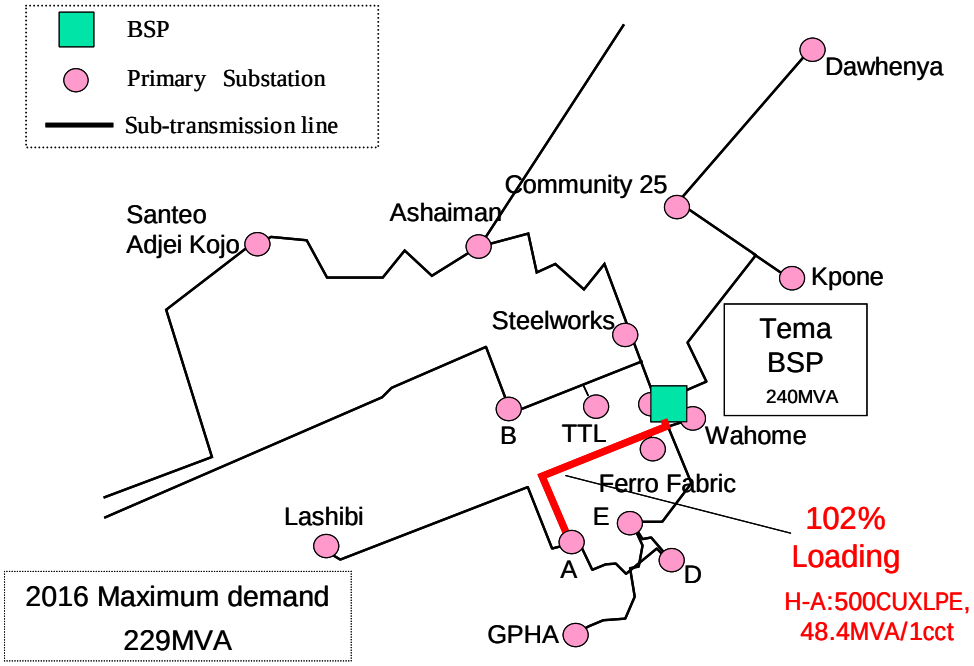


Figure 6 Diagram of the Tema 33-kV system in 2016

Table 2 Proposed project for the Tema system

Facility name	Bottleneck	Countermeasure	Cost (USD1,000)	Year of implementation
H(Tema)-A	- Subtransmission line overload	- Installation of two new 630 ALXLPE circuits between H and E (1 circuits x 5.6 km)	588	2016

(c) Planning results for the Kumasi system

Figure 7 shows a diagram for the current 33-kV system in the Kumasi area. In 2008, the maximum peak demand was 174 MVA. The Kumasi 33-kV system is supplied from the Kumasi BSP.

Figure 8 presents a diagram of the system as of 2012 upon implementation of the GEDAP in its entirety. In that year, the maximum peak demand would reach 211 MVA. Attachment 1 lists the existing projects in the Kumasi area. By 2012, the GEDAP is anticipated to add a total of 120 MVA in transformer capacity and 52 km of subtransmission lines (through extensions). A second BSP is to be constructed in the eastern part of the Kumasi area.

Analysis of the system as of 2012 found that there would not be any overload or voltage problems for the primary substations and subtransmission lines in the Kumasi area. The existing future plans for primary substations and sub-transmission lines are enough for the maximum demand in 2012.

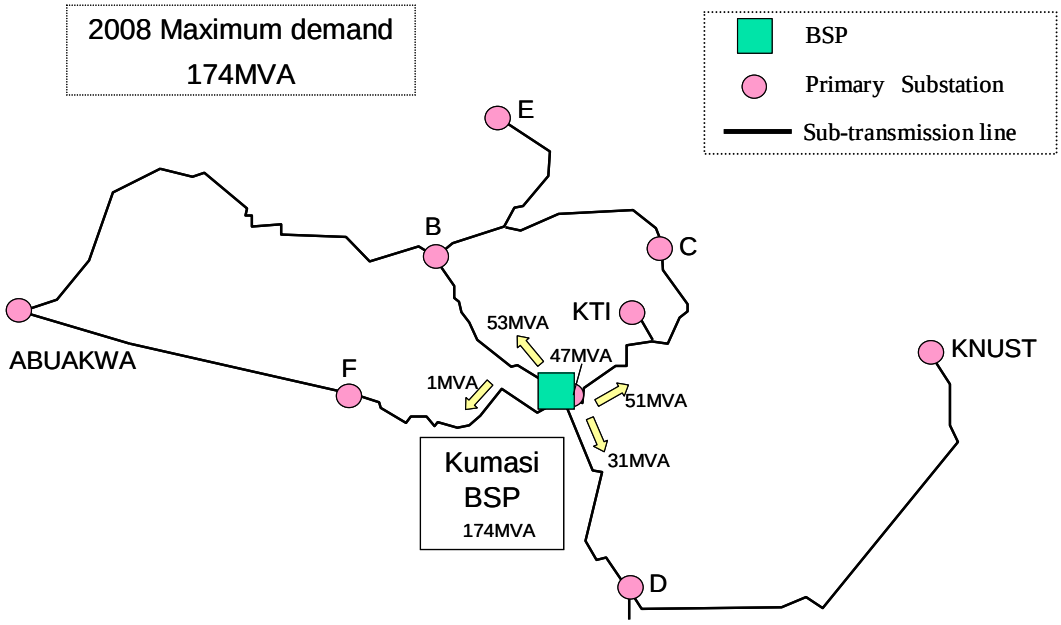


Figure 7 Diagram of the current Kumasi 33-kV system

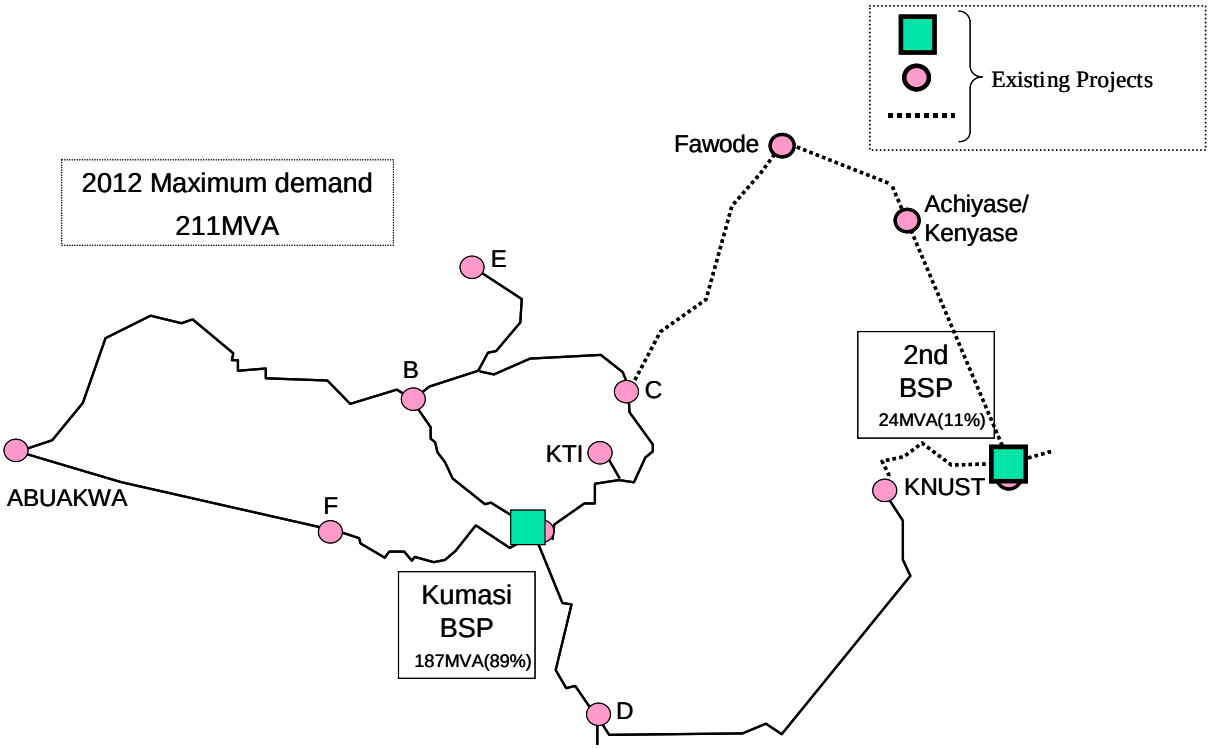


Figure 8 Diagram of the Kumasi 33-kV system in 2012

Although there are no additional plans for the years following 2012 in the Kumasi area either, an analysis was made of the system over the years 2013 - 2017 to check for bottlenecks. This analysis found overload on the subtransmission line between the A and KTI points in the system diagram for 2017 shown in Figure 9.

As shown in Table 3, the installation of an additional subtransmission line at the overload point was

selected as the solution for the aforementioned bottleneck. This step would resolve the bottleneck in 2017.

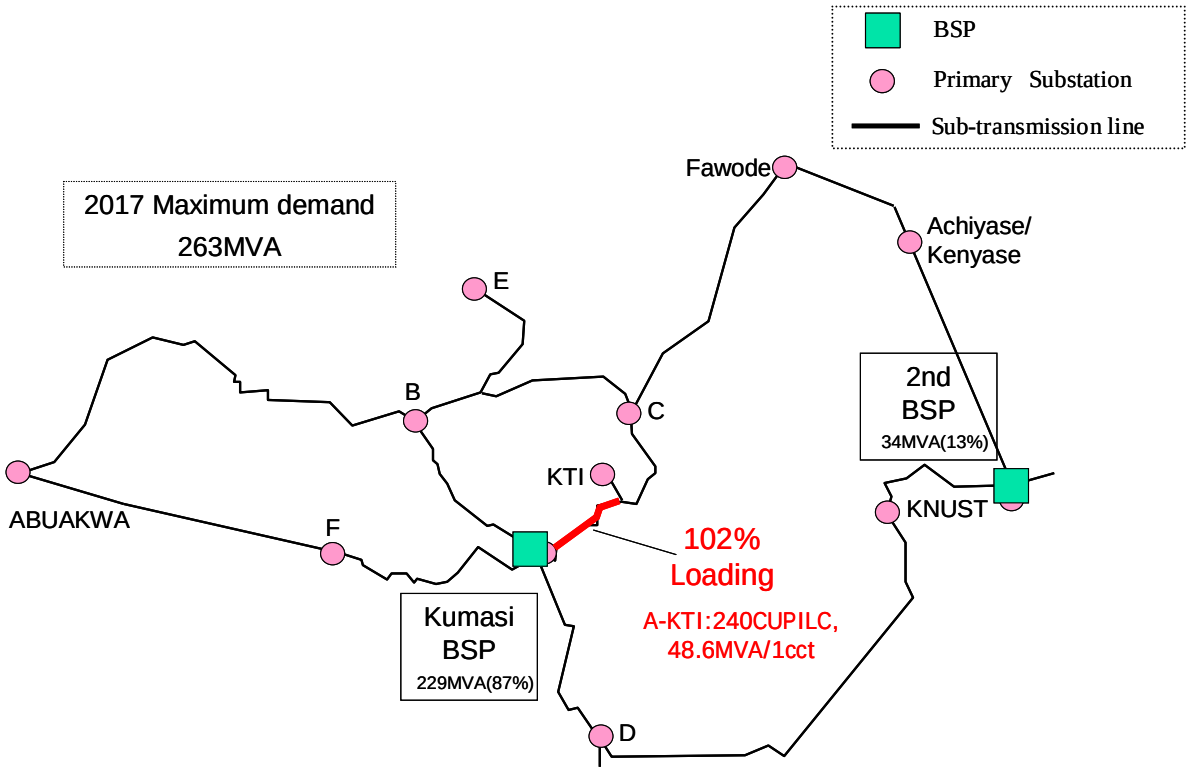


Figure 9 Diagram of the Kumasi 33-kV system in 2017

Table 3 Proposed project for the Kumasi system

Facility name	Bottleneck	Countermeasure	Cost (USD1,000)	Year of impleme ntation
A-KTI	- Subtransmission line overload	- Installation of two new 630 ALXLPE circuits between H and E (1 circuits x 5.0 km)	525	2017

(d) Planning results for the Takoradi system

Figure 10 shows a diagram for the current 33-kV system in the Takoradi area. In 2008, the maximum peak demand was 86 MVA. The Takoradi 33-kV system is supplied from the Takoradi BSP.

Figure 11 presents a diagram of the system as of 2012 upon implementation of the GEDAP and other existing projects in their entirety. In that year, the maximum peak demand would reach 98 MVA. Attachment 1 lists the existing projects in the Takoradi area. By 2012, the GEDAP and other projects are anticipated to add a total of 90 MVA in transformer capacity and 6 km of subtransmission lines (through extensions).

Analysis of the system as of 2012 found that there would not be any overload or voltage problems for the primary substations and subtransmission lines in the Takoradi area. The existing future plans for primary substations and sub-transmission lines are enough for the maximum demand in 2012.

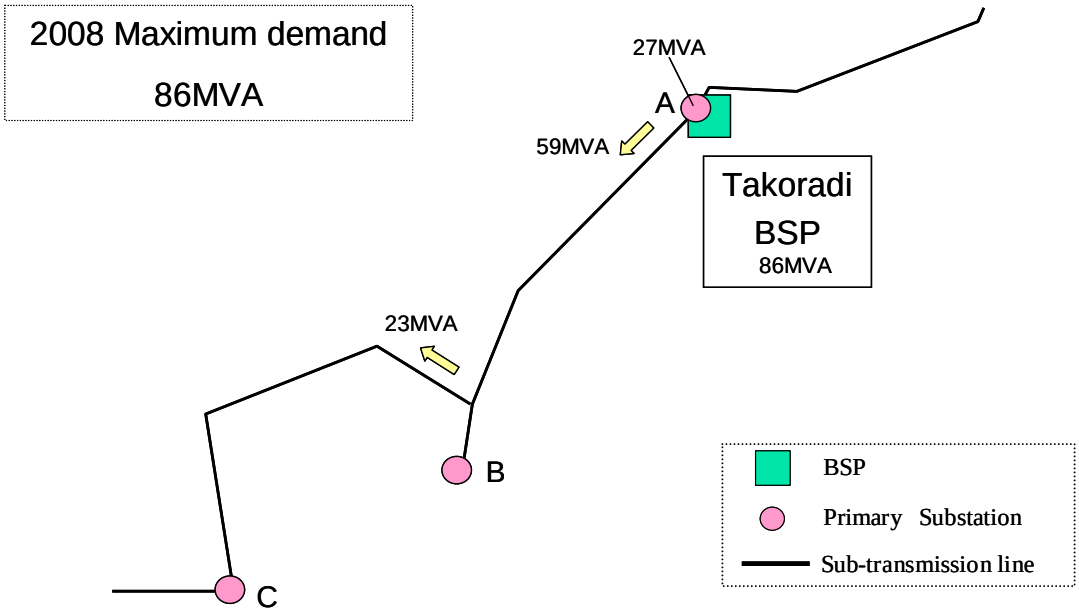


Figure 10 Diagram of the current Takoradi 33-kV system

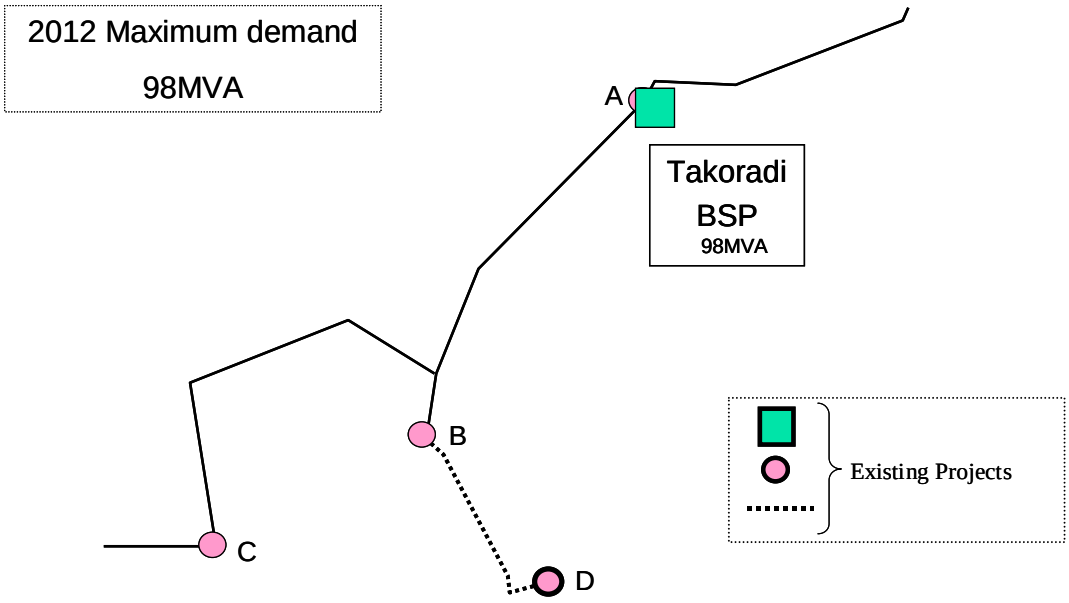


Figure 11 Diagram of the Takoradi 33-kV system in 2012

Although there are no additional plans for the years following 2012 in the Takoradi area either, an analysis was made of the system over the years 2013 - 2017 to check for bottlenecks. This analysis found that there would not be any problems in primary substations or on subtransmission lines even in 2017 (when the maximum peak demand would reach 116 MVA), as shown in Figure 12. There are consequently no additional projects proposed for the Takoradi system.

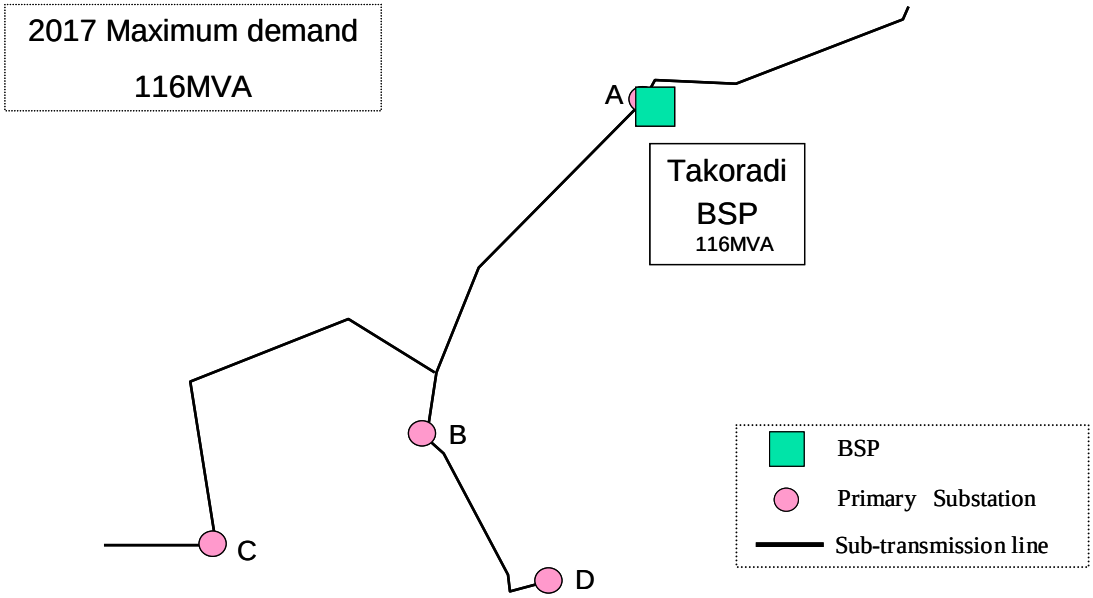


Figure 12 Diagram of the Takoradi 33-kV system in 2017

(3) Planning results for other areas

For areas other than the major urbanized ones (Accra, Tema, Kumasi, and Takoradi), the Study Team analyzed the propriety of the primary substation capacity and determined the requisite countermeasures.

The analysis found overload at nine primary substations. The overload at the Cape Coast primary substation in the Central Region is anticipated to be resolved by the construction of a new substation at Elmina in an existing project. The Study Team therefore considered countermeasures for the other eight cases.

As a result, it was decided to propose the installation of additional transformers in order to resolve overload. This was becuse all of the primary substations in question have space for additional transformers. Upon consultation with the C/P, a capacity of 10 MVA was chosen for all of these transformers, because the demand may be expected to grow at a fast pace in all of these areas.

Table 4 lists the proposed projects for primary substations in other areas. The proposed projects concern eight primary substations in five regions/areas, and would add a total of 80 MVA in transformer capacity at a total cost of USD1.6 million.

Table 4 Proposed projects for primary substations in other areas

Region/area	Facility name	Countermeasure	Capacity	Cost (USD1,000)	Year of implementation
Tema	Kpong	- Installation of an additional transformer	10MVA	200	2016
Western	Atuabo	- Installation of an additional transformer	10MVA	200	2009
	Axim	- Installation of an additional transformer	10MVA	200	2015
Eastern	ODA	- Installation of an additional transformer	10MVA	200	2012
Central	Saltpond	- Installation of an additional transformer	10MVA	200	2009
Volta	Kpeve	- Installation of an additional transformer	10MVA	200	2009
	Tsito	- Installation of an additional transformer	10MVA	200	2015
	Hohoe	- Installation of an additional transformer	10MVA	200	2012

1.1.2 Plans for VRA-NED primary substations and subtransmission lines

Figure 13 presents a diagram of the VRA-NED system. It consists of six BSPs, five primary substations, and one switching station.

Table 5 presents the results of analysis for VRA-NED subtransmission lines and primary substations. The analysis found that the voltage drop would fail to meet the standard on four of the six subtransmission lines. On any of the six lines, there was judged to be no problem with the current load rate. For primary substations, the analysis found overload at four.

Table 6 lists the proposed projects. For subtransmission lines, the proposed countermeasures for improving voltage are installation of capacity banks or thicker line cable. The 34.5-kV Bolgatanga-Bawku line was excluded from the proposed projects because the installation of a new 34.5-kV subtransmission line along with the construction of the Zebilla BSP currently undertaken by the VRA is anticipated to resolve the bottleneck. For primary substations, the Study Team proposed the installation of additional transformers to resolve overload because there is space for them at all substations.

The proposed projects in the VRA-NED service area would entail a total cost of USD629,000 for subtransmission lines and add 16 MVA in transformer capacity at primary substations at a total cost of USD262,000.

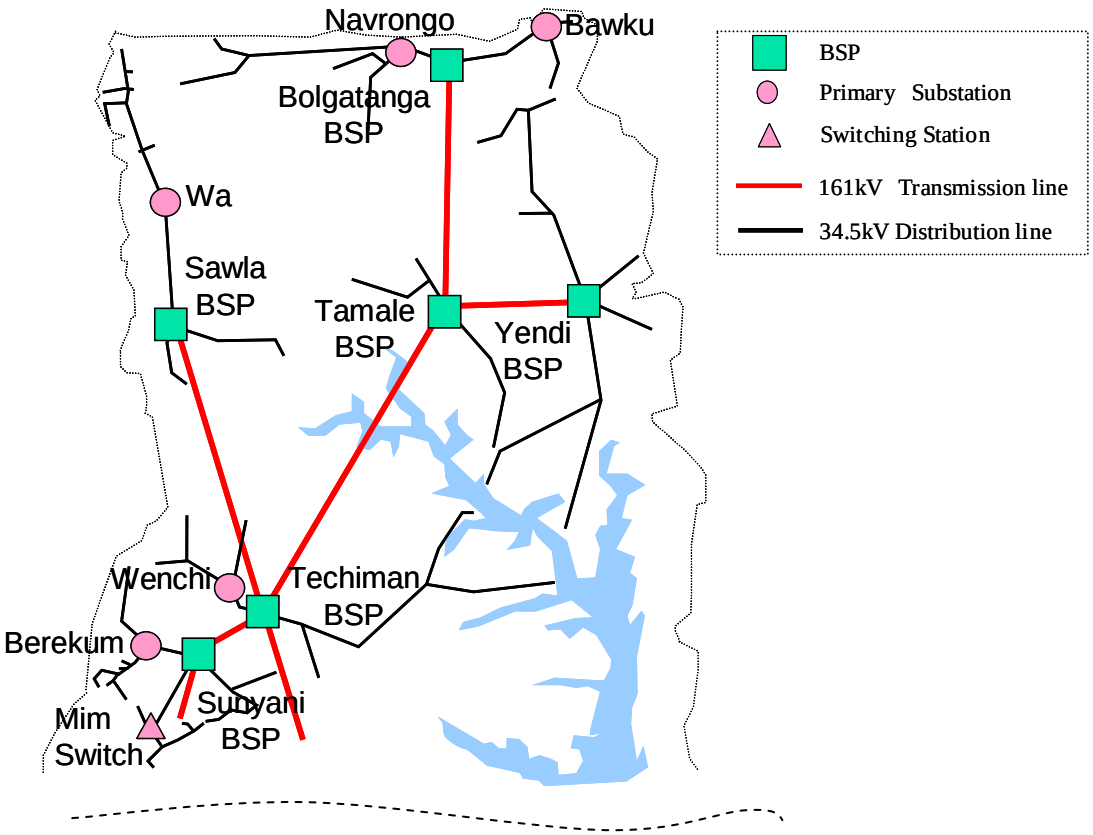


Figure 13 Power system diagram of VRA-NED

Table 5 Results of analysis for VRA-NED subtransmission lines and primary substations

(a) Analysis result of sub-transmission lines

Region/area	Name of Primary substations and sub-transmission lines	Analysis result	
		Voltage drop (%)	Current loading (%)
Brong Afaho	34.5kV Sunyani-Brekum line	19.3	73.4
Brong Afaho	34.5kV Sunyani-Mim line	29.5	58.5
Brong Afaho	34.5kV Techiman-Wenchi line	3.5	14.0
Upper West	34.5kV Sawla-Wa line	32.5	46.1
Upper East	34.5kV Bolgatanga-Bawku line	16.0	67.0
Upper East	34.5kV Bolgatanga-Navrongo line	1.0	24.8

(b) Analysis result of primary substations

Region	Substation Name	Capacity (MVA)	Maximum Demand (MVA)									
			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
VRA-NED	Berekum	5	4.9 (97%)	5.0 (101%)	5.2 (104%)	5.4 (108%)	5.6 (112%)	5.8 (117%)	6.1 (121%)	6.3 (126%)	6.5 (131%)	6.8 (136%)
	Wa	5	4.3 (86%)	4.5 (90%)	4.7 (94%)	4.9 (98%)	5.1 (103%)	5.4 (107%)	5.6 (112%)	5.9 (117%)	6.1 (122%)	6.4 (128%)
	Navrongo	3	1.7 (56%)	1.8 (61%)	2.0 (65%)	2.1 (71%)	2.3 (76%)	2.5 (82%)	2.7 (89%)	2.9 (96%)	3.1 (103%)	3.3 (111%)
	Bawku	3	2.9 (98%)	3.2 (105%)	3.4 (112%)	3.6 (120%)	3.9 (128%)	4.1 (137%)	4.4 (147%)	4.7 (157%)	5.0 (168%)	5.4 (179%)
	Wenchi	3	1.1 (37%)	1.1 (38%)	1.2 (40%)	1.2 (41%)	1.3 (43%)	1.3 (45%)	1.4 (47%)	1.5 (48%)	1.5 (50%)	1.6 (52%)

Table 6 Proposed projects for the VRA-NED system

Facility	Facility name	Countermeasure	Amount	Cost (1,000US$)	Year of implementation
Sub-transmission line	34.5kV Sunyani-Brekum	- Installation of capacity bank	3000kVar	4	2010
		- Increase in thickness (from 120 to 200 mm2 AAC)	43km	616	
	34.5kV Sunyani-Mim	- Installation of capacity bank	4000kVar	6	2010
	34.5kV Sawla-Wa	- Installation of capacity bank	2000kVar	3	2011
	34.5kV Bolgatanga-Bawku	- Resolution of bottleneck by installation of a new 34.5-kV subtransmission line along with construction of the Zebilla BSP	—	—	—
Primary substation	Berekum	- Installation of an additional transformer	5MVA	83	2009
	Bawku	- Installation of an additional transformer	3MVA	48	2009
	Wa	- Installation of an additional transformer	5MVA	83	2012
	Navrongo	- Installation of an additional transformer	3MVA	48	2016

1.2 Preparation of plans for distribution network renewal, reinforcement, and extension

1.2.1 Distribution network renewal plan

As locations requiring renewal, the Study Team selected spots on dilapidated distribution facilities judged to have a substantial adverse impact on public safety or supply reliability. The main items of deterioration requiring repair are medium-voltage distribution lines, distribution transformers, switching equipment, insulators, and supporting structures.

The specific renewal plans are as follows (with indications of the number of facilities and cost).

Table 7 Results of preparation of plans for ECG and VRA-NED distribution network renewal (number of facilities)

Enterprise/office		Number of facilities requiring renewal					
		Medium-voltage lines (km)	Transformers (number)	Switching equipment (number)	Insulators (number)	Supprting structures (number)	Guys, crossarms, etc. (number)
ECG	Accra East	58	—	5	243	—	—
	Accra West	28	21	1	—	—	—
	Tema	—	—	15	—	—	—
	Ashanti East	84	—	3	—	55	—
	Ashanti West	86	—	8	—	—	—
	Western	—	—	9	3,726	74	—
	Eastern	30	17	—	—	—	—
	Central	12	—	—	3,330	17	563
	Volta	28	5	62	1,090	160	—
ECG(Total)		326	43	103	8,389	306	563
VRA-NED (Total)		—	38	12	—	—	—

Table 8 Results of preparation of plans for ECG and VRA-NED distribution network renewal (cost)

［Unit: USD1,000］

Enterprise/area		Cost (USD1,000)						Total
		Medium-voltage lines	Transformers	Switching equipment	Insulators	Supporting structures	Guys, crossarms, etc.	
ECG	Accra	540	562	35	17	－	－	1,153
	Tema	－	－	69	－	－	－	69
	Ashanti	3,221	－	990	－	90	－	4,301
	Western	－	－	226	253	79	－	558
	Eastern	335	270	－	－	－	－	606
	Central	75	－	－	226	42	116	459
	Volta	174	55	1,152	74	245	－	1,701
ECG (Total)		4,344	888	2,472	570	456	116	8,847
VRA (Total)		－	449	359	－	－	－	808

1.2.2 Plans for reinforcement

When the amperage and voltage drop level on individual distribution lines fail to meet the conditions noted below, they must be reinforced to cope with the steadily increasing demand. The planning procedure begins with calculation of the yearly distribution line amperage based on the yearly rate of demand increase extrapolated from the demand forecast. This is followed by application of the yearly amperage to the existing distribution lines. The results provide footing for determination of the types and years of countermeasures to reinforce the lines to cope with the demand increase. (Upon consultation with the counterpart, it was decided to use the rated amperage on the line as the upper limit of allowable current in preparation of the Master Plan. For voltage drop, the study used an upper limit of 7 percent for the ECG and 10 percent for the VRA-NED, based on the standards at these enterprises.)

Table 9 shows the breakdown of the reinforcement plan and Table 10 shows the cost. Appendix 4 shows details of the reinforcement plans. Total cost for the reinforcement plan is 40,740 thousand US$ for ECG and 6,522 thousand US$ for VRA-NED respectively. The timing of construction is the year in excess of the standard value. Figure 14 shows the yealy cost for the reinforcement plan. Over the immediately following years (from 2008 to 2010), the plan would require a lot of budget because such work has not been undertaken extensively thus far.

For ECG, the average value of countermeasures between 2009 and 2017 is about 2,600 thousand US$ per year. It is thought that the reinforcement countermeasure of this level is necessary annually after the year of 2017.

Table 9 Reinforcement plan (number of lines for each countermeasure)

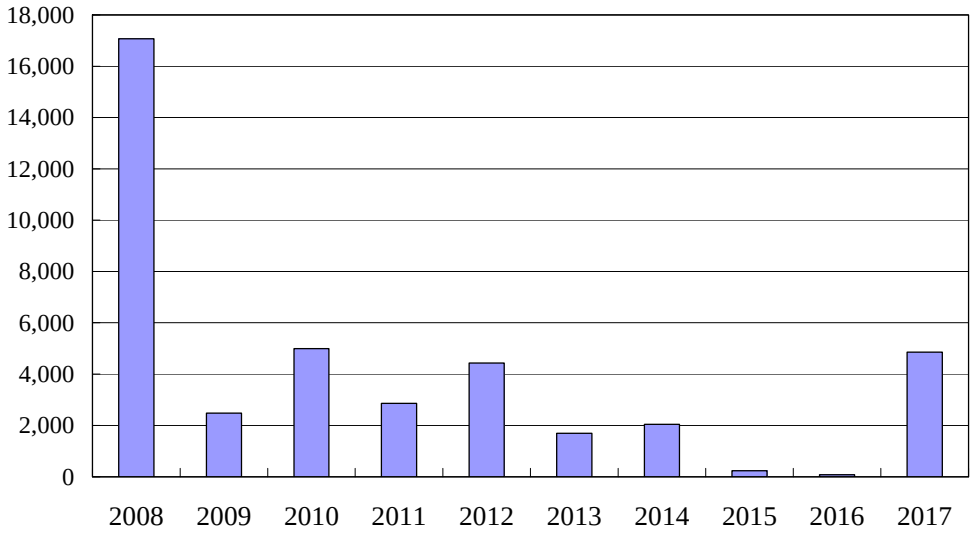
Enterprise/area		Reinforcement plan (number of lines for each countermeasure)							
		New 33kV/11kV substation construction (including ancillary facilities such as 33kV distribution lines)	Installation of new distribution line	Enlargement of lines		Voltage increase	Installation of a capacitor bank, condensor or Booster	Alleviation of load by construction of a switching station	Total
				Overhead line	Cable				
ECG	Accra	54	17	1	20	0	2	0	94
	Tema	3	4	1	5	0	1	0	14
	Ashanti	9	8	3	1	0	4	0	25
	Western	1	0	7	4	1	0	1	14
	Eastern	3	2	1	1	2	0	0	9
	Central	6	1	0	0	0	2	0	9
	Volta	1	4	1	0	0	1	0	7
ECG (Total)		77	36	14	31	3	10	1	172
VRA-NED (Total)		2	4	14	0	3	1	0	24

Table 10 Reinforcement plan (cost)

（Unit：1,000 US$）

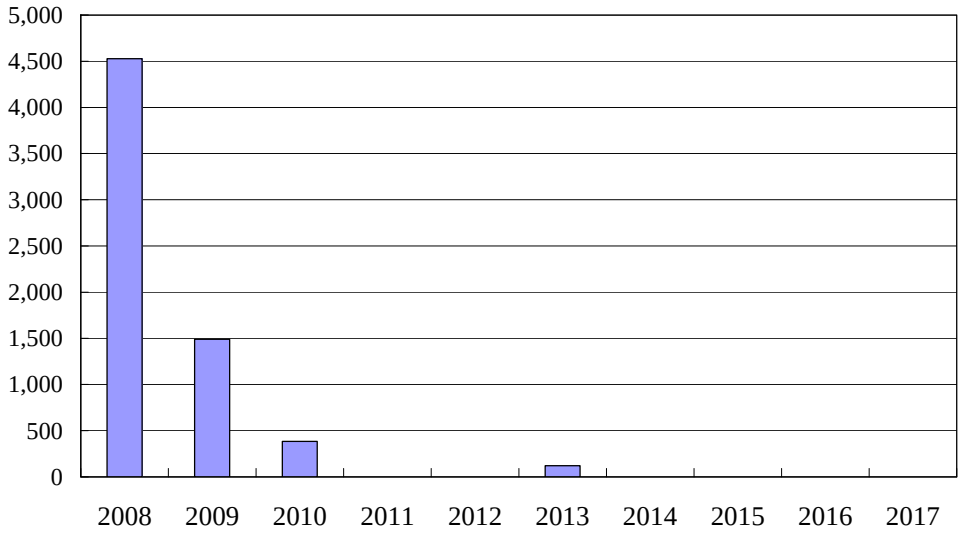
Enterprise/area		Reinforcement plan (cost, but excluding of new primary substation construction cost)							
		New 33kV/11kV substation construction (including ancillary facilities such as 33kV distribution lines)	Installation of new distribution line	Enlargement of lines		Voltage increase	Installation of a capacitor bank, condensor or Booster	Alleviation of load by construction of a switching station	Total
				Overhead line	Overhead line				
ECG	Accra	0	4,903	103	14,407	0	12	0	19,425
	Tema	0	1,387	358	760	0	1	0	2,506
	Ashanti	0	996	240	93	0	24	0	1,353
	Western	745	0	4,590	831	719	0	400	7,285
	Eastern	3,733	1,396	374	189	1,886	0	0	7,578
	Central	0	85	0	0	0	4	0	89
	Volta	243	1,461	700	0	0	100	0	2,504
ECG (Total)		4,721	10,228	6,365	16,280	2,605	141	400	40,740
VRA-NED (Total)		2,337	722	1,490	0	1,873	100	0	6,522

(Unit: thousand US$)



(a) Reinforcement plan for ECG

(Unit: thousand US$)



(b) Reinforcement plan for VRA-NED

Figure 14 Reinforcement plan for ECG and VRA-NED

1.2.3 Distribution network extension planning

(1) Results of master plan preparation

The results of the preparation of plans for distribution network extension are shown in Figure 11, Appendix 6 and Appendix 7. Trial calculation of the cost required for execution of this plan yielded a figure of about USD103 million for electrification of all of the 472 subject localities. The electrification cost came to about USD220,000 per locality and USD1,500 per customer.

Table 11 Electrification cost

	Number of localities	Number of customers	Electrification cost		
			Total cost (USD, millions)	Electrification cost per locality (USD, thousands)	Electrification cost per customer (USD)
ECG	226	40,265	58.4	258,3	1,450
VRA-NED	246	28,861	44.4	180.5	1,540
Total	472	69,126	102.8	217.8	1,500

Based on these resulta, it is estimated that a 10-percent increase in the electrifiction rate over the next ten years would entail a cost at approximately USD 50 million per year by on-grid electrification.

Chapter 2 Implementation Plan of the Master Plan

Chapter 1 presented the Master Plan based on the technical perspective. Stable supply requires construction of facilities with enough capacity to meet the demand, and the Master Plan presented in Chapter 1 should ideally be implemented as scheduled. For conformance with financial planning, however, the Study Team considered approaches to deferring some construction for distribution network reinforcement within the allowable scope in the immediately following years.

In the current SHEP scheme, the MOE or the concerned local governments and localities (villages) assume the burden of plans for distribution network extension (rural electrification), which is not undertaken with funds from the ECG and VRA-NED budgets. For this reason, extension was examined separately from the plans for renewal and reinforcment.

(1) Implementation plan for primary substations and subtransmission lines

Because planning delays would affect the entire area, it was assumed that the plan would be implemented as scheduled in the Master Plan.

(2) Implementation plan for distribution network renewal and reinforcement

1) Plan for distribution network renewal

In the renewal plan, the Study Team calculated the amount of funds required each year assuming implementation of the improvements for the locations selected as requiring them over a period of five years, and inclusion of this amount in the implementation plan. The selection of specific locations should be studied separately by the ECG and the VRA-NED with consideration of factors such as degree of urgency and synchronization with other construction. As noted above, a calculation was made of the funds that would be required each year of the five-year period of renewal work for the selected locations. The five-year total was estimated at USD8.85 million for the ECG and USD810,000 for the VRA-NED. As a result, the yearly requirement would be USD1.77 million for the ECG and USD160,000 for the VRA-NED. Because there would emerge additional locations requiring renewal even after this five-year period, such funding would have to continue to be budgeted.

2) Plan for distribution line reinforcement

As is clear from the Master Plan findings, there is a fairly large number of distribution lines that already do not meet standards, and this increases the need for reinforcement over the immediately coming years. As a result, the cost from 2008 to 2010 will inevitably be higher. In response, the Study Team considered approaches to deferral of some construction in accordance with the following guidelines.

(a) ECG

Toleration of excess current (overcurrent) could lead to distribution line failure. As such, the Study Team decided to ease the standard for voltage drop alone from the present 7 percent to 10 percent over the immediately following years (up to 2011), and to defer construction falling under this level. Similarly, for primary substations, the work of increasing voltage from 11 to 33 kV and replacing cable were judged to be, in effect, difficult to implement in 2008 owing to the large scale. It was consequently decided to defer this work to 2009 and succeeding years.

(b) VRA-NED

Based on the same thinking as for the ECG, the Study Team proposed an easing of the voltage drop standard from 10 to 20 percent until 2011 and deferral of improvement in the case of locations under this line. In the same way, construction to increase voltage from 11 to 34.5 kV was rescheduled to 2009 and succeeding years.

Based on these guidelines, the years of implementation for each project are revised as shown in Table 12. Appendix 5 shows the result of reinforcement plan for each regional office.

Figure 15 and Figure 16 show the implementation plans for primary substation, subtransmission line, and distribution network renewal and reinforcement based on these results.

In addition to the above, with respect to seven new primary substations where the necessity became clear from a distribution network reinforcement plan as shown in Appendix 3, the plans are reflected as primary substation plans.

Table 12 List of measures modified in the implementation planning

ECG

Office	Substation (existing)	Distribution line (existing)	Countermeasure	Year of implementation	
				Before	After
Accra West	Main D (Avenor)	D16	Cable replacement ($185mm^2$ Al →$6x630mm^2$ Cu, 3.2km)	2008	2009
Eastern	Tafo	Kibi/Suhum	Voltage increase from 11 to 33 kV	2008	2010
		Tafo	Installation of a new 33-kV distribution line (240 mm2 AAC, 24 km) from the Tafo BSP, construction of a new 33/11-kV substation (10 MVA) ahead of it, and connection to the existing Tafo distribution line along the way	2008	2010
		Koforidua	Installation of a new 33-kV distribution line (240 mm2 AAC, 17 km) from the Tafo BSP, and connection to the existing Tafo Koforidua distribution line	2008	2009
	Akwatia	Akwatia	Voltage increase from 11 to 33 kV	2008	2010
		Asamankese	Installation of a new 33-kV distribution line (240 mm2 AAC, 25 km) from the Akwatia BSP, construction of a new 33/11-kV substation (5 MVA) ahead of it, and connection to the existing Asamkese distribution line along the way	2008	2009
Western	Atuabo	Manganese	Voltage increase from 11 to 33 kV and construction of a new 33/11-kV substation (5 MVA)	2008	2010
Volta	SOGAKOPE	SOGA-AKATSI	Installation of a new 33-kV distribution line and division of the Keta distribution line from Akatsi and Sogakope ($120mm^2$ AAC, 12.5km)	2008	2009
	Anloga	Keta	Replacement of aerial lines ($16mm^2$ Cu →$120mm^2$ AAC, 3.5km) ($35mm^2$ Cu→$120mm^2$ AAC, 14.4km) ($70mm^2$ Cu→$120mm^2$ AAC, 2.4km)	2008	2009

VRA-NED (1/2)

Substation (existing)	Distribution line (existing)	Countermeasure	Year of implementation	
			Before	After
Tamale	28F3B	Installation of new 34.5-kV line (185 mm2 ALXLPE, 18 km) from the Tamale BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Tolon), and connection to the existing 28F3B distribution line along the way	2008	2011
	28F4B	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2009	2011
	28F6B	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2008	2009
	28F8B	Aerial line replacement ($100mm^2$ AAC → $240mm^2$ AAC, 19km)	2009	2010
	28F9B	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2010	2012
Brekum	Sunyani - Brekum (27F1Y)	Installation of a capacitor bank (3,000 kVar) in the Berekum substation, and aerial line replacement Aerial line replacement ($120mm^2$ AAC →$200mm^2$ AAC, 43km)	2010	2012
	"Berekum - Dormaa (BRYF2)"	Aerial line replacement ($120mm^2$ AAC →$150mm^2$ AAC, 31km)	2009	2011
	Berekum F1 (BRBF1)	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($35mm^2$ Cu, $50mm^2$ AAC →$200mm^2$ AAC, 23km)	2008	2009
	Berekum F2 (BRBF2)	Aerial line replacement ($50mm^2$ AAC →$100mm^2$ AAC, 6km)	2008	2012
Sunyani	"Sunyani- Mim (27F5Y)"	Installation of a capacitor bank (4,000 kVar) in the Mim switching station to improve voltage	2010	2011
	"Mim/Goaso /Hwidien (MMF1Y)"			
	Scanstyle (MM2FY)			
	Ayum(MMF3Y)			
	Sunyani F3 (27F3B)	Installation of a 11.5kV new line ($120mm^2$ AAC, 13km)	2008	2009
	Sunyani F7 (27F7B)	Aerial line replacement ($35mm^2$ AAC →$100mm^2$ AAC, 7km)	2008	2012
	Sunyani F8 (27F8B)	Installation of new 34.5-kV line (120 mm2 AAC, 14 km) from the Sunyani BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Chiraa), and connection to the existing 27F8B distribution line along the way	2008	2009

VRA-NED (2/2)

Substation (existing)	Distribution line (existing)	Countermeasure	Year of implementation	
			Before	After
Sawla	Sawla-Wa (38YF6)	Installation of a capacitor bank (2,000 kVar) in the Mim switching station to improve voltage	2011	2012
	Wa-Hamile (WAFY1)			
	Wa Township 1 (479BF1)	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 6km)	2009	2010
	Wa Township 3 (479BF3)	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 5km)	2008	2010
Yendi	Bimbilla (35F5Y)	Installation of a 10-MVA booster station to improve voltage	2008	2011
Bolgatanga	29F1B (BOLGA)	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC, $120mm^2$ AAC → $150mm^2$ AAC, 5km)	2010	2011
	29F4B (BOLGA)	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 20km)	2008	2010
	29F6B (BOLGA)	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 8km)	2008	2012

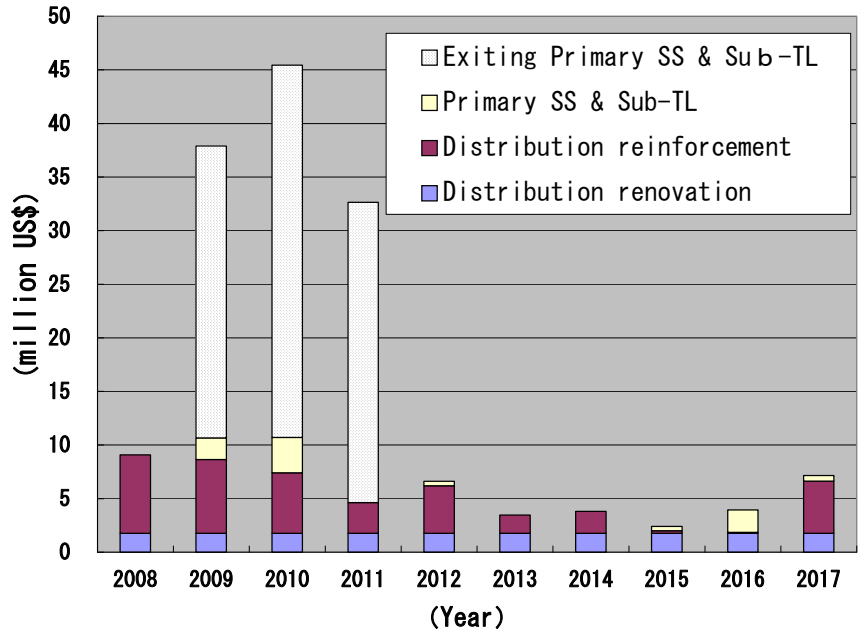


Figure 15 Master Plan implementation plan - ECG

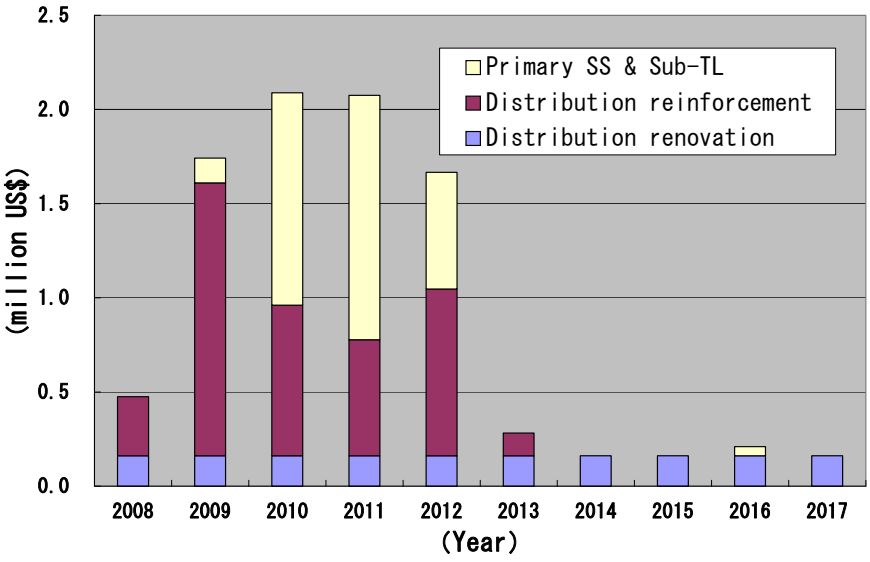


Figure 16 Master Plan implementation plan - VRA-NED

(3) Implementation plan for distribution network extension

Plans for distribution network extension cannot be determined merely with reference to financial plans; they require consideration of electrification policy and various other factors. For this reason, the Study Team estimated that attainment of the goal of a 70-percent rate of household electrification by 2020 posted in the NES would require appropriation of about USD50 million per year for construction. (Because the rate in 2006 was 54 percent, this estimate assumed that the electrification work would have to proceed at a pace of about 1 percentage point per year to increase the rate to 70 percent by 2020.)

Chapter 3 Economic and Financial Analysis of the Master Plan

3.1 Overview of the Master Plan

In the preceding chapters, the existing facilities and plans have been reviewed. Generally, the existing projects have been found to be sound, but based on the future demand, additional projects were identified.

Over the next 10 years, the whole master plan will provide a cumulative power of 25,238 GWh[1], and will require a total investment of about 142 million USD. Of that amount, the newly identified projects will cost about 52 million USD, providing 13,894 GWh over 10 years. The breakdown of the existing projects, and the newly identified projects, are shown in Table 13.

Table 13 Investment for the Master Plan: Total and the Newly Identified

	Whole Master Plan	Existing Projects (including not-yet financed ones)	Newly Identified Projects
Investment (1,000USD)	142,161	89,976	52,185
		63%	37%
Additional Culmulative Demand for the next 10 years (GWh)	25,238	11,344	13,894
		45%	55%

Source: JICA Study Team

It is important to note that the existing projects are not fully financed yet. As mentioned, the existing projects have been found to be sound, and the newly identified projects are based on the assumptions that the existing projects will come on line as planned. Therefore, while most of the analysis here will focus on the newly identified projects, the importance of providing finance to the existing projects must be emphasized.

[1] The “10 years” here does not necessarily mean 2008-2017. The additional demand is calculated as 10 years after the completion of the individual projects. If there is a project in 2017, the demand will be calculated up to 2026, while demand from projects in 2008 will only be counted up to 2018. There fore, the figure does not correspond exactly with the aggregated power demand.

3.2 Financial Analysis

The financial analysis of the Master Plan is straight forward. The investment has been identified, along with the incremental demand that they provide.

In making the financial analysis, however, a crucial assumption needs to be made. Under the current tariff structure, the utilities do not turn any profit for the additional power sales. Under this structure, the master plan cannot hope to make any financial sense. While this master plan is expected to improve costs in various areas, much of the tariff is taken up by the wholesale cost, which leaves little room for improvement on the utilities' side. In order to make a proper financial assessment, a certain level of profit margin for the power sales needed to be assumed.

Currently, the average tariff for the whole use is about 0.12 GHC/kWh (approximately 12 US cents/kWh). Here, we assume that 5% profit margin is secured on this tariff, which provides a profit of 0.6 US cents/kWh.

Another benefit comes from the decrease in loss. It is assumed that the improvement of the primary substations will bring 0.2 % point improvement in the loss, and the reinforcement of the distribution network will also bring a 3.1% point improvement in the loss of the affected system. This will result in the savings for the power purchase, which would bring huge financial and economic benefits.

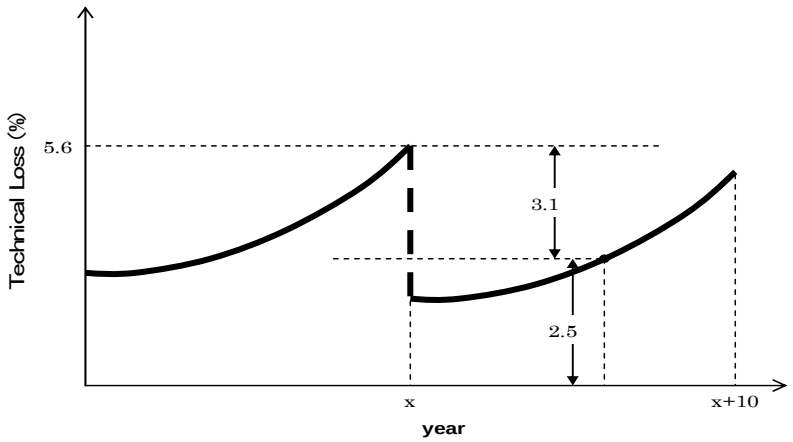


Figure 17 Process of technical loss

The regional investment schedule and the demand schedule are shown in the following pages, for the whole master plan and for the newly identified projects within the whole master plan. Since the figures do not assume inflation, this is in real terms. The summary of the results is shown below.

Table 14 Investment and Sales for the Whole Master Plan

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Accra	**Investment (1000 USD)**	7,072	18,358	20,208	13,978	0	1,252	2,042	235	1,323	4,653	0	0	0	0	0	0	0	0	0
	Sale (GWh)		128.4	461.8	828.8	1,082.7	1,082.7	1,105.4	1,142.5	1,146.8	1,170.8	1,126.9	793.5	426.5	172.6	172.6	149.9	112.8	108.5	84.5
	Sales (1000 USD)		15,412	55,420	99,459	129,922	129,922	132,650	137,100	137,612	140,496	135,224	95,216	51,177	20,714	20,714	17,986	13,536	13,024	10,140
	Cost (1000 USD)		14,641	52,649	94,486	123,426	123,426	126,018	130,245	130,732	133,471	128,463	90,455	48,618	19,679	19,679	17,087	12,859	12,372	9,633
	Saved Loss	847	3,031	5,433	7,100	7,100	7,251	7,496	7,524	7,683	8,241		0	0	0	0	0	0	0	0
	CF (1000 USD)	−6,225	−14,556	−12,004	−1,905	13,596	12,495	12,086	14,144	13,241	10,613	6,761	4,761	2,559	1,036	1,036	899	677	651	507
	IRR= 19.3%																			
Tema	**Investment (1000 USD)**	358	1,779	3,759	16,902	124	342	0	0	788	0	0	0	0	0	0				
	Sale (GWh)		5.2	31.0	85.4	330.3	332.1	337.1	337.1	337.1	348.5	343.3	317.5	263.1	18.2	16.4	11.4	11.4	11.4	0.0
	Sales (1000 USD)		622	3,716	10,252	39,640	39,855	40,450	40,450	40,450	41,820	41,198	38,104	31,568	2,180	1,965	1,370	1,370	1,370	0
	Cost (1000 USD)		591	3,530	9,739	37,658	37,862	38,427	38,427	38,427	39,729	39,138	36,199	29,990	2,071	1,867	1,302	1,302	1,302	0
	Saved Loss	8	47	130	495	498	505	505	505	523	523		0	0	0	0	0	0	0	0
	CF (1000 USD)	−350	−1,701	−3,443	−15,895	2,356	2,156	2,528	2,528	1,757	2,614	2,060	1,905	1,578	109	98	69	69	69	0
	IRR= −1.6%																			
Ashanti	Investment (1000 USD)	691	438	10,556	0	0	0	0	0	0	531	0	0	0	0	0				
	Sale (GWh)		7.6	12.4	128.0	128.0	128.0	128.0	128.0	128.0	128.0	126.2	121.4	5.8	5.8	5.8	5.8	5.8	5.8	5.8
	Sales (1000 USD)		908	1,484	15,358	15,358	15,358	15,358	15,358	15,358	15,358	15,148	14,572	698	698	698	698	698	698	698
	Cost (1000 USD)		863	1,410	14,590	14,590	14,590	14,590	14,590	14,590	14,590	14,390	13,844	663	663	663	663	663	663	663
	Saved Loss	53	86	866	866	866	866	866	866	866	906									
	CF (1000 USD)	−638	−306	−9,616	1,634	1,634	1,634	1,634	1,634	1,634	1,143	757	729	35	35	35	35	35	35	35
	IRR= 3.9%																			
Western	Investment (1000 USD)	985	4,230	1,378	0	4,313	100	0	200	0	197	0	0	0	0	0				
	Sale (GWh)		30	157	198	198	328	331	331	337	337	313	186	144	144	15	12	12	6	6
	Sales (1000 USD)		3,550	18,797	23,763	23,763	39,309	39,669	39,669	40,390	40,390	37,550	22,303	17,337	17,337	1,791	1,431	1,431	710	710
	Cost (1000 USD)		3,373	17,857	22,575	22,575	37,343	37,686	37,686	38,370	38,370	35,672	21,188	16,470	16,470	1,702	1,359	1,359	675	675
	Saved Loss	101	529	669	669	1,105	1,116	1,116	1,136	1,136	1,156									
	CF (1000 USD)	−884	−3,524	231	1,857	−2,020	2,981	3,099	2,920	3,156	2,979	1,877	1,115	867	867	90	72	72	36	36
	IRR= 26.8%																			
East	Investment (1000 USD)	7,013	0	3,398	0	200	0	0	0	0	0	0	0	0	0	0				
	Sale (GWh)		69.4	69.4	103.0	103.0	105.0	105.0	105.0	105.0	105.0	35.6	35.6	2.0	2.0	0.0	0.0	0.0	0.0	0.0
	Sales (1000 USD)		8,328	8,328	12,363	12,363	12,600	12,600	12,600	12,600	12,600	4,272	4,272	237	237	0	0	0	0	0
	Cost (1000 USD)		7,911	7,911	11,744	11,744	11,970	11,970	11,970	11,970	11,970	4,059	4,059	226	226	0	0	0	0	0
	Saved Loss	150	150	223	223	228	228	228	228	228	228									
	CF (1000 USD)	−6,863	566	−2,758	841	646	858	858	858	858	858	214	214	12	12	0	0	0	0	0
	IRR= −6.1%																			
Central	Investment (1000 USD)	2	4,180	85	0	0	0	0	0	0	0	0	0	0	0	0				
	Sale (GWh)		0.1	128.5	131.1	131.1	131.1	131.1	131.1	131.1	131.1	131.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sales (1000 USD)		7	15,419	15,732	15,732	15,732	15,732	15,732	15,732	15,732	15,725	313	0	0	0	0	0	0	0
	Cost (1000 USD)		7	14,648	14,945	14,945	14,945	14,945	14,945	14,945	14,945	14,938	298	0	0	0	0	0	0	0
	Saved Loss	0	388	396	396	396	396	396	396	396	396									
	CF (1000 USD)	−2	−3,792	1,082	1,183	1,183	1,183	1,183	1,183	1,183	1,183	786	16	0	0	0	0	0	0	0
	IRR= 26.6%																			
Volta	Investment (1000 USD)	1067.0	1320.0	343.0	0.0	200.0	0.0	0.0	200.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0				
	Sale (GWh)		25	55	63	63	67	67	67	72	74	49	19	11	11	6	6	6	2	0
	Sales (1000 USD)		2,940	6,578	7,523	7,523	8,074	8,074	8,074	8,625	8,832	5,892	2,254	1,309	1,309	758	758	758	207	0
	Cost (1000 USD)		2,793	6,249	7,147	7,147	7,670	7,670	7,670	8,194	8,390	5,597	2,141	1,244	1,244	720	720	720	196	0
	Saved Loss	0	0	0	0	0	0	0	0	0	0									
	CF (1000 USD)	−1,067	−1,173	−14	376	176	404	404	204	356	442	295	113	65	65	38	38	38	10	0
	IRR= 4.2%																			
ECG	Investment (1000 USD)	17,188	30,305	39,727	30,880	4,837	1,694	2,042	635	2,186	5,381	0	0	0	0	0	0	0	0	0
	Sale (GWh)	0	265	914	1,537	2,036	2,174	2,204	2,242	2,256	2,294	2,125	1,475	853	354	216	185	148	133	96
	Sales (1000 USD)		31,768	109,740	184,450	244,300	260,850	264,533	268,984	270,768	275,228	255,008	177,036	102,326	42,476	25,926	22,243	17,792	16,008	11,548
	Cost (1000 USD)		30,180	104,253	175,227	232,085	247,807	251,307	255,534	257,229	261,466	242,257	168,184	97,210	40,352	24,630	21,130	16,903	15,208	10,971
	Saved Loss	1,158	4,231	7,717	9,749	10,192	10,361	10,606	10,655	10,831	11,450									
	CF (1000 USD)	−16,030	−24,486	−26,523	−11,908	17,570	21,709	21,791	23,469	22,184	19,831	12,750	8,852	5,116	2,124	1,296	1,112	890	800	577
	IRR= 12.7%																			
VRA-NED	Investment (1000 USD)	4,528	1,627	1,088	3	0	121	0	0	48	0	0	0	0	0	0				
	Sale (GWh)		82	111	131	131	131	133	133	133	134	52	23	3	3	3	1	1	1	0
	Sales (1000 USD)		9,827	13,358	15,719	15,725	15,725	15,988	15,988	15,988	16,092	6,265	2,734	373	367	367	104	104	104	0
	Cost (1000 USD)		9,335	12,690	14,933	14,939	14,939	15,188	15,188	15,188	15,287	5,952	2,598	355	348	348	99	99	99	0
	Saved Loss	0	0	0	0	0	0	0	0	0	0									
	CF (1000 USD)	−4,528	−1,136	−420	783	786	665	799	799	751	805	313	137	19	18	18	5	5	5	0
	IRR= −0.5%																			
Whole Ghana	Investment (1000 USD)	21,716	31,932	40,815	30,883	4,837	1,815	2,042	635	2,234	5,381	0	0	0	0	0	0	0	0	0
	Sale (GWh)	0	347	1,026	1,668	2,167	2,305	2,338	2,375	2,390	2,428	2,177	1,498	856	357	219	186	149	134	96
	Sales (1000 USD)		41,595	123,097	200,168	260,025	276,575	280,521	284,971	286,756	291,320	261,273	179,771	102,700	42,843	26,293	22,347	17,897	16,112	11,548
	Cost (1000 USD)		39,515	116,943	190,160	247,024	262,746	266,495	270,723	272,418	276,754	248,209	170,782	97,565	40,700	24,978	21,229	17,002	15,307	10,971
		1,158	4,231	7,717	9,749	10,192	10,361	10,606	10,655	10,831	11,450									
	CF (1000 USD)	−20,558	−25,621	−26,943	−11,125	18,357	22,375	22,590	24,268	22,935	20,635	13,064	8,989	5,135	2,142	1,315	1,117	895	806	577

Table 15 Investment and demand for newly identified projects

			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Accra	**Investment (1000 USD)**		7,073	640	813	2,719	0	1,252	2,042	235	1,323	4,653	0	0	0	0	0	0	0	0	0
	Sale (GWh)			204.3	222.8	246.3	324.8	324.8	361.0	420.0	426.8	465.0	395.1	376.6	353.1	274.6	274.6	238.4	179.4	172.6	134.4
	Sales (1000 USD)			24,518	26,736	29,555	38,980	38,980	43,320	50,398	51,213	55,799	47,410	45,192	42,373	32,948	32,948	28,608	21,530	20,715	16,129
	Cost (1000 USD)			23,292	25,400	28,077	37,031	37,031	41,154	47,878	48,652	53,009	45,040	42,932	40,255	31,301	31,301	27,178	20,453	19,680	15,323
	Saved Loss		742	809	895	1,181	1,181	1,313	1,527	1,552	1,691	2,180									
	CF (1000 USD)		−6,331	1,395	1,419	−61	3,130	2,010	1,651	3,837	2,929	317	2,371	2,260	2,119	1,647	1,647	1,430	1,076	1,036	806
	IRR=	25.5%																			
Tema	**Investment (1000 USD)**		358	284	1,259	138	124	342	0	0	788	0	0	0	0	0	0				
	Sale (GWh)			16.2	29.0	86.0	92.3	97.9	113.3	113.3	113.3	149.0	132.8	120.0	63.0	56.7	51.1	35.7	35.7	35.7	0.0
	Sales (1000 USD)			1,944	3,486	10,322	11,071	11,744	13,601	13,601	13,601	17,880	15,936	14,394	7,558	6,809	6,136	4,279	4,279	4,279	0
	Cost (1000 USD)			1,847	3,312	9,806	10,518	11,157	12,921	12,921	12,921	16,986	15,139	13,674	7,180	6,468	5,829	4,065	4,065	4,065	0
	Saved Loss		79	143	421	452	479	555	555	555	730	730									
	CF (1000 USD)		−279	−44	−664	830	909	800	1,235	1,235	622	1,624	797	720	378	340	307	214	214	214	0
	IRR=	61.8%																			
Ashanti	Investment (1000 USD)		691	438	219	0	0	0	0	0	0	531	0	0	0	0	0				
	Sale (GWh)			26.8	43.7	52.2	52.2	52.2	52.2	52.2	52.2	52.2	46.0	29.1	20.6	20.6	20.6	20.6	20.6	20.6	20.6
	Sales (1000 USD)			3,213	5,249	6,267	6,267	6,267	6,267	6,267	6,267	6,267	5,523	3,487	2,469	2,469	2,469	2,469	2,469	2,469	2,469
	Cost (1000 USD)			3,052	4,987	5,954	5,954	5,954	5,954	5,954	5,954	5,954	5,247	3,313	2,345	2,345	2,345	2,345	2,345	2,345	2,345
	Saved Loss		244	398	476	476	476	476	476	476	476	663									
	CF (1000 USD)		−447	121	519	789	789	789	789	789	789	445	276	174	123	123	123	123	123	123	123
	IRR=	90.0%																			
Western	Investment (1000 USD)		865	200	1,378	0	4,313	100	0	200	0	197	0	0	0	0	0				
	Sale (GWh)			23	29	66	66	183	186	186	191	191	173	167	130	130	13	11	11	5	5
	Sales (1000 USD)			2,809	3,459	7,934	7,934	21,942	22,267	22,267	22,916	22,916	20,747	20,097	15,622	15,622	1,614	1,289	1,289	640	640
	Cost (1000 USD)			2,669	3,286	7,538	7,538	20,845	21,153	21,153	21,770	21,770	19,709	19,092	14,841	14,841	1,533	1,225	1,225	608	608
	Saved Loss		128	158	361	361	996	1,011	1,011	1,040	1,040	1,069									
	CF (1000 USD)		−737	98	−844	758	−2,921	2,008	2,124	1,954	2,186	2,018	1,037	1,005	781	781	81	64	64	32	32
	IRR=	31.5%																			
East	Investment (1000 USD)		7,013	0	898	0	200	0	0	0	0	0	0	0	0	0	0				
	Sale (GWh)			90.8	90.8	102.4	102.4	105.0	105.0	105.0	105.0	105.0	14.2	14.2	2.6	2.6	0.0	0.0	0.0	0.0	0.0
	Sales (1000 USD)			10,894	10,894	12,289	12,289	12,600	12,600	12,600	12,600	12,600	1,706	1,706	311	311	0	0	0	0	0
	Cost (1000 USD)			10,350	10,350	11,675	11,675	11,970	11,970	11,970	11,970	11,970	1,620	1,620	295	295	0	0	0	0	0
	Saved Loss		415	415	469	469	481	481	481	481	481	481									
	CF (1000 USD)		−6,598	960	116	1,084	896	1,111	1,111	1,111	1,111	1,111	85	85	16	16	0	0	0	0	0
	IRR=	5.5%																			
Central	Investment (1000 USD)		2	202	85	0	0	0	0	0	0	0	0	0	0	0	0				
	Sale (GWh)			0.4	42.1	59.6	59.6	59.6	59.6	59.6	59.6	59.6	59.2	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sales (1000 USD)			49	5,048	7,152	7,152	7,152	7,152	7,152	7,152	7,152	7,103	2,104	0	0	0	0	0	0	0
	Cost (1000 USD)			47	4,796	6,794	6,794	6,794	6,794	6,794	6,794	6,794	6,747	1,998	0	0	0	0	0	0	0
	Saved Loss		1	130	184	184	184	184	184	184	184	184									
	CF (1000 USD)		−1	−70	352	542	542	542	542	542	542	542	355	105	0	0	0	0	0	0	0
	IRR=	517.0%																			
Volta	Investment (1000 USD)		1067.0	1320.0	343.0	0.0	200.0	0.0	0.0	200.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0				
	Sale (GWh)			25	55	63	63	67	67	67	72	74	49	19	11	11	6	6	6	2	0
	Sales (1000 USD)			2,940	6,578	7,523	7,523	8,074	8,074	8,074	8,625	8,832	5,892	2,254	1,309	1,309	758	758	758	207	0
	Cost (1000 USD)			2,793	6,249	7,147	7,147	7,670	7,670	7,670	8,194	8,390	5,597	2,141	1,244	1,244	720	720	720	196	0
	Saved Loss		111	248	284	284	305	305	305	325	333	333									
	CF (1000 USD)		−956	−925	270	660	481	708	708	529	690	775	295	113	65	65	38	38	38	10	0
	IRR=	21.9%																			
ECG	Investment (1000 USD)		17,069	3,084	4,995	2,857	4,837	1,694	2,042	635	2,186	5,381	0	0	0	0	0	0	0	0	0
	Sale (GWh)		0	386	512	675	760	890	944	1,003	1,020	1,095	869	744	580	496	366	312	253	236	160
	Sales (1000 USD)			46,368	61,451	81,042	91,217	106,759	113,281	120,360	122,375	131,446	104,316	89,233	69,642	59,467	43,925	37,403	30,324	28,309	19,238
	Cost (1000 USD)			44,049	58,378	76,990	86,656	101,422	107,617	114,342	116,256	124,874	99,100	84,772	66,160	56,494	41,728	35,533	28,808	26,894	18,276
	Saved Loss		1,720	2,301	3,090	3,407	4,101	4,324	4,539	4,614	4,936	5,641									
	CF (1000 USD)		−15,349	1,535	1,168	4,602	3,825	7,968	8,161	9,997	8,868	6,832	5,216	4,462	3,482	2,973	2,196	1,870	1,516	1,415	962
	IRR=	26.8%																			
VRA-NED	Investment (1000 USD)		4,528	1,621	1,088	3	0	121	0	0	48	0	0	0	0	0	0				
	Sale (GWh)			82	111	131	131	131	133	133	133	134	52	23	3	3	3	1	1	1	0
	Sales (1000 USD)			9,835	13,355	15,718	15,725	15,725	15,988	15,988	15,988	16,092	6,257	2,737	374	367	367	104	104	104	0
	Cost (1000 USD)			9,343	12,688	14,933	14,939	14,939	15,188	15,188	15,188	15,287	5,945	2,600	355	349	349	99	99	99	0
	Saved Loss		384	522	615	615	615	626	626	626	630	630									
	CF (1000 USD)		−4,144	−607	195	1,398	1,402	1,291	1,425	1,425	1,381	1,434	313	137	19	18	18	5	5	5	0
	IRR=	14.8%																			
Whole Ghana	Investment (1000 USD)		21,597	4,705	6,083	2,860	4,837	1,815	2,042	635	2,234	5,381	0	0	0	0	0	0	0	0	0
	Sale (GWh)		0	468	623	806	891	1,021	1,077	1,136	1,153	1,229	921	766	583	499	369	313	254	237	160
	Sales (1000 USD)			56,202	74,806	96,761	106,942	122,484	129,269	136,347	138,363	147,538	110,574	91,970	70,015	59,834	44,292	37,507	30,429	28,413	19,238
	Cost (1000 USD)			53,392	71,066	91,923	101,595	116,360	122,805	129,530	131,444	140,161	105,045	87,371	66,514	56,843	42,077	35,632	28,907	26,993	18,276
			2,104	2,823	3,705	4,022	4,717	4,950	5,165	5,240	5,566	6,271									
	CF (1000 USD)		−19,493	928	1,362	6,000	5,227	9,259	9,586	11,422	10,250	8,267	5,529	4,598	3,501	2,992	2,215	1,875	1,521	1,421	962

Table 16 Summary of the Financial Analysis

Profit margin = 5.0%

	Whole Master Plan			Newly Identified Projects		
	Investment (1000USD)	Total GWh (10 yrs)	FIRR	Investment (1000USD)	Total GWh (10 yrs)	FIRR
Accra	59,298	12,553	19.3%	20,750	5,994	25.5%
Tema	17,063	3,485	−1.6%	3,293	1,490	61.8%
Ashanti	11,986	1,338	3.9%	1,879	728	90.0%
Western	8,809	3,425	26.8%	7,685	1,963	31.5%
East	9,832	1,050	−6.1%	7,779	1,050	5.5%
Central	1,197	1,311	26.6%	289	596	517.0%
Volta	2,417	736	4.2%	3,105	736	21.9%
ECG	110,602	23,898	12.7%	44,780	12,557	26.8%
VRA/NED	9,362	1,341	−0.5%	7,408	1,341	14.8%
Whole Ghana	119,964	25,239	11.9%	52,188	13,898	24.6%
NPV=	7,387 (1000USD, r=10%)			16,496 (1000USD, r=10%)		

The FIRR for the whole Master plan is shown to be about 11.9%, while for the newly identified projects, FIRR is 24.6%.

It is difficult to determine the hurdle rate in this situation. In former reports, 10% has been used as a discount rate for economic performance. Also, the World Bank often asks 8% of ROA in real terms for power sector projects. If we use these figures as benchmarks, both the whole master plan and the newly identified projects are financially justifiable. Using 10% as a discount rate, the whole master plan has an NPV of 7.4 million USD, while the newly identified projects have an NPV of 16 million USD. These figures, however, depend heavily on the profit margin assumptions.

The relationship between the profit margin and the FIRRs are shown in the next table. It can be seen that a level of at least 5% (i.e., a profit of about 0.6 US cents/kWh) is required to make the distribution plan financially viable. Otherwise, the utilities will have a hard time sustaining the facilities.

Table 17 Summary of the Financial Analysis

Profit Margin	Whole Master Plan	Newly Identified
3%	4.20%	15.70%
4%	8.30%	20.50%
5%	11.90%	24.60%
6%	15.30%	28.90%
7%	18.60%	32.80%

3.3 Economic Analysis

In the economic analysis, the benefits to the whole economy needs to be considered, as well as the costs.

It is challenging to estimate the total benefits of power to the end user. One way is to use the willingness to pay survey conducted in the socio economic survey. Since the large portion of demand is residential, we will look at the residential willingness to pay. According the survey, the monthly willingness to pay for various energy items in electrified village households were 9.8 USD /month. For the unelectrified villages, the figure was 6.4 USD/month. The difference may reflect the overall wealth of these villages, but it also reflects the familiarity with electricity and the resulting accurate assessment of its value. Initial installment cost should add about 0.5USD/month to both figures. Another survey suggests that the rural energy use of these village households are about 22 kWh/month, based on substitute use[2]. This suggests that the value of power is about 0.47 USD/kWh.

Another way is to base the assumption on previous studies. In the National Electrification Project Feasibility Study (1992), the overall willingness to pay is estimated at 0.25 USD/kWh. This amount will likely increase over the years due to general economic growth, which will likely match pace with the general GDP growth.

The real GDP growth of Ghana since 1992 has been quite steady, as seen in the following table. In the 1990s the growth was generally in the 4% zone, but growth accelerated to above 5% since 2003, and moving higher over 6% in recent years.

Table 18 Ghana Real GDP Growth

Year	Real GDP Growth (%)
1992	6.173
1993	4.921
1994	3.28
1995	4.023
1996	4.596
1997	4.199
1998	4.691
1999	4.428
2000	3.736
2001	4.184
2002	4.549
2003	5.246
2004	5.585
2005	5.866
2006	6.368
2007	6.388
2008	6.853

[2] National Electrification Project Feasibility Study (1992), Table 6.2.

Based on this figure, the general wealth of Ghana would have doubled since 1992. Using this GDP growth figure as a deflator, willingness to pay can be assessed at 0.54 USD/kWh, which can be seen as the benefit of a kWh today. As seen, this figure compares nicely with the 0.47 USD/kWh figure derived from the socio-economic survey today.

Based on this figure, the EIRR was calculated, which is summarized as follows

Table 19 Summary of the Economic Analysis

Profit margin =	5%			
	Whole Master Plan		Newly Identified Projects	
	Total GWh (10 yrs)	EIRR	Total GWh (10 yrs)	EIRR
Accra	12,553	33.1%	5,994	45.8%
Tema	3,485	11.4%	1,490	93.4%
Ashanti	1,338	13.9%	728	121.7%
Western	3,425	50.4%	1,963	53.5%
East	1,050	3.3%	1,050	15.2%
Central	1,311	46.6%	596	815.8%
Volta	736	21.1%	736	37.2%
ECG	23,898	26.6%	12,557	44.6%
VRA/NED	1,341	14.2%	1,341	27.9%
Whole Ghana	25,239	25.6%	13,898	41.5%
NPV=	50,313 (1000USD, r=12%)		43,053 (1000USD, r=12%)	

The whole master plan will have an EIRR of 25.6%, while the newly identified projects will have an EIRR o 41.5%. The hurdle rate for an EIRR is difficult to determine. In a previous study, 10% was used, while Asian Development Bank uses a 12% cut-off rate for all projects that applies for a loan. The results are shown that both the whole master plan and the newly identified projects exceed these hurdle rates by a large margin. Therefore, the plan is economically viable.

Using 12% discount rate, the NPV of each project for the whole economy is 50 million USD for the whole master plan, and 43 million for the newly identified projects.

Appendix 1

Existing Pimary Substation Plans

Region	Name	Financer	Equipment	Year of Completion	Cost (1000US$)
Accra	Dansoman	GEDAP	2X 20MVA, 33/11kV	2009	2,700
	Adabraka	GOG	2X 20MVA, 33/11kV	2009	2,700
	Nmai Djorn	GEDAP	2X 20MVA, 33/11kV	2010	2,500
	Sowutom	GEDAP	2X 20MVA, 33/11kV	2010	2,500
	Kwabenya	GEDAP	2X 20MVA, 33/11kV	2010	2,500
	Cantonments	GEDAP	2X 20MVA, 33/11kV	2010	2,700
	Trade Fair	GOG	2X 20MVA, 33/11kV	2009	2,700
	Darukuman	-	2X 20MVA, 33/11kV	2011	2,500
	Gbawe/Weija	-	2X 20MVA, 33/11kV	2011	2,700
	T(Adenta)	GEDAP	Upgrade to 2*20MVA	2011	680
	3rd BSP	GOG	2X 20MVA, 33/11kV	2009	2,500
	Mallam BSP	GOG	Install 2X 20MVA, 33/11kV	2009	680
Tema	Dawhenya	GEDAP	2X 20MVA, 33/11kV	2010	2,500
	Santeo Adjei Kojo	-	2X 20MVA, 33/11kV	2011	2,700
	Afienya	-	2X 20MVA, 33/11kV	2011	2,500
	Community 25	-	2X 20MVA, 33/11kV	2011	2,700
	Kpone	-	2X 20MVA, 33/11kV	2011	2,700
Ashanti	2nd BSP	GEDAP	2X 20MVA, 33/11kV	2010	2,500
	Fawode	GEDAP	2X 20MVA, 33/11kV	2010	2,500
	Achiase/Kenyase	GEDAP	2X 20MVA, 33/11kV	2010	2,500
Central	Elmina	ECG	2X 10MVA, 33/11kV	2009	1,700
	Swedru	GOG	2X 10MVA, 33/11kV	2009	1,700
	Winneba	GOG	2X 15MVA, 33/11kV	2009	578
Western	Station A	GEDAP	Upgrade to 2*20MVA	2009	680
	Station B	GEDAP	Upgrade to 1*20MVA	2009	340
	Station C	GEDAP	Upgrade to 2*20MVA	2009	680
	Station D	LUTON	2X 10MVA, 33/11kV	2009	1,700
Eastern	Koforidua	-	2X 20MVA, 33/11kV	2010	2,500

Existing Sub-transmission line Plans

Region	Section	Year of Completion	Line Type	Line Length (km)	Cost (1000US$)
Accra	B-Dansoman	2009	3*630 Al XLPE	8.6	903
	Mallam-Dansoman	2009	265AAC 2cct	4.3	421
	V(old)-Dansoman	2009	3*630ALXLPE	6	630
	B-Darkuman	2011	3*630ALXLPE	8	840
	A-Darkuman	2011	3*630ALXLPE	14	1,470
	E-Adabraka	2009	3*630ALXLPE	3.8	399
	X-G	2011	3*630ALXLPE	8.5	893
	J-Sowutuom	2010	265AAC 2cct	10	980
	Sowutuom-Mallam	2010	265AAC 2cct	4.5	441
	J-C	2010	265AAC 2cct	5	490
	J-C	2010	3*630ALXLPE	6	630
	J-N	2010	265AAC 2cct	18.8	1,842
	Kwabenya-C	2010	3*630ALXLPE	14	1,470
	Kwabenya-T	2010	265AAC 2cct	14	1,372
	GwabeAJ-Mallam	2011	265AAC 2cct	4	392
	GwabeAJ-Z	2011	265AAC 2cct	10	980
	K-Cantonment	2010	3*630ALXLPE	5	525
	L-Cantonment	2010	3*630ALXLPE	5	525
	L-Trade Fair	2009	3*630ALXLPE	2.1	221
	L-Trade Fair	2009	265AAC 1cct	1	33
	Q-Trade Fair	2009	265AAC 1cct	3.2	106
	T-Dodowa	2009	265AAC 2cct	20	1,960
	Nmai Jorn- 3rd BSP	2010	400AAC 2cct	8	920
	H-M	2009	265AAC 2cct	7.5	735
	M-T	2009	265AAC 2cct	7	686
	Z-Tokuse	2011	265AAC 2cct	8.2	804
	3rd BSP-Y	2009	400AAC 2cct	3	345
Tema	H-Kpone	2011	400AAC 2cct	6	690
	Kpone-Community25	2011	400AAC 2cct	7	805
	Dawhenya-Community25	2011	400AAC 2cct	5	575
	Dawhenya-Afienya	2011	265AAC 2cct	12	1,176
	Afienya-Ashaiman	2011	265AAC 2cct	11	1,078
	B(Tema)-3rd BSP(Accra)	2009	400AAC 2cct	13	1,495
	Santeo Adjei Kojo-3rd BSP	2011	400AAC 2cct	8.7	1,001
	Ashiman-Santeo Adjei Kojo	2011	400AAC 2cct	7.3	840
Ashante	Fawode-C	2010	265AAC 2cct	9	882
	Fawode-Achiyase/Kenyase	2010	400AAC 2cct	7	805
	Achiyase/Kenyase-2nd BSP	2010	400AAC 2cct	10	1,150
Western	D-B	2009	3*630ALXLPE	6	630

Appendix 2

Primary substation and sub-transmission line plans

Area		Facility name	Countermeasure	Cost (1,000US$)	Year of implementation
ECG	Accra	H(Achimota)-E	- Installation of two new 630 ALXLPE circuits between H and E (2 circuits x 6.3 km)	1,323	2016
	Tema	H(Tema)-A	- Installation of two new 630 ALXLPE circuits between H and E (1 circuits x 5.6 km)	588	2016
		Kpong Primary substation	- Installation of an additional 10MVA transformer	200	2016
	Ashanti	A-KTI	- Installation of two new 630 ALXLPE circuits between H and E (1 circuits x 5.0 km)	525	2017
	Western	Atuabo Primary substation	- Installation of an additional 10MVA transformer	200	2009
		Axim Primary substation	- Installation of an additional 10MVA transformer	200	2015
	Eastern	ODA Primary substation	- Installation of an additional 10MVA transformer	200	2012
	Central	Saltpond Primary substation	- Installation of an additional 10MVA transformer	200	2009
	Volta	Kpeve Primary substation	- Installation of an additional 10MVA transformer	200	2009
		Tsito Primary substation	- Installation of an additional 10MVA transformer	200	2015
		Hohoe Primary substation	- Installation of an additional 10MVA transformer	200	2012
ECG Total				4,036	-
VRA-NED	Sunyani	Sunyani-Brekum	- Installation of capacity bank 3,000kVar	4	2010
			- Increase in thickness (from 120 to 200 mm2 AAC)	616	2010
		Sunyani-Mim	- Installation of capacity bank 4,000kVar	6	2010
		Berekum Primary substation	- Installation of an additional 5MVA transformer	83	2009
	Upper East	Bawku Primary substation	- Installation of an additional 3MVA transformer	48	2009
		Navrongo Primary substation	- Installation of an additional 3MVA transformer	48	2016
	Upper West	Sawla-Wa	- Installation of capacity bank 2,000kVar	3	2011
		Wa Primary substation	- Installation of an additional 5MVA transformer	83	2010
VRA-NED Total				891	-
Ghana Total				4,927	-

Appendix 3

Primary substation plans where necessity was found by distiribution reinforcement plans

Office	Substation (existing)	Distribution line (existing)	Countermeasure	Cost [1,000 US$]
Eastern	Tafo	Tafo	Installation of a new 33-kV distribution line (240 mm2 AAC, 24 km) from the Tafo BSP, construction of a new 33/11-kV substation (10 MVA) ahead of it, and connection to the existing Tafo distribution line along the way	1,743
	Akwatia	Asamankese	Installation of a new 33-kV distribution line (240 mm2 AAC, 25 km) from the Akwatia BSP, construction of a new 33/11-kV substation (5 MVA) ahead of it, and connection to the existing Asamkese distribution line along the way	1,425
	Nkawkaw	Mountains	Aerial line replacement ($16mm^2$ Cu→$120mm^2$ AAC, 32km) Construction of a 33/11-kV substation (5 MVA) along the way, and partial shift of load on the existing Mountains distribution line to the Donkorkrom distribution line	898
Western	Atuabo	Manganese	Voltage increase from 11 to 33 kV and construction of a new 33/11-kV substation (5 MVA)	312
Volta	Tsito	Peki	Construction of new 33/11-kV substations (10 MVA) at the center of the load distribution, installation of a new 33-kV distribution line (120 mm2 AAC, 2 km), and connection for division of the load	343
VRA-NED	Tamale	28F3B	Installation of new 34.5-kV line (185 mm2 ALXLPE, 18 km) from the Tamale BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Tolon), and connection to the existing 28F3B distribution line along the way	1,292
	Sunyani	27F8B	Installation of new 34.5-kV line (120 mm2 AAC, 14 km) from the Sunyani BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Chiraa), and connection to the existing 27F8B distribution line along the way	1,045

Appendix 4

Distribution network reinforcement master plan

①: New 33kV/11kV substation construction
(including ancillary facilities such as 33kV distribution lines)
②: Installation of new distribution line
③: Enlargement of lines（Overhead line）
④: Enlargement of lines（Cable）
⑤: Voltage increase
⑥: Installation of Capacitor Bank and Condensor, or Booster
⑦: Alleviation of load by construction of a switching station

(ECG Accra East Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main F	F03(FD38), F15(FK02), F11(FD19), F04(FD48)	①	Partial transfer of load after construction of the Adabraka substation	2009	GEDAP	
Main G	G013(G56), G07(G06), G11(G13), G19(G60), G12(G47), G02(G33), G06(G64), G04(G351), G21(G25)	①	Partial shift of load after construction of the Adabraka substation	2009	GEDAP	
Main H	H02(H351)	④	Cable replacement (120 mm2 Al -> 185 mm2 Al, 15 km) and partial shift of load to the M01 feeder	2008	572	3,800
	H05(H06)	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 13km)	2017	900	
	H10(H10)	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 14km)	2017	969	
	H04(H07)	②	* Installation of a new distribution line from the Main H substation, and partial shift of load ($120mm^2$ AAC, 15km)	2011	320	
	H08(H24)	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 15km)	2013	1,039	

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main K	K03(K09)	①	Installation of a new distribution line from the Trade Fair substation (to be constructed in 2009), and partial shift of load (120mm^2 AAC, 8km)	2009	171 Only for cost of installing a new line	3,533
	K04(K10)	①	Installation of a new distribution line from the Trade Fair substation, and partial shift of load (120mm^2 AAC, 8km)	2009	171 Only for cost of installing a new line	
	K05(K150)	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 18km)	2008	1,246	
	K13(K13)	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 17km)	2014	1,177	
	K06(K60)	②	Installation of a new distribution line from the Airport substation (already constructed), and partial shift of load (120mm^2 AAC, 9km)	2011	192	
	K10(K61)	②	Same as above (120mm^2 AAC, 7km)	2017	149	
	K11(K06)	②	Same as above (120mm^2 AAC, 9km)	2009	192	
	K12(K07)	②	Same as above (120mm^2 AAC, 11km)	2011	235	
Main L	L11(L01)	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 17km)	2017	1,177	2,456
	L10(L22)	①	Installation of a new distribution line from the Trade Fair substation, and partial shift of load (120mm^2 AAC, 6km)	2017	128	
	L06(L12)	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 12km)	2017	831	
	L04(L03)	①	Installation of a new distribution line from the Trade Fair substation, and partial shift of load (120mm^2 AAC, 6km)	2015	128	
	L03(L02)	①	Same as above (120mm^2 AAC, 9km)	2010	192	
Main M	M05 (Old Legon 2)	①	Partial shift of load after construction of the Nmai Djorn substation	2010	GEDAP	1,172
	M01 (Old Legon 1)	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 16km)	2011	1,108	
	M07 (Madina)	①	Partial shift of load after construction of the Nmai Djorn substation	2010	GEDAP	
	M08 (Kwabenya)	①	Installation of a new distribution line from the Kwabenya substation (to be constructed in 2010 under the GEDAP), and partial shift of load (120mm^2 AAC, 3km)	2010	GEDAP New distribution line installation cost: 64	

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main Q	Q03 (Teshie 1)	②	Installation of a new distribution line from the Main Q substation, and partial shift of load (120mm^2 AAC, 5km)	2009	107	406
	Q06 (Teshie 3)	②	Same as above (120mm^2 AAC, 5km)	2015	107	
	Q01 (Old Spintex)	②	Same as above (120mm^2 AAC, 4km)	2008	85	
	Q07 (Teshie 2)	②	Same as above (120mm^2 AAC, 5km)	2014	107	
Main T	T03 (Adenta Est.1)	①	Partial shift of load after construction of the Nmai Djorn substation	2010	GEDAP	362
	T09 (Agbogba)	①	Installation of a new distribution line from the Kwabenya substation (to be constructed in 2010 under the GEDAP), and partial shift of load (120mm^2 AAC, 7km)	2010	GEDAP New distribution line installation cost: 149	
	T11 (Pantang)	①	Same as above (120mm^2 AAC, 10km)	2010	213	
Main W	Peduase	⑥	Installation of a capacitor bank (tentatively 4,000 kVar) to improve voltage	2008	6	12
	"W03 (Akropong)"	⑥	Installation of a capacitor bank (tentatively 4,000 kVar) to improve voltage	2008	6	
Main Y	"Y04 (Johnson Wax)"	①	Installation of a new distribution line from the Nami Djorn substation (to be constructed in 2010 under the GEDAP), and partial shift of load (120mm^2 AAC, 5km)	2010	GEDAP New distribution line installation cost: 107	576
	"Y10 (Texpo)", "Y11 (Spintex)"	②	Installation of a new distribution line from the Main Y substation, and partial shift of load (120mm^2 AAC, 12km)	2008	256	
	"Y02 (Old Spintex)"	②	Installation of a new distribution line from the Airport substation (already constructed), and partial shift of load (120mm^2 AAC, 10km)	2013	213	

（ECG Accra West Office）

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main A (Odorkor)	A120, A13, A01, A61	①	Partial shift of load after construction of the Darkman substation (2011) and the Sowutuom substation (2010)	2011 2010	GEDAP	
Main B (Korie Bu)	B25, B27, B35, B15, B42, B24, B28, B19, B20	①	Partial shift of load after construction of the New Dansoman substation	2009	GEDAP	
Main C (Achimota Village)	ABC	③	Aerial line replacement ($35mm^2$ Cu →$120mm^2$ AAC, 20km)	2008	103	103
	C20, C60, C14, C13	①	* Partial shift of load after construction of the Sowutuom substation	2010	GEDAP	
Main D (Avenor)	D150	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 2.2km)	2011	152	3,978
	D123	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 4.4km)	2010	305	
	D16	④	Cable replacement ($185mm^2$ Al →$6x630mm^2$ Cu, 3.2km)	2008	2,032	
	D101	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 4.2km)	2008	291	
	D103	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 5.3km)	2008	367	
	D01	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 5.4km)	2011	374	
	D114	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 6.6km)	2008	457	
Main E (Tran-shipment)	E08, E07, EG14, E20, E150	①	Partial shift of load after construction of the Adabraka substation	2009	GEDAP	
Main F (Koko-miemie)	F11, F10	①	Partial shift of load after construction of the Adabraka substation	2009	GEDAP	

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main G (Power House)	G25	②	Installation of a new distribution line from the Main G substation, and partial shift of load ($185mm^2$ Alcable, 10km)	2008	329	1,087
	G56	②	Same as above ($185mm^2$ Alcable, 10km)	2014	329	
	GE19	④	Cable replacement ($185mm^2$ Al →$258mm^2$ Cu, 6.2km)	2014	429	
Main N (Nsawam)	Nsawam - Accra,	①	Partial shift of load after construction of the Ofankor substation	2008	Posting as new substation construction cost	320
	Adoagyiri -Coaltar	②	Partial shift of load to a new feeder from Asamankese feeders	2008	320	
Main R (Ridge)	R12	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 4.9km)	2011	339	983
	R11	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 2.1km)	2010	145	
	R3	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 7.2km)	2017	499	
Main S (Kuwa-shieman)	S10	①	Partial shift of load after construction of the Sowutuomr substation	2010	GEDAP	
Main V (Dansoman)	V02, V10, V11	①	Partial shift of load after construction of the New Dansoman substation	2009	GEDAP	
Main Z (Tokuse)	RADIO	②	Installation of a new distribution line from the Main Z substation, and partial shift of load ($120mm^2$ AAC, 15km)	2008	320	640
	TUBA	②	Installation of a new distribution line from the Main Z substation, and partial shift of load ($120mm^2$ AAC, 15km)	2008	320	

(ECG Tema Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Tema A	A31	④	Cable replacement ($120mm^2$ Cu →$240mm^2$ Cu, 3km)	2009	213	213
Tema B	B111	①	Installation of a new distribution line from the Adjei Kojo substation (to be constructed in 2010 under the GEDAP), and partial shift of load ($120mm^2$ AAC, 3km)	2010	GEDAP Distribution line installation cost: 64	64
Tema C	LUBE OIL	④	Cable replacement ($120mm^2$ Cu →$240mm^2$ Cu, 1.75km)	2012	124	369
	F/H#2	②	Installation of a new distribution line toward PFC Tank and partial shift of load ($240mm^2$ Cu ケーブル, 0.5km)	2010	32	
	AGRONA	④	Cable replacement ($120mm^2$ Cu →$240mm^2$ Cu, 3km)	2010	213	
Tema E	E21	④	Cable replacement ($120mm^2$ Cu →$240mm^2$ Cu, 1km)	2009	71	71
Tema H	Prampram	①	Installation of a new distribution line from the Dawhenya substation (to be constructed in 2010 under the GEDAP), and partial shift of load ($120mm^2$ AAC, 15km)	2010	GEDAP Distribution line installation cost: 320	1.089
	Western Castling	④	Cable replacement ($185mm^2$ Al →$240mm^2$ Cu, 2km)	2011	139	
	H-B1	②	Connection of the cable on the trunk portion of the existing H-B2 line to H-B1, for two lines on the trunk portion of H-B1, plus installation of a new cable (630 mm2 Al XLPE, 6 km) for H-B2	2010	630	
	H-B2					
Tema L (Lashibi)	Comm.20 (L91)	⑥	Installation of a capacitor bank (tentatively 300 kVar) to improve voltage	2013	1	1
Tema S (Ashiaman)	S31 (AFARIWA)	①	Partial shift of load after construction of the Mobole substation now under planning	2010	Construction of a new substation	
KPONG	Krobo Area	②	Installation of a new distribution line from the substation and partial shift of load ($120mm^2$ AAC, 16km)	2013	341	341
Asutsuare	Asutsuare	③	Aerial line replacement ($35mm^2$ Cu →$120mm^2$ AAC, 16km)	2008	358	358

(ECG Ashanti East Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main C	NSUTA -KUWAWU	①	Partial shift of load after construction of the Fawode and Achiase substations (both in 2010)	2010	GEDAP	213
	C21	②	Installation of a new distribution line from the Main F substation and partial shift of load (completed)	2007	Already implemented	
	C41	②	Partial shift of load to the KTI substation (120mm^2 AAC, 10km)	2008	213	
	Airport 1	①	Partial shift of load after construction of the Achiase substation (2010)	2010	GEDAP	
	Airport 2	①	Partial shift of load after construction of the Fawode substation (2010), and partial shift of load to the distribution line from Main E	2010	GEDAP	
Main E	E21	①	Partial shift of load after construction of the Fawode substation (2010), and partial shift of load to the distribution line from Main C	2010	GEDAP new distribution line installation cost: 213	
NSUTA	Mampong	③	Aerial line replacement (16mm^2 Cu →120mm^2 AAC, 10.9km)	2008	67	67
AGONA	NSUTA	①	Partial shift of load after construction of the Achiase substation (2010)	2010	GEDAP	
KONONGO	KONONGO	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2009	6	18
	AGOGO	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2010	6	
	ODUMASI	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2017	6	
EJISU	EJISU	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2009	6	6

(ECG Ashanti West Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main A	OBR	②	Partial shift of load to the Guiness 1 feeder completed; installation of four new distribution lines from the Amanform substation (already constructed) and partial shift of load (installation work already started; lengths of 0.1 km (three) and 1 km (one)	2008	(Already implemented) distribution line installation cost: 28	129
	IND OHL	④	Cable replacement ($35mm^2$ Cu →$185mm^2$ Al, 2.7km)	2008	92	
	LAKE ROAD	①	Installation of a new distribution line from the KTI (Japckson Park) substation now under construction and partial shift of load, plus installation of three new distribution lines (each with 185 mm2 Al cable and a length of 0.1 km)	2008	10	
	POWER HOUSE 2					
Main B	B11	②	Installation of a new distribution line from the Main E substation and partial shift of load ($120mm^2$ AAC, 5km)	2009	107	533
	B21	②	Installation of a new distribution line from the Main E substation and partial shift of load ($120mm^2$ AAC, 5km)	2009	107	
	B61	②	Installation of a new distribution line from the Abuakawa substation and partial shift of load ($120mm^2$ AAC, 5km)	2008	107	
	B71	②	Installation of a new distribution line from the Abuakawa substation and partial shift of load($120mm^2$ AAC, 5km)	2009	107	
	B81	②	Installation of a new distribution line from the Abuakawa substation and partial shift of load($120mm^2$ AAC, 5km)	2009	107	
Main D	D21	①	Plan for a partial shift of load to the Knust substation already constructed	2008	Substation already constructed	
	D31	①	Plan for a partial shift of load to the Knust substation already constructed	2008	Substation already constructed	
BEKWAI	KOKOFU	③	Aerial line replacement ($16mm^2$ Cu →$120mm^2$ AAC, 1.9km)	2008	12	12
Dunkwa	DUNKWA	③	Aerial line and cable replacement ($35mm^2$ Cu →$120mm^2$ AAC, 8.7km) ($16mm^2$ Cu →$120mm^2$ AAC, 1.5km) ($35mm^2$ Cu cable →$185mm^2$ Al XLPE, 2.7km)	2008	162	162

(ECG Western Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Western A	A10	④	Cable replacement ($120mm^2$ Cu PILC →$185mm^2$ Cu PILC, 1.5km)	2017	74	637
	A31	④	Cable replacement ($120mm^2$ Cu PILC →$240mm^2$ Cu PILC, 4.3km) Partial shift of load from the existing distribution line A41 to A57	2008	304	
	A55	③	Aerial line replacement ($150mm^2$ Al → $265mm^2$ Al, 7.6km)	2010	259	
Western B	B21	④	Cable replacement ($185mm^2$ Cu PILC →$240mm^2$ Cu PILC, 2.9km)	2012	205	453
	B71	④	Cable replacement ($120mm^2$ Cu PILC →$240mm^2$ Cu PILC, 3.5km)	2008	248	
Western C	C08	⑤	Voltage increase from 11 to 33 kV	2010	719	719
Bogoso	"Bogoso / Asanko"	⑦	Construction of a switching station and division of the existing distribution lines	2010	400	400
Atuabo	Aboso 1	③	Aerial line replacement ($150mm^2$ AAC → $240mm^2$ AAC, 38km)	2012	775	1,976
	Aboso 2	③	Aerial line replacement ($150mm^2$ AAC → $240mm^2$ AAC, 38.7km)	2012	789	
	Town 2	③	Aerial line replacement ($70mm^2$ Cu→$240mm^2$ AAC, 12km)	2013	100	
	Manganese	①	Voltage increase from 11 to 33 kV and construction of a new 33/11-kV substation (5 MVA)	2008	312	
Asawinso	Awaso /Wiawso	③	Aerial line replacement ($150mm^2$ AAC →$200mm^2$ AAC, 15km)	2017	123	725
	Bibiani	③	Aerial line replacement ($150mm^2$ AAC →$400mm^2$ AAC, 29.5km)	2012	602	
Dwenase	Juaboso	③	Aerial line replacement （$120mm^2$ AAC →$240mm^2$ AAC, about 60km、Need for replacement of supporting structures as well）	2012	1,942	1,942

(ECG Eastern Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Tafo	Kibi / Suhum	⑤	Voltage increase from 11 to 33 kV	2008	1,270	3,518
	Tafo	①	Installation of a new 33-kV distribution line (240 mm2 AAC, 24 km) from the Tafo BSP, construction of a new 33/11-kV substation (10 MVA) ahead of it, and connection to the existing Tafo distribution line along the way	2008	1,743	
	Koforidua	②	Installation of a new 33-kV distribution line (240 mm2 AAC, 17 km) from the Tafo BSP, and connection to the existing Tafo Koforidua distribution line	2008	505	
Akwatia	Akwatia	⑤	Voltage increase from 11 to 33 kV	2008	616	2,932
	Asamankese	①	Installation of a new 33-kV distribution line (240 mm2 AAC, 25 km) from the Akwatia BSP, construction of a new 33/11-kV substation (5 MVA) ahead of it, and connection to the existing Asamkese distribution line along the way	2008	1,425	
	Oda	②	Installation of a new 33-kV distribution line (240 mm2 AAC, 30 km) from the Akwatia BSP, and connection to the existing Oda distribution line	2008	891	
Oda	Achiase	③	Aerial line replacement ($35mm^2$ Cu →$120mm^2$ AAC, 56km) ($50mm^2$ AAC→$120mm^2$ AAC, 4km)	2008	374	374
Nkawkaw	Mountains	①	Aerial line replacement ($16mm^2$ Cu→$120mm^2$ AAC, 32km) Construction of a 33/11-kV substation (5 MVA) along the way, and partial shift of load on the existing Mountains distribution line to the Donkorkrom distribution line	2010	898	1,087
	Town	④	Cable replacement ($95mm^2$ Al XLPE, $185mm^2$ Al XLPE →$240mm^2$ Cu XLPE, 3km)	2008	189	

(ECG Central Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
WINNEBA	WINNEBA	②	Installation of a new distribution line (120 mm2 AAC, 4 km) and partial shift of load, or partial shift of load to the APAM distribution line	2010	85	86
	SWEDRU 1	①	Partial shift of load after construction of the Swedru substation	2009	GEDAP	
	SWEDRU 2	①	Partial shift of load after construction of the Swedru substation	2009	GEDAP	
	APAM	⑥	Installation of a condensor to increase voltage	2008	1	
SALTPOND	MANKESSIM	⑥	Installation of a condensor to increase voltage	2008	1	1
Cape Coast	SALTPOND	①	Partial shift of load after construction of the Elmina substation, and installation of a condensor to increase voltage	2009	GEDAP 1	2
	FOSU	①	Partial shift of load after construction of the Elmina substation, and installation of a condensor to increase voltage	2009	GEDAP 1	
	ELMINA	①	Partial shift of load after construction of the Elmina substation	2009	GEDAP	
	TOWN 2	①	Partial shift of load after construction of the Elmina substation	2009	GEDAP	

(ECG Volta Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
KPANDO	HOHOE	⑥	Installation of a 33-kV booster station to increase voltage	2008	100	1,124
	"HOHOE-JASIKAN"	②	Installation of a new 11-kV distribution line ($120mm^2$ AAC, 48km)	2009	1,024	
KPEVE	TOWNSHIP	②	Installation of a tie between the Tsibu Bethel and Agbate distribution lines to take in the existing Township load ($120mm^2$ AAC, 5km)	2009	96	96
HO	TANYIGBE	②	Installation of a new 11-kV distribution line and division of the existing Tanyigbe load ($120mm^2$ AAC, 4km)	2016	75	75
SOGAKOPE	"SOGA-AKATSI"	②	Installation of a new 33-kV distribution line and division of the Keta distribution line from Akatsi and Sogakope ($120mm^2$ AAC, 12.5km)	2008	267	267
TSITO	PEKI	①	Construction of new 33/11-kV substations (2 x 10 MVA) at the center of the load distribution, installation of a new 33-kV distribution line (120 mm2 AAC, 2 km), and connection for division of the load	2010	343	343
Anloga	Keta	③	Replacement of aerial lines ($16mm^2$ Cu →$120mm^2$ AAC, 3.5km) ($35mm^2$ Cu → $120mm^2$ AAC, 14.4km) ($70mm^2$ Cu→$120mm^2$ AAC, 2.4km)	2008	700	700

(VRA-NED Area)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Tamale	28F3B	①	Installation of new 34.5-kV line (185 mm2 ALXLPE, 18 km) from the Tamale BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Tolon), and connection to the existing 28F3B distribution line along the way	2008	1,292	1,907
	28F4B	②	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2009	131	
	28F6B	②	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2008	131	
	28F7B	③	Aerial line replacement ($100mm^2$ AAC → $240mm^2$ AAC, 8km)	2013	66	
	28F8B	③	Aerial line replacement ($100mm^2$ AAC → $240mm^2$ AAC, 19km)	2009	156	
	28F9B	②	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2010	131	
Brekum	Sunyani - Drobo (BRYF1)	③	Aerial line replacement ($120mm^2$ AAC →$150mm^2$ AAC, 40km)	2009	279	1,141
	"Berekum - Dormaa (BRYF2)"	③	Aerial line replacement ($120mm^2$ AAC →$150mm^2$ AAC, 31km)	2009	216	
	Berekum F1 (BRBF1)	⑤	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($35mm^2$ Cu, $50mm^2$ AAC →$200mm^2$ AAC, 23km)	2008	555	
	Berekum F2 (BRBF2)	③	Aerial line replacement ($50mm^2$ AAC →$100mm^2$ AAC, 6km)	2008	42	
	Berekum F3 (BRBF3)	③	Aerial line replacement ($16mm^2$ Cu, $50mm^2$ AAC →$100mm^2$ AAC, 8km)	2008	49	
Sunyani	Sunyani F3 (27F3B)	②	Installation of a 11.5kV new line ($120mm^2$ AAC, 13km)	2008	327	1,421
	Sunyani F7 (27F7B)	③	Aerial line replacement ($35mm^2$ AAC →$100mm^2$ AAC, 7km)	2008	43	
	Sunyani F8 (27F8B)	①	Installation of new 34.5-kV line (120 mm2 AAC, 14 km) from the Sunyani BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Chiraa), and connection to the existing 27F8B distribution line along the way	2008	1,045	

(VRA-NED Area)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Sawla	Sawla-Wa (38YF6)	⑥	Installation of a capacitor bank (2,000 kVar) in the Mim switching station to improve voltage	2011	3	155
	Wa-Hamile (WAFY1)					
	Wa Township 1 (479BF1)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 6km)	2009	37	
	Wa Township 2 (479BF2)	③	Aerial line replacement ($100mm^2$ AAC, $120mm^2$ AAC → $150mm^2$ AAC, 12km)	2010	84	
	Wa Township 3 (479BF3)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 5km)	2008	31	
Yendi	Bimbilla (35F5Y)	⑥	Installation of a 10-MVA booster station to improve voltage	2008	100	100
Bolgatanga	29F1B (BOLGA)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC, $120mm^2$ AAC → $150mm^2$ AAC, 5km)	2010	168	1,486
	29F4B (BOLGA)	⑤	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 20km)	2008	649	
	29F6B (BOLGA)	⑤	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 8km)	2008	669	
Techiman	26F1B (TECHIMAN)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC→ $150mm^2$ AAC, 17km)	2008	125	319
	26F2B (TECHIMAN)	③	Aerial line replacement ($50mm^2$ AAC → $120mm^2$ AAC, 8km)	2009	55	
	WHF2B (WENCHI)	③	Aerial line replacement ($25mm^2$ AAC → $100mm^2$ AAC, 20km)	2008	139	

Appendix 5

Distribution network reinforcement implementation plan

①: New 33kV/11kV substation construction
(including ancillary facilities such as 33kV distribution lines)
②: Installation of new distribution line
③: Enlargement of lines（Overhead line）
④: Enlargement of lines（Cable）
⑤: Voltage increase
⑥: Installation of Capacitor Bank and Condensor, or Booster
⑦: Alleviation of load by construction of a switching station

(ECG Accra East Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main F	F03(FD38), F15(FK02), F11(FD19), F04(FD48)	①	Partial transfer of load after construction of the Adabraka substation	2009	GEDAP	
Main G	G013(G56), G07(G06), G11(G13), G19(G60), G12(G47), G02(G33), G06(G64), G04(G351), G21(G25)	①	Partial shift of load after construction of the Adabraka substation	2009	GEDAP	
Main H	H02(H351)	④	Cable replacement (120 mm2 Al -> 185 mm2 Al, 15 km) and partial shift of load to the M01 feeder	2008	572	3,800
	H05(H06)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 13km)	2017	900	
	H10(H10)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 14km)	2017	969	
	H04(H07)	②	* Installation of a new distribution line from the Main H substation, and partial shift of load ($120mm^2$ AAC, 15km)	2011	320	
	H08(H24)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 15km)	2013	1,039	

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main K	K03(K09)	①	Installation of a new distribution line from the Trade Fair substation (to be constructed in 2009), and partial shift of load ($120mm^2$ AAC, 8km)	2009	171 Only for cost of installing a new line	3,532
	K04(K10)	①	Installation of a new distribution line from the Trade Fair substation, and partial shift of load ($120mm^2$ AAC, 8km)	2009	171 Only for cost of installing a new line	
	K05(K150)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 18km)	2008	1,246	
	K13(K13)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 17km)	2014	1,177	
	K06(K60)	②	Installation of a new distribution line from the Airport substation (already constructed), and partial shift of load ($120mm^2$ AAC, 9km)	2011	192	
	K10(K61)	②	Same as above ($120mm^2$ AAC, 7km)	2017	149	
	K11(K06)	②	Same as above ($120mm^2$ AAC, 9km)	2009	192	
	K12(K07)	②	Same as above ($120mm^2$ AAC, 11km)	2011	235	
Main L	L11(L01)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 17km)	2017	1,177	2,456
	L10(L22)	①	Installation of a new distribution line from the Trade Fair substation, and partial shift of load ($120mm^2$ AAC, 6km)	2017	128	
	L06(L12)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 12km)	2017	831	
	L04(L03)	①	Installation of a new distribution line from the Trade Fair substation, and partial shift of load ($120mm^2$ AAC, 6km)	2015	128	
	L03(L02)	①	Same as above ($120mm^2$ AAC, 9km)	2010	192	
Main M	M05 (Old Legon 2)	①	Partial shift of load after construction of the Nmai Djorn substation	2010	GEDAP	1,172
	M01 (Old Legon 1)	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 16km)	2011	1,108	
	M07 (Madina)	①	Partial shift of load after construction of the Nmai Djorn substation	2010	GEDAP	
	M08 (Kwabenya)	①	Installation of a new distribution line from the Kwabenya substation (to be constructed in 2010 under the GEDAP), and partial shift of load ($120mm^2$ AAC, 3km)	2010	GEDAP New distribution line installation cost: 64	

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main Q	Q03 (Teshie 1)	②	Installation of a new distribution line from the Main Q substation, and partial shift of load (120mm^2 AAC, 5km)	2009	107	405
	Q06 (Teshie 3)	②	Same as above (120mm^2 AAC, 5km)	2015	107	
	Q01 (Old Spintex)	②	Same as above (120mm^2 AAC, 4km)	2008	85	
	Q07 (Teshie 2)	②	Same as above (120mm^2 AAC, 5km)	2014	107	
Main T	T03 (Adenta Est.1)	①	Partial shift of load after construction of the Nmai Djorn substation	2010	GEDAP	363
	T09 (Agbogba)	①	Installation of a new distribution line from the Kwabenya substation (to be constructed in 2010 under the GEDAP), and partial shift of load (120mm^2 AAC, 7km)	2010	GEDAP New distribution line installation cost: 149	
	T11 (Pantang)	①	Same as above (120mm^2 AAC, 10km)	2010	213	
Main W	Peduase	⑥	Installation of a capacitor bank (tentatively 4,000 kVar) to improve voltage	2008	6	12
	"W03 (Akropong)"	⑥	Installation of a capacitor bank (tentatively 4,000 kVar) to improve voltage	2008	6	
Main Y	"Y04 (Johnson Wax)"	①	Installation of a new distribution line from the Nami Djorn substation (to be constructed in 2010 under the GEDAP), and partial shift of load (120mm^2 AAC, 5km)	2010	GEDAP New distribution line installation cost: 107	576
	"Y10 (Texpo)", "Y11 (Spintex)"	②	Installation of a new distribution line from the Main Y substation, and partial shift of load (120mm^2 AAC, 12km)	2008	256	
	"Y02 (Old Spintex)"	②	Installation of a new distribution line from the Airport substation (already constructed), and partial shift of load (120mm^2 AAC, 10km)	2013	213	
ECG Accra East Office Total						12,316

（ECG Accra West Office）

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main A (Odorkor)	A120, A13, A01, A61	①	Partial shift of load after construction of the Darkman substation (2011) and the Sowutuom substation (2010)	2011 2010	GEDAP	
Main B (Korie Bu)	B25, B27, B35, B15, B42, B24, B28, B19, B20	①	Partial shift of load after construction of the New Dansoman substation	2009	GEDAP	
Main C (Achimota Village)	ABC	③	Aerial line replacement (35mm^2 Cu →120mm^2 AAC, 20km)	2008	103	103
	C20, C60, C14, C13	①	* Partial shift of load after construction of the Sowutuom substation	2010	GEDAP	
Main D (Avenor)	D150	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 2.2km)	2011	152	3,978
	D123	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 4.4km)	2010	305	
	D16	④	Cable replacement (185mm^2 Al → 6x630mm^2 Cu, 3.2km)	2009	2,032	
	D101	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 4.2km)	2008	291	
	D103	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 5.3km)	2008	367	
	D01	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 5.4km)	2011	374	
	D114	④	Cable replacement (185mm^2 Al → 240mm^2 Cu, 6.6km)	2008	457	
Main E (Tran-shipment)	E08, E07, EG14, E20, E150	①	Partial shift of load after construction of the Adabraka substation	2009	GEDAP	
Main F (Koko-miemie)	F11, F10	①	Partial shift of load after construction of the Adabraka substation	2009	GEDAP	

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main G (Power House)	G25	②	Installation of a new distribution line from the Main G substation, and partial shift of load ($185mm^2$ Al cable, 10km)	2008	329	1,087
	G56	②	Same as above ($185mm^2$ Al cable, 10km)	2014	329	
	GE19	④	Cable replacement ($185mm^2$ Al → $258mm^2$ Cu, 6.2km)	2014	429	
Main N (Nsawam)	Nsawam - Accra	①	Partial shift of load after construction of the Ofankor substation	2008	Posting as new substation construction cost	320
	Adoagyiri -Coaltar	②	Partial shift of load to a new feeder from Asamankese feeders	2008	320	
Main R (Ridge)	R12	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 4.9km)	2011	339	983
	R11	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 2.1km)	2010	145	
	R3	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 7.2km)	2017	499	
Main S (Kuwa-shieman)	S10	①	Partial shift of load after construction of the Sowutuomr substation	2010	GEDAP	
Main V (Dansoman)	V02, V10, V11	①	Partial shift of load after construction of the New Dansoman substation	2009	GEDAP	
Main Z (Tokuse)	RADIO	②	Installation of a new distribution line from the Main Z substation, and partial shift of load ($120mm^2$ AAC, 15km)	2008	320	640
	TUBA	②	Installation of a new distribution line from the Main Z substation, and partial shift of load ($120mm^2$ AAC, 15km)	2008	320	
ECG Accra West Office Total						7,111

(ECG Tema Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Tema A	A31	④	Cable replacement ($120mm^2$ Cu → $240mm^2$ Cu, 3km)	2009	213	213
Tema B	B111	①	Installation of a new distribution line from the Adjei Kojo substation (to be constructed in 2010 under the GEDAP), and partial shift of load ($120mm^2$ AAC, 3km)	2010	GEDAP Distribution line installation cost: 64	64
Tema C	LUBE OIL	④	Cable replacement ($120mm^2$ Cu → $240mm^2$ Cu, 1.75km)	2012	124	369
	F/H#2	②	Installation of a new distribution line toward PFC Tank and partial shift of load ($240mm^2$ Cu ケーブル, 0.5km)	2010	32	
	AGRONA	④	Cable replacement ($120mm^2$ Cu → $240mm^2$ Cu, 3km)	2010	213	
Tema E	E21	④	Cable replacement ($120mm^2$ Cu → $240mm^2$ Cu, 1km)	2009	71	71
Tema H	Prampram	①	Installation of a new distribution line from the Dawhenya substation (to be constructed in 2010 under the GEDAP), and partial shift of load ($120mm^2$ AAC, 15km)	2010	GEDAP Distribution line installation cost: 320	1,089
	Western Castling	④	Cable replacement ($185mm^2$ Al → $240mm^2$ Cu, 2km)	2011	139	
	H-B1	②	Connection of the cable on the trunk portion of the existing H-B2 line to H-B1, for two lines on the trunk portion of H-B1, plus installation of a new cable (630 mm2 Al XLPE, 6 km) for H-B2	2010	630	
	H-B2					
Tema L (Lashibi)	Comm.20 (L91)	⑥	Installation of a capacitor bank (tentatively 300 kVar) to improve voltage	2013	1	1
Tema S (Ashiaman)	S31 (AFARIWA)	①	Partial shift of load after construction of the Mobole substation now under planning	2010	Construction of a new substation	
KPONG	Krobo Area	②	Installation of a new distribution line from the substation and partial shift of load ($120mm^2$ AAC, 16km)	2013	341	341
Asutsuare	Asutsuare	③	Aerial line replacement ($35mm^2$ Cu →$120mm^2$ AAC, 16km)	2008	358	358
ECG Tema Offiice Total						2,506

(ECG Ashanti East Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main C	NSUTA -KUWAWU	①	Partial shift of load after construction of the Fawode and Achiase substations (both in 2010)	2010	GEDAP	213
	C21	②	Installation of a new distribution line from the Main F substation and partial shift of load (completed)	2007	Already implemented	
	C41	②	Partial shift of load to the KTI substation (120mm^2 AAC, 10km)	2008	213	
	Airport 1	①	Partial shift of load after construction of the Achiase substation (2010)	2010	GEDAP	
	Airport 2	①	Partial shift of load after construction of the Fawode substation (2010), and partial shift of load to the distribution line from Main E	2010	GEDAP	
Main E	E21	①	Partial shift of load after construction of the Fawode substation (2010), and partial shift of load to the distribution line from Main C	2010	GEDAP new distribution line installation cost: 213	
NSUTA	Mampong	③	Aerial line replacement (16mm^2 Cu →120mm^2 AAC, 10.9km)	2008	67	67
AGONA	NSUTA	①	Partial shift of load after construction of the Achiase substation (2010)	2010	GEDAP	
KONONGO	KONONGO	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2009	6	18
	AGOGO	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2010	6	
	ODUMASI	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2017	6	
EJISU	EJISU	⑥	Installation of a capacitor bank (tentatively 4000 kVar) to improve voltage	2009	6	6
ECG Ashanti East Office Total						517

(ECG Ashanti West Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation units
Main A	OBR	②	Partial shift of load to the Guiness 1 feeder completed; installation of four new distribution lines from the Amanform substation (already constructed) and partial shift of load (installation work already started; lengths of 0.1 km (three) and 1 km (one)	*2007* 2008	(Already implemented) distribution line installation cost: 28	129
	IND OHL	④	Cable replacement ($35mm^2$ Cu →$185mm^2$ Al, 2.7km)	2008	92	
	LAKE ROAD	①	Installation of a new distribution line from the KTI (Japckson Park) substation now under construction and partial shift of load, plus installation of three new distribution lines (each with 185 mm2 Al cable and a length of 0.1 km)	2008	10	
	POWER HOUSE 2					
Main B	B11	②	Installation of a new distribution line from the Main E substation and partial shift of load ($120mm^2$ AAC, 5km)	2009	107	533
	B21	②	Installation of a new distribution line from the Main E substation and partial shift of load ($120mm^2$ AAC, 5km)	2009	107	
	B61	②	Installation of a new distribution line from the Abuakawa substation and partial shift of load ($120mm^2$ AAC, 5km)	2008	107	
	B71	②	Installation of a new distribution line from the Abuakawa substation and partial shift of load ($120mm^2$ AAC, 5km)	2009	107	
	B81	②	Installation of a new distribution line from the Abuakawa substation and partial shift of load ($120mm^2$ AAC, 5km)	2009	107	
Main D	D21	①	Plan for a partial shift of load to the Knust substation already constructed	2008	Substation already constructed	
	D31	①	Plan for a partial shift of load to the Knust substation already constructed	2008	Substation already constructed	
BEKWAI	KOKOFU	③	Aerial line replacement ($16mm^2$ Cu → $120mm^2$ AAC, 1.9km)	2008	12	12
Dunkwa	DUNKWA	③	Aerial line and cable replacement ($35mm^2$ Cu → $120mm^2$ AAC, 8.7km) ($16mm^2$ Cu → $120mm^2$ AAC, 1.5km) ($35mm^2$ Cu cable →$185mm^2$ Al XLPE, 2.7km)	2008	162	162
ECG Ashanti West Office Total						836

(ECG Western Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Western A	A10	④	Cable replacement ($120mm^2$ Cu PILC →$185mm^2$ Cu PILC, 1.5km)	2017	74	637
	A31	④	Cable replacement ($120mm^2$ Cu PILC →$240mm^2$ Cu PILC, 4.3km) Partial shift of load from the existing distribution line A41 to A57	2008	304	
	A55	③	Aerial line replacement ($150mm^2$ Al → $265mm^2$ Al, 7.6km)	2010	259	
Western B	B21	④	Cable replacement ($185mm^2$ Cu PILC →$240mm^2$ Cu PILC, 2.9km)	2012	205	453
	B71	④	Cable replacement ($120mm^2$ Cu PILC →$240mm^2$ Cu PILC, 3.5km)	2008	248	
Western C	C08	⑤	Voltage increase from 11 to 33 kV	2010	719	719
Bogoso	"Bogoso / Asanko"	⑦	Construction of a switching station and division of the existing distribution lines	2010	400	400
Atuabo	Aboso 1	③	Aerial line replacement ($150mm^2$ AAC → $240mm^2$ AAC, 38km)	2012	775	1,976
	Aboso 2	③	Aerial line replacement ($150mm^2$ AAC → $240mm^2$ AAC, 38.7km)	2012	789	
	Town 2	③	Aerial line replacement ($70mm^2$ Cu→$240mm^2$ AAC, 12km)	2013	100	
	Manganese	①	Voltage increase from 11 to 33 kV and construction of a new 33/11-kV substation (5 MVA)	2008	312	
Asawinso	Awaso /Wiawso	③	Aerial line replacement ($150mm^2$ AAC →$200mm^2$ AAC, 15km)	2017	123	725
	Bibiani	③	Aerial line replacement ($150mm^2$ AAC →$400mm^2$ AAC, 29.5km)	2012	602	
Dwenase	Juaboso	③	Aerial line replacement（$120mm^2$ AAC →$240mm^2$ AAC, about 60km 、Need for replacement of supporting structures as well）	2012	1,942	1,942
ECG Western Office Total						6,853

(ECG Eastern Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Tafo	Kibi / Suhum	⑤	Voltage increase from 11 to 33 kV	2010	1,270	3,518
	Tafo	①	Installation of a new 33-kV distribution line (240 mm2 AAC, 24 km) from the Tafo BSP, construction of a new 33/11-kV substation (10 MVA) ahead of it, and connection to the existing Tafo distribution line along the way	2010	1,743	
	Koforidua	②	Installation of a new 33-kV distribution line (240 mm2 AAC, 17 km) from the Tafo BSP, and connection to the existing Tafo Koforidua distribution line	2009	505	
Akwatia	Akwatia	⑤	Voltage increase from 11 to 33 kV	2010	616	2,932
	Asamankese	①	Installation of a new 33-kV distribution line (240 mm2 AAC, 25 km) from the Akwatia BSP, construction of a new 33/11-kV substation (5 MVA) ahead of it, and connection to the existing Asamkese distribution line along the way	2009	1,425	
	Oda	②	Installation of a new 33-kV distribution line (240 mm2 AAC, 30 km) from the Akwatia BSP, and connection to the existing Oda distribution line	2008	891	
Oda	Achiase	③	Aerial line replacement ($35mm^2$ Cu → $120mm^2$ AAC, 56km) ($50mm^2$ AAC → $120mm^2$ AAC, 4km)	2008	374	374
Nkawkaw	Mountains	①	Aerial line replacement ($16mm^2$ Cu → $120mm^2$ AAC, 32km) Construction of a 33/11-kV substation (5 MVA) along the way, and partial shift of load on the existing Mountains distribution line to the Donkorkrom distribution line	2010	898	1,087
	Town	④	Cable replacement ($95mm^2$ Al XLPE, $185mm^2$ Al XLPE →$240mm^2$ Cu XLPE, 3km)	2008	189	
ECG Eastern Office Total						7,911

(ECG Central Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
WINNEBA	WINNEBA	②	Installation of a new distribution line (120 mm2 AAC, 4 km) and partial shift of load, or partial shift of load to the APAM distribution line	2010	85	86
	SWEDRU 1	①	Partial shift of load after construction of the Swedru substation	2009	GEDAP	
	SWEDRU 2	①	Partial shift of load after construction of the Swedru substation	2009	GEDAP	
	APAM	⑥	Installation of a condensor to increase voltage	2008	1	
SALTPOND	MANKESSIM	⑥	Installation of a condensor to increase voltage	2008	1	1
Cape Coast	SALTPOND	①	Partial shift of load after construction of the Elmina substation, and installation of a condensor to increase voltage	2009	GEDAP 1	2
	FOSU	①	Partial shift of load after construction of the Elmina substation, and installation of a condensor to increase voltage	2009	GEDAP 1	
	ELMINA	①	Partial shift of load after construction of the Elmina substation	2009	GEDAP	
	TOWN 2	①	Partial shift of load after construction of the Elmina substation	2009	GEDAP	
ECG Central Office Total						89

(ECG Volta Office)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
KPANDO	HOHOE	⑥	Installation of a 33-kV booster station to increase voltage	2008	100	1,124
	"HOHOE-JASIKAN"	②	Installation of a new 11-kV distribution line ($120mm^2$ AAC, 48km)	2009	1,024	
KPEVE	TOWNSHIP	②	Installation of a tie between the Tsibu Bethel and Agbate distribution lines to take in the existing Township load ($120mm^2$ AAC, 5km)	2009	96	96
HO	TANYIGBE	②	Installation of a new 11-kV distribution line and division of the existing Tanyigbe load ($120mm^2$ AAC, 4km)	2016	75	75
SOGAKOPE	"SOGA-AKATSI"	②	Installation of a new 33-kV distribution line and division of the Keta distribution line from Akatsi and Sogakope ($120mm^2$ AAC, 12.5km)	2009	267	267
TSITO	PEKI	①	Construction of new 33/11-kV substations (10 MVA) at the center of the load distribution, installation of a new 33-kV distribution line (120 mm2 AAC, 2 km), and connection for division of the load	2010	343	343
Anloga	Keta	③	Replacement of aerial lines ($16mm^2$ Cu → $120mm^2$ AAC, 3.5km) ($35mm^2$ Cu → $120mm^2$ AAC, 14.4km) ($70mm^2$ Cu → $120mm^2$ AAC, 2.4km)	2009	700	700
ECG Volta Office Total						2,604

(VRA-NED Area)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Tamale	28F3B	①	Installation of new 34.5-kV line (185 mm2 ALXLPE, 18 km) from the Tamale BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Tolon), and connection to the existing 28F3B distribution line along the way	2011	1,292	1,907
	28F4B	②	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2011	131	
	28F6B	②	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2009	131	
	28F7B	③	Aerial line replacement ($100mm^2$ AAC → $240mm^2$ AAC, 8km)	2013	66	
	28F8B	③	Aerial line replacement ($100mm^2$ AAC → $240mm^2$ AAC, 19km)	2009	156	
	28F9B	②	Installation of a 11.5kV new line ($185mm^2$ ALXLPE, 4km)	2012	131	
Brekum	Sunyani - Drobo (BRYF1)	③	Aerial line replacement ($120mm^2$ AAC →$150mm^2$ AAC, 40km)	2009	279	1,141
	"Berekum - Dormaa (BRYF2)"	③	Aerial line replacement ($120mm^2$ AAC →$150mm^2$ AAC, 31km)	2011	216	
	Berekum F1 (BRBF1)	⑤	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($35mm^2$ Cu, $50mm^2$ AAC →$200mm^2$ AAC, 23km)	2009	555	
	Berekum F2 (BRBF2)	③	Aerial line replacement ($50mm^2$ AAC →$100mm^2$ AAC, 6km)	2012	42	
	Berekum F3 (BRBF3)	③	Aerial line replacement ($16mm^2$ Cu, $50mm^2$ AAC →$100mm^2$ AAC, 8km)	2008	49	
Sunyani	Sunyani F3 (27F3B)	②	Installation of a 11.5kV new line ($120mm^2$ AAC, 13km)	2009	327	1,421
	Sunyani F7 (27F7B)	③	Aerial line replacement ($35mm^2$ AAC →$100mm^2$ AAC, 7km)	2012	43	
	Sunyani F8 (27F8B)	①	Installation of new 34.5-kV line (120 mm2 AAC, 14 km) from the Sunyani BSP, construction of a 34.5/11.5-kVsubstation (5 MVA) ahead of this line (near Chiraa), and connection to the existing 27F8B distribution line along the way	2010	1,045	

(VRA-NED Area)

Substations (existing)	Distribution lines (existing)	Type of countermeasure		Year	Cost (USD1,000)	
					Distribution line units	Substation unit
Sawla	Sawla-Wa (38YF6)	⑥	Installation of a capacitor bank (2,000 kVar) in the Mim switching station to improve voltage	2012	3	155
	Wa-Hamile (WAFY1)					
	Wa Township 1 (479BF1)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 6km)	2010	37	
	Wa Township 2 (479BF2)	③	Aerial line replacement ($100mm^2$ AAC, $120mm^2$ AAC → $150mm^2$ AAC, 12km)	2010	84	
	Wa Township 3 (479BF3)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 5km)	2010	31	
Yendi	Bimbilla (35F5Y)	⑥	Installation of a 10-MVA booster station to improve voltage	2011	100	100
Bolgatanga	29F1B (BOLGA)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC, $120mm^2$ AAC → $150mm^2$ AAC, 5km)	2011	168	1,486
	29F4B (BOLGA)	⑤	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 20km)	2010	649	
	29F6B (BOLGA)	⑤	Voltage increase from 11 to 34.5 kV, and aerial line replacement ($50mm^2$ AAC → $100mm^2$ AAC, 8km)	2012	669	
Techiman	26F1B (TECHIMAN)	③	Replacement of the feeder cable in the starting section with 185 mm2 Al XLPE, and aerial line replacement ($50mm^2$ AAC→ $150mm^2$ AAC, 17km)	2008	125	319
	26F2B (TECHIMAN)	③	Aerial line replacement ($50mm^2$ AAC → $120mm^2$ AAC, 8km)	2009	55	
	WHF2B (WENCHI)	③	Aerial line replacement ($25mm^2$ AAC → $100mm^2$ AAC, 20km)	2008	139	
VRA-NED Total						6,522

Appendix 6

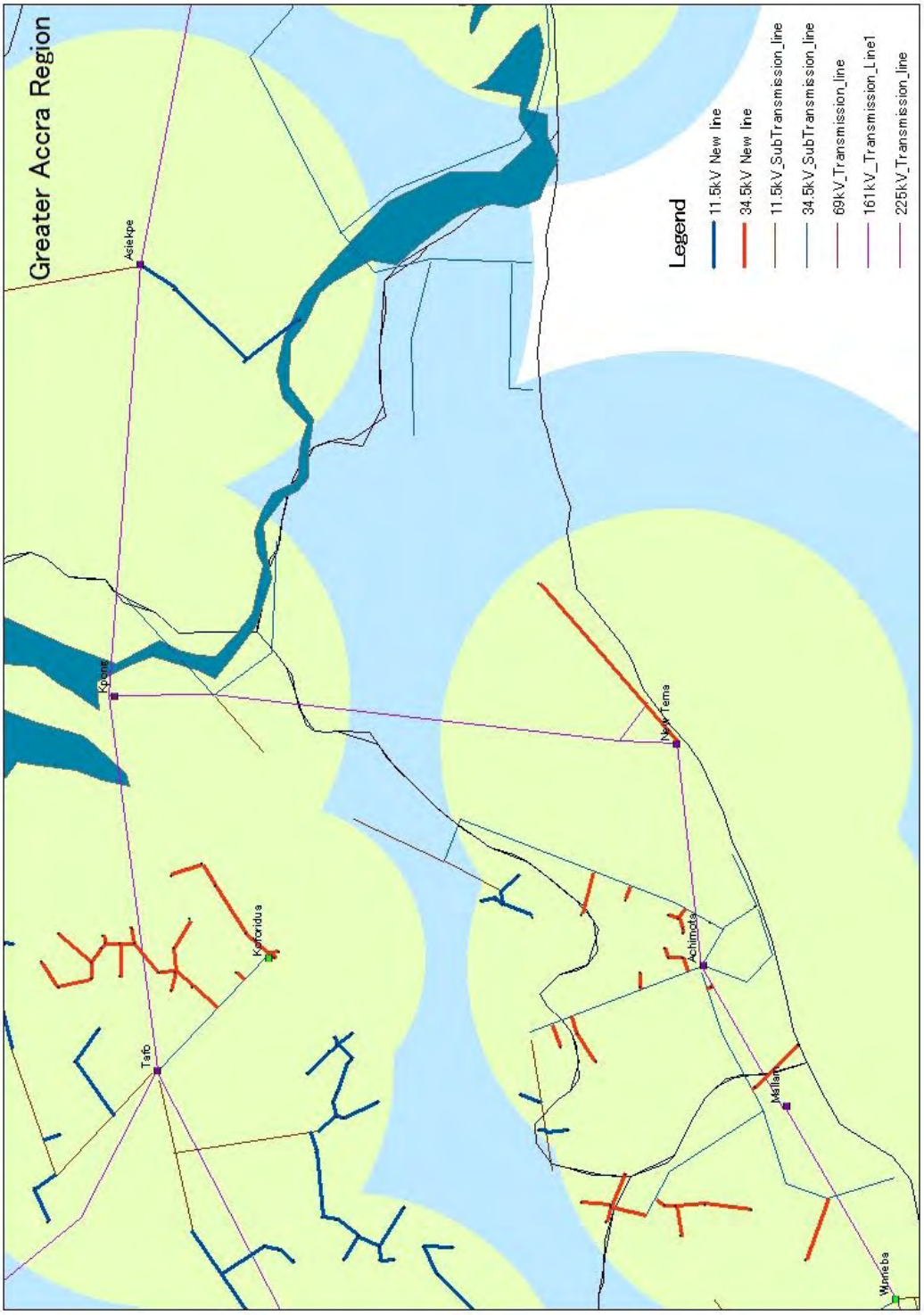
Outline of distribution network extension plan

Regional Name	Substation	No. of u.e. Villages	Total Population	No. of Facilities	Total Demand (kW)	Construction or Installation Cost (US$)					
						MV Line	Secondary S/S	LV line	Service Wire	Meter	**Total**
Great Accra	Mallam	12	9,554	1,632	250.56	973,340	121,681	1,043,143	122,387	212,137	2,472,687
	New Tema	1	634	108	16.63	556,555	10,140	69,223	8,122	14,077	658,116
	Achimota	23	30,375	5,188	796.68	991,951	219,743	3,316,461	389,104	674,447	5,591,705
Ashanti	Obuasi	2	2,395	409	62.81	379,566	20,280	261,495	30,680	53,179	745,200
	New Obuasi	3	3,688	630	96.73	541,628	30,420	402,670	47,243	81,888	1,103,850
	Bekwai	4	6,169	1,054	161.80	392,361	29,846	673,555	79,025	136,976	1,311,763
	Kumasi	6	5,321	909	139.56	283,608	55,483	580,968	68,162	118,147	1,106,369
	Barekese	3	2,999	512	78.66	223,901	22,384	327,443	38,417	66,590	678,735
Western	Daboase	3	2,635	450	69.11	744,206	22,384	287,700	33,754	58,508	1,146,551
	Asawinso	3	4,440	758	116.45	255,887	30,420	484,777	56,876	98,586	926,546
	Takoradi	2	1,684	288	44.17	255,887	20,280	183,866	21,572	37,392	518,997
	Axim	3	2,351	402	61.66	373,169	30,420	256,691	30,116	52,202	742,599
	Tarkwa	3	2,447	418	64.17	270,814	22,384	267,173	31,346	54,333	646,051
	Prestea	2	1,985	339	52.06	511,775	20,280	216,730	25,428	44,075	818,288
	Bogoso	2	1,693	289	44.40	300,668	20,280	184,848	21,687	37,591	565,075
Eastern	Akwatia	7	8,908	1,521	233.63	629,056	56,141	972,610	114,111	197,793	1,969,713
	Oda	6	4,120	704	108.06	838,031	60,841	449,838	52,777	91,480	1,492,967
	Tafo	55	53,916	9,209	1,414.07	4,478,988	444,904	5,886,759	690,664	1,197,151	12,698,466
	Koforidua	6	5,917	1,011	155.19	473,392	60,841	646,041	75,797	131,381	1,387,451
	Nkawkaw	12	8,830	1,508	231.58	1,458,558	95,469	964,094	113,112	196,061	2,827,294
Central	Asebu	1	2,727	466	71.52	38,383	11,458	297,744	34,933	60,550	443,069
	Winneba	28	29,822	5,094	782.17	2,210,322	250,204	3,256,082	382,020	662,168	6,760,796
	Cape Coast	6	4,755	812	124.70	839,192	47,447	519,169	60,912	105,580	1,572,300
	Saltpond	1	600	102	15.74	31,986	7,461	65,510	7,686	13,322	125,966
	Damang	11	10,196	1,741	267.40	1,507,210	111,541	1,113,239	130,611	226,392	3,088,993
	Dunkwa	6	7,223	1,234	189.45	605,987	62,158	788,635	92,527	160,379	1,709,687
Volta	Keta	2	3,508	599	92.00	119,414	21,598	383,017	44,937	77,892	646,858
	Afao	6	5,471	934	143.49	607,732	60,841	597,345	70,084	121,478	1,457,480
	Asiekpe	3	7,046	1,203	184.79	562,952	24,968	769,310	90,259	156,449	1,603,939
	Kpeve	1	825	141	21.64	394,493	7,461	90,077	10,568	18,318	520,918
	Tsito	1	1,705	291	44.72	21,324	10,140	186,159	21,841	37,858	277,321
	Hohoe	2	1,806	308	47.36	481,921	20,280	197,186	23,135	40,100	762,623
Northern	Sawala	14	12,985	1,539	211.14	2,996,014	141,961	983,628	115,404	200,034	4,437,042
	Yendi	6	6,937	822	112.80	518,172	60,841	525,486	61,653	106,864	1,273,015
	Tamale	9	8,161	967	132.70	1,174,949	95,469	618,205	72,531	125,720	2,086,874
Brong Ahafo	Wenchi	4	6,020	1,028	157.88	245,225	31,738	657,287	77,116	133,668	1,145,035
	Brekum	2	3,257	556	85.42	281,476	20,280	355,612	41,722	72,318	771,409
	Techiman	6	6,297	1,076	165.14	910,532	60,841	687,531	80,665	139,819	1,879,387
Upper East	Bawku	53	47,809	5,665	777.40	3,226,698	537,425	3,621,586	424,902	736,498	8,547,108
	Bolgatanga	97	89,637	10,622	1,457.49	4,183,754	860,370	6,790,104	796,649	1,380,858	14,011,735
	Navrongo	38	37,998	4,503	617.86	1,676,447	375,183	2,878,391	337,707	585,359	5,853,088
Upper West	Wa	17	17,574	2,083	285.74	2,476,872	167,024	1,331,250	156,189	270,727	4,402,063
Sub-total (ECG area)		226	235,745	40,265	6,182.96	22,354,257	2,030,182	25,739,559	3,019,893	5,234,482	58,378,373
Sub-total (VRA-NED area)		246	236,675	28,861	4,003.57	17,690,140	2,351,133	18,449,080	2,164,538	3,751,866	44,406,756
Total		**472**	**472,420**	**69,126**	**10,186.53**	**40,044,397**	**4,381,314**	**44,188,638**	**5,184,432**	**8,986,348**	**102,785,129**

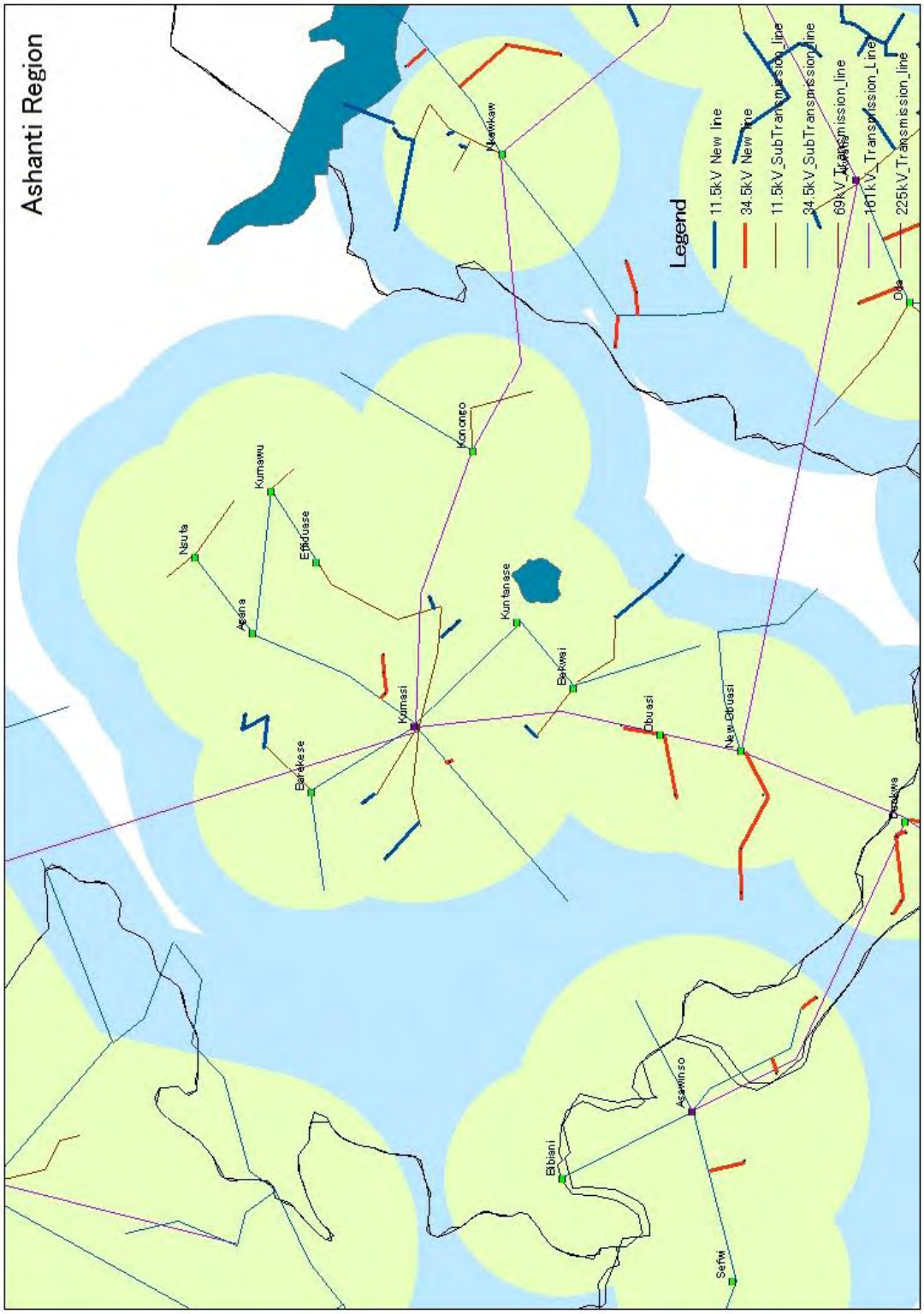
Appendix 7

Drawing of distribution network extension plan

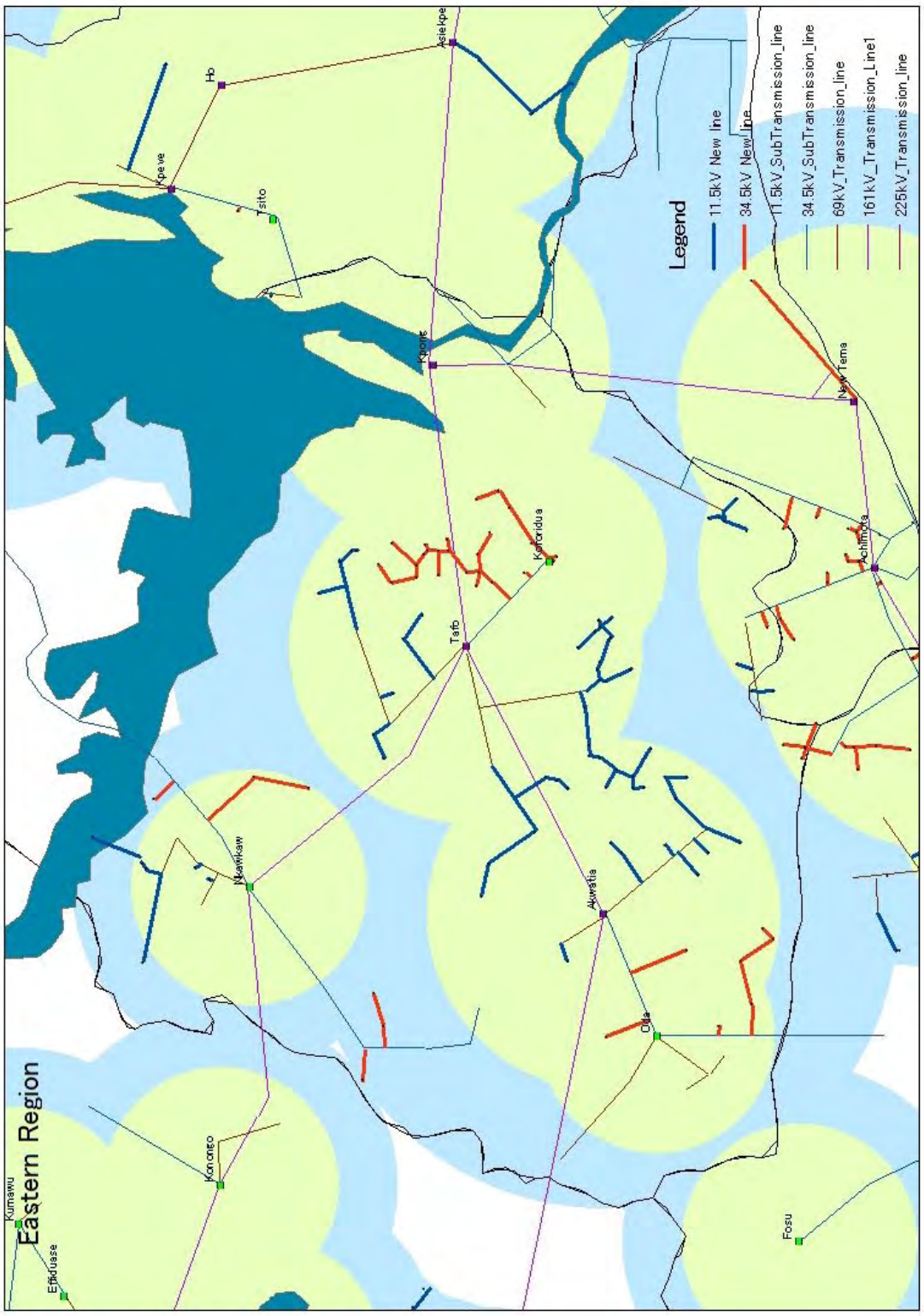
Great Accra Region



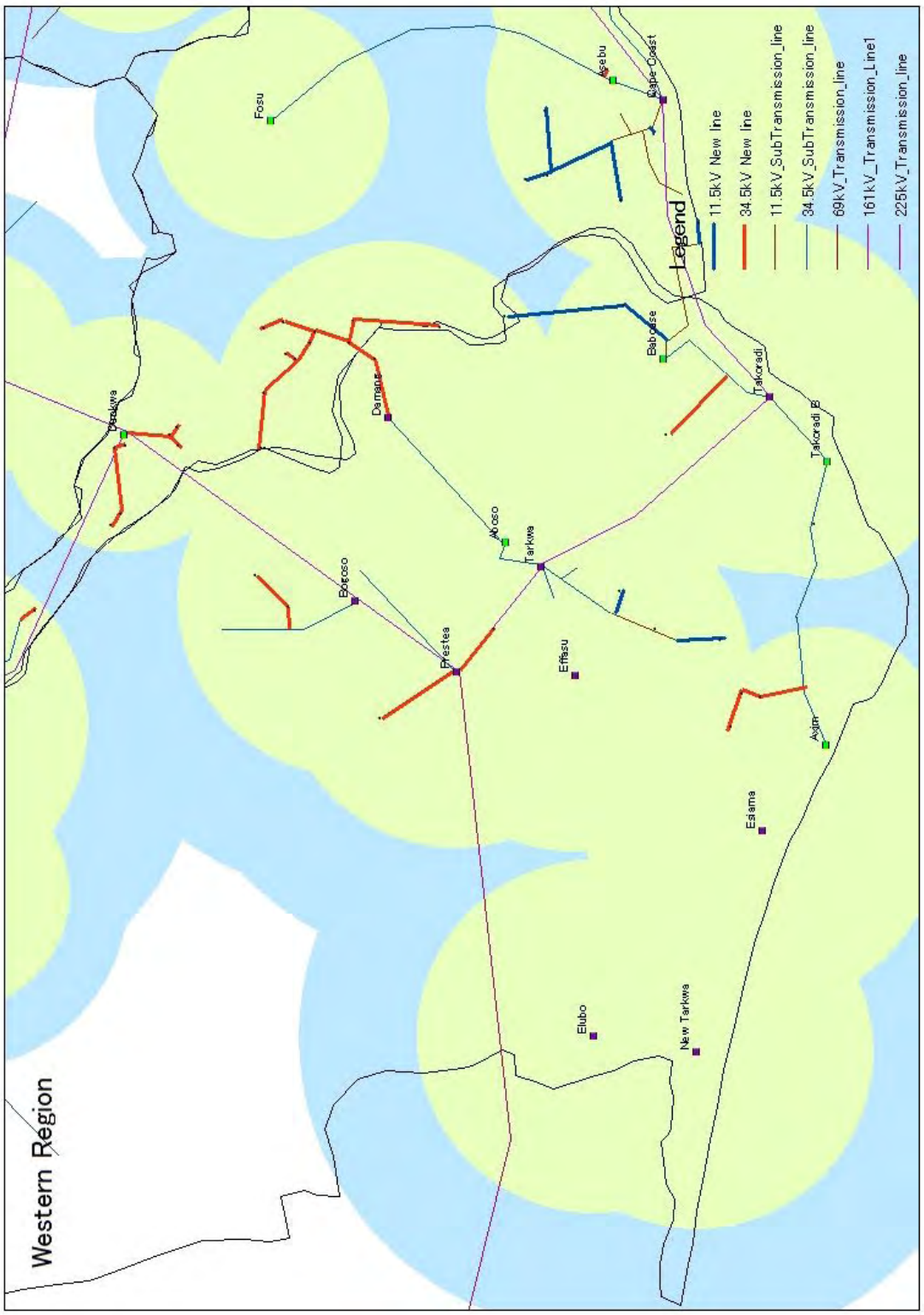
Ashanti Region



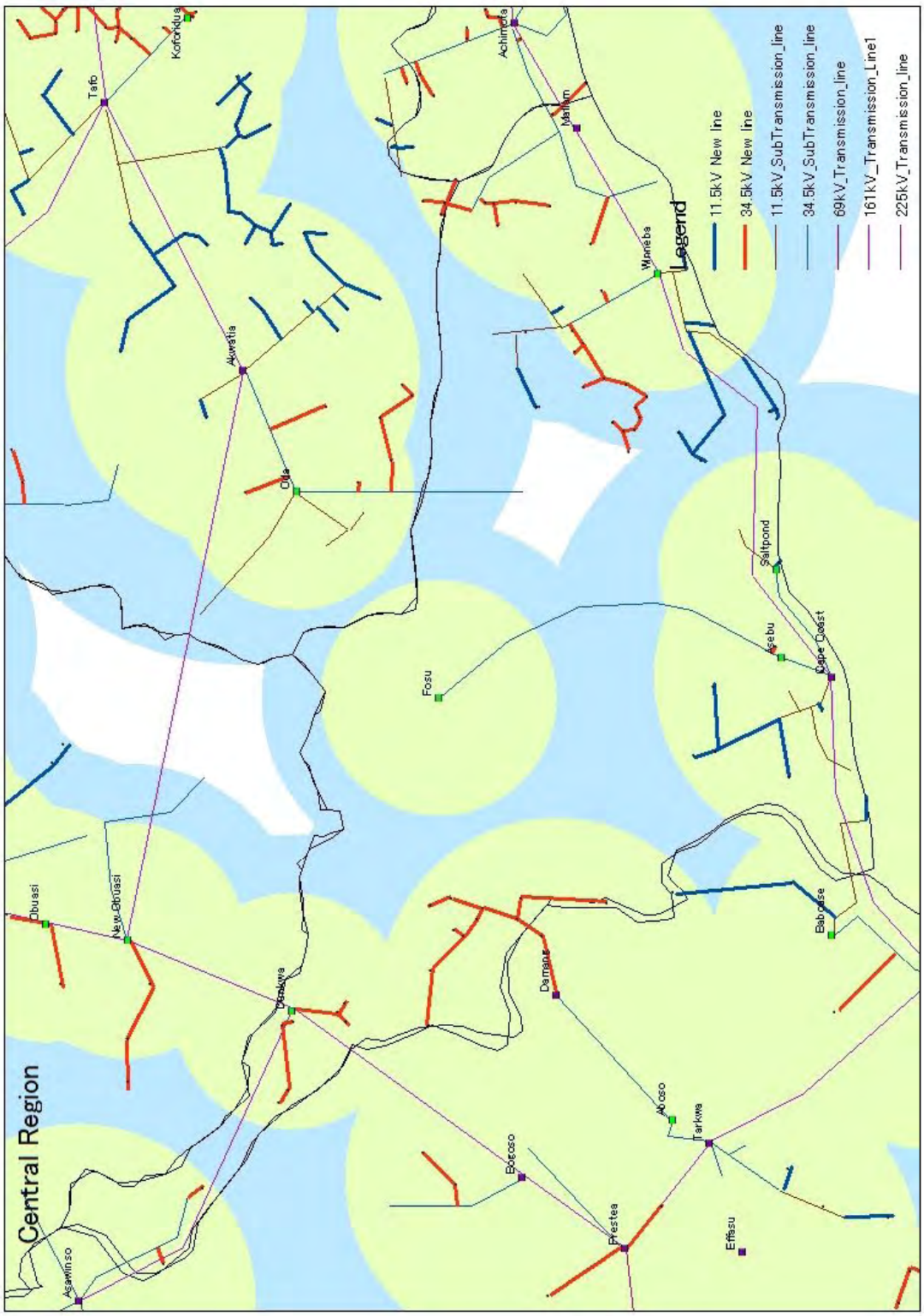
Eastern Region



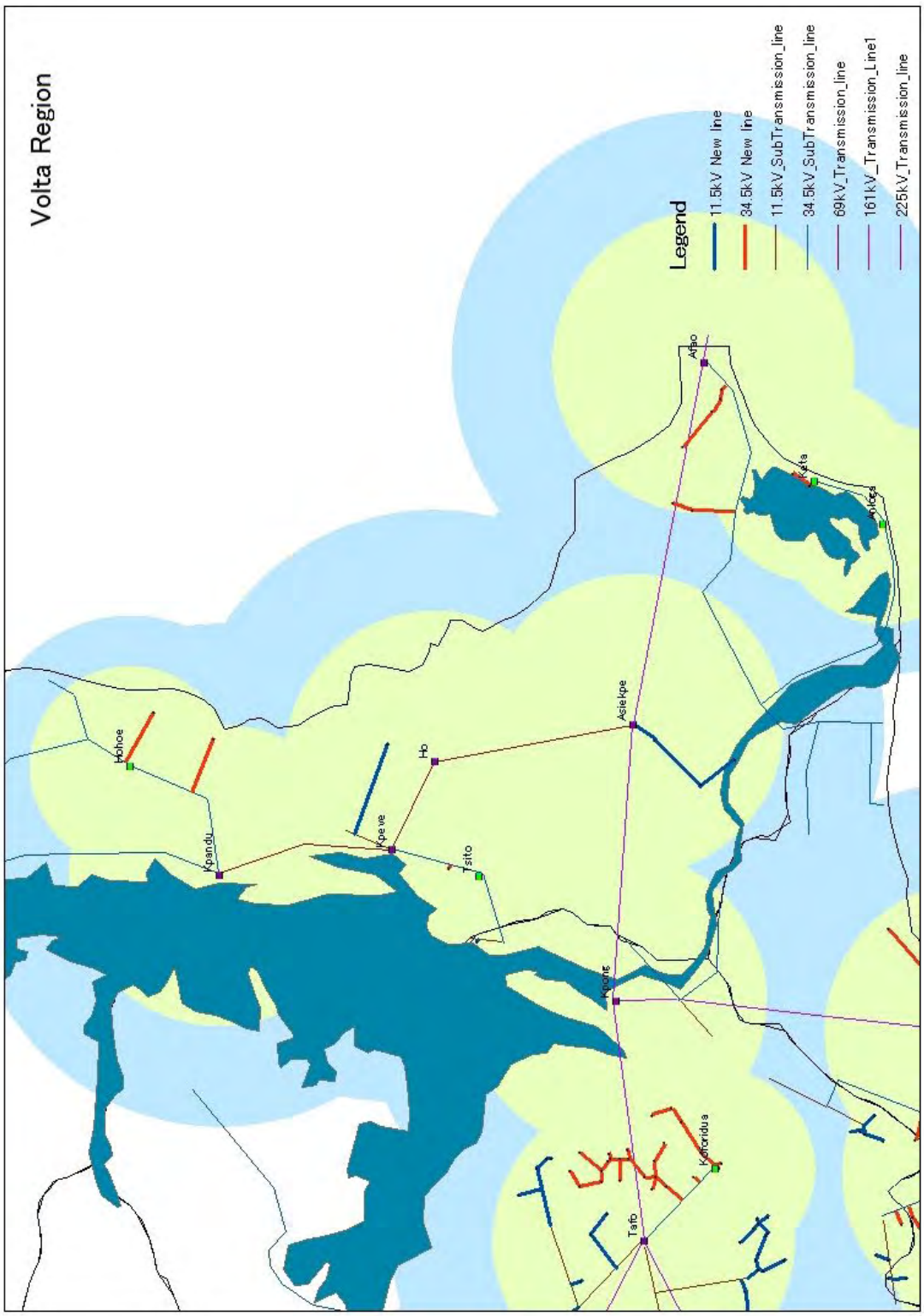
Western Region



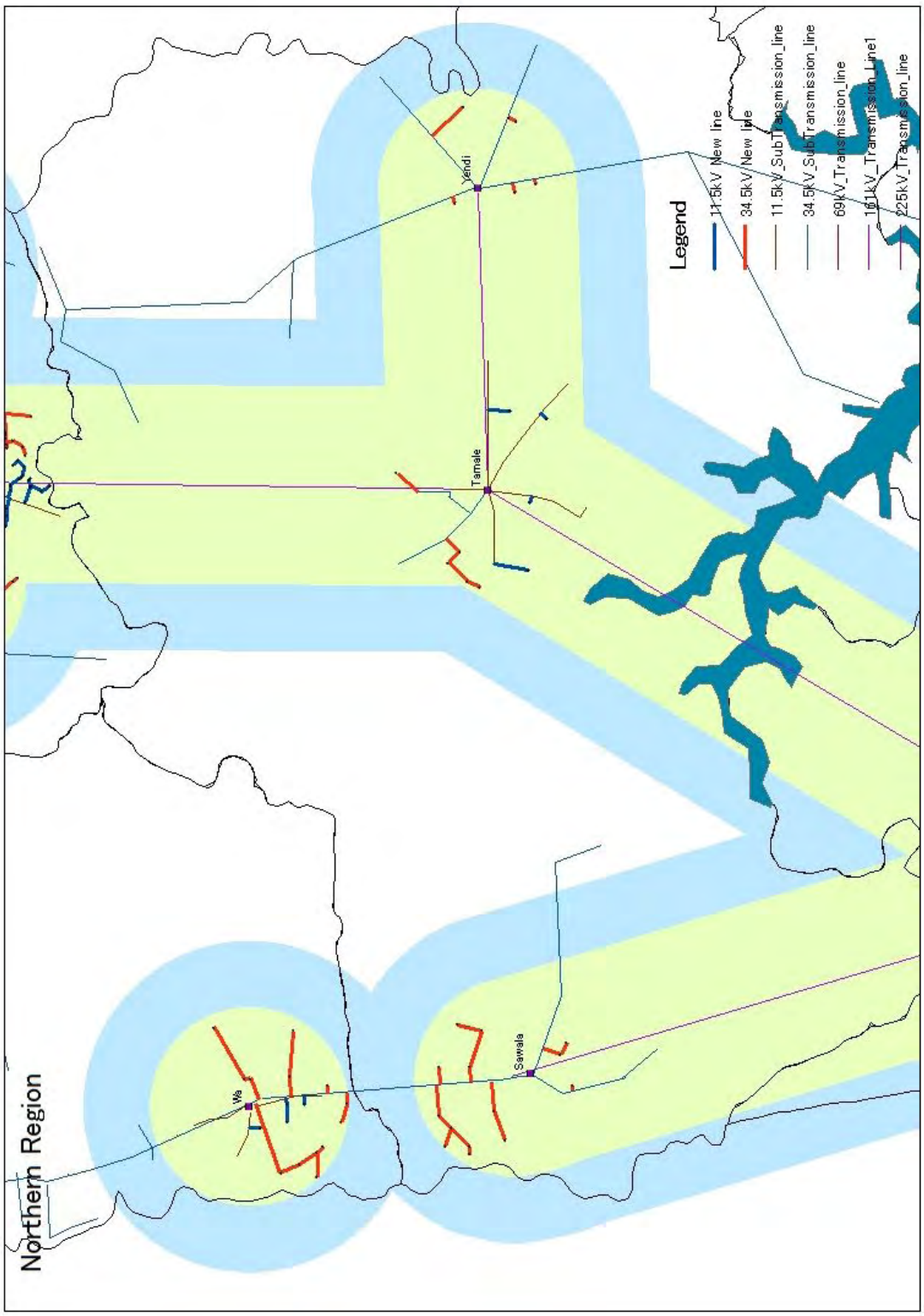
Central Region



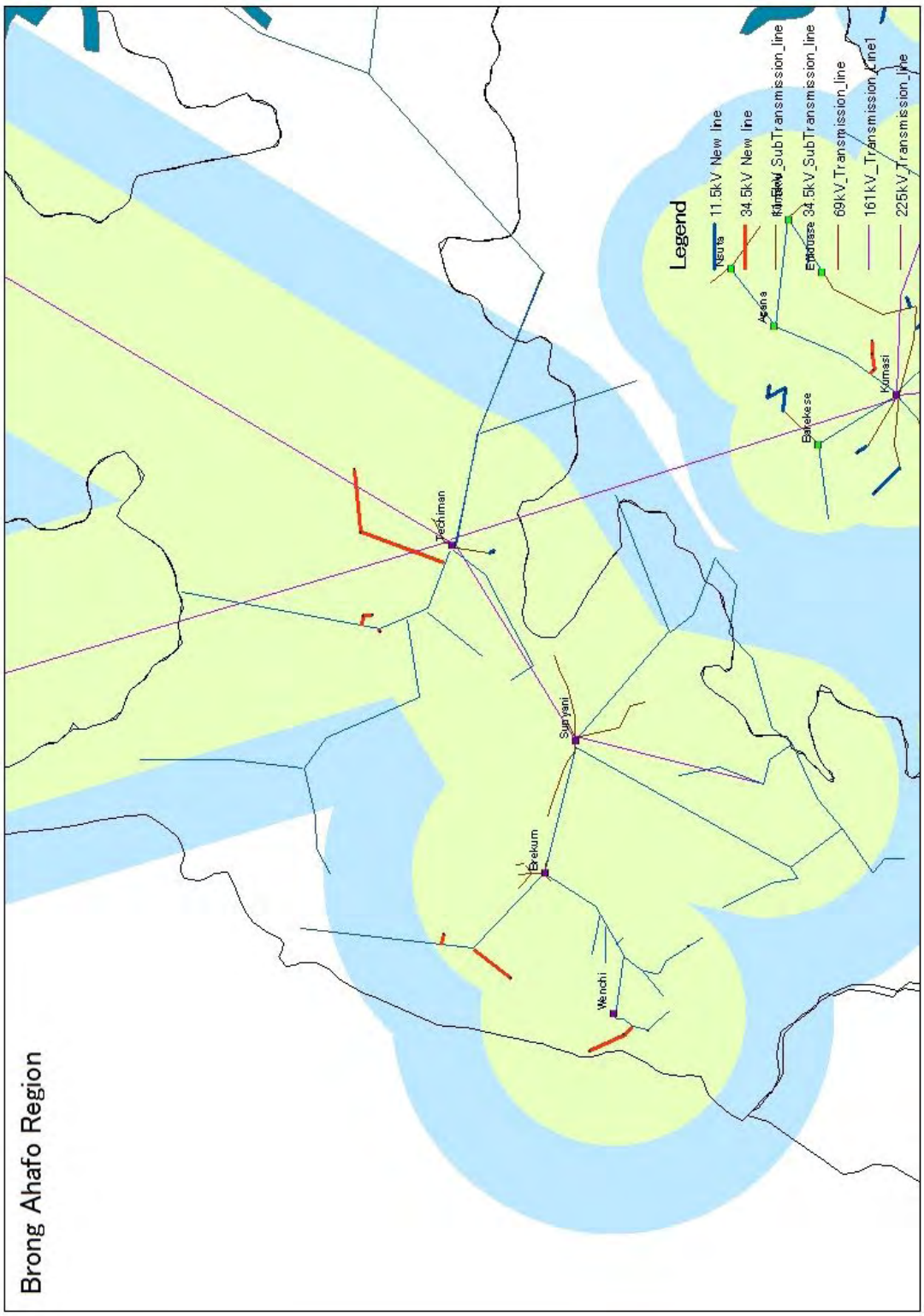
Volta Region



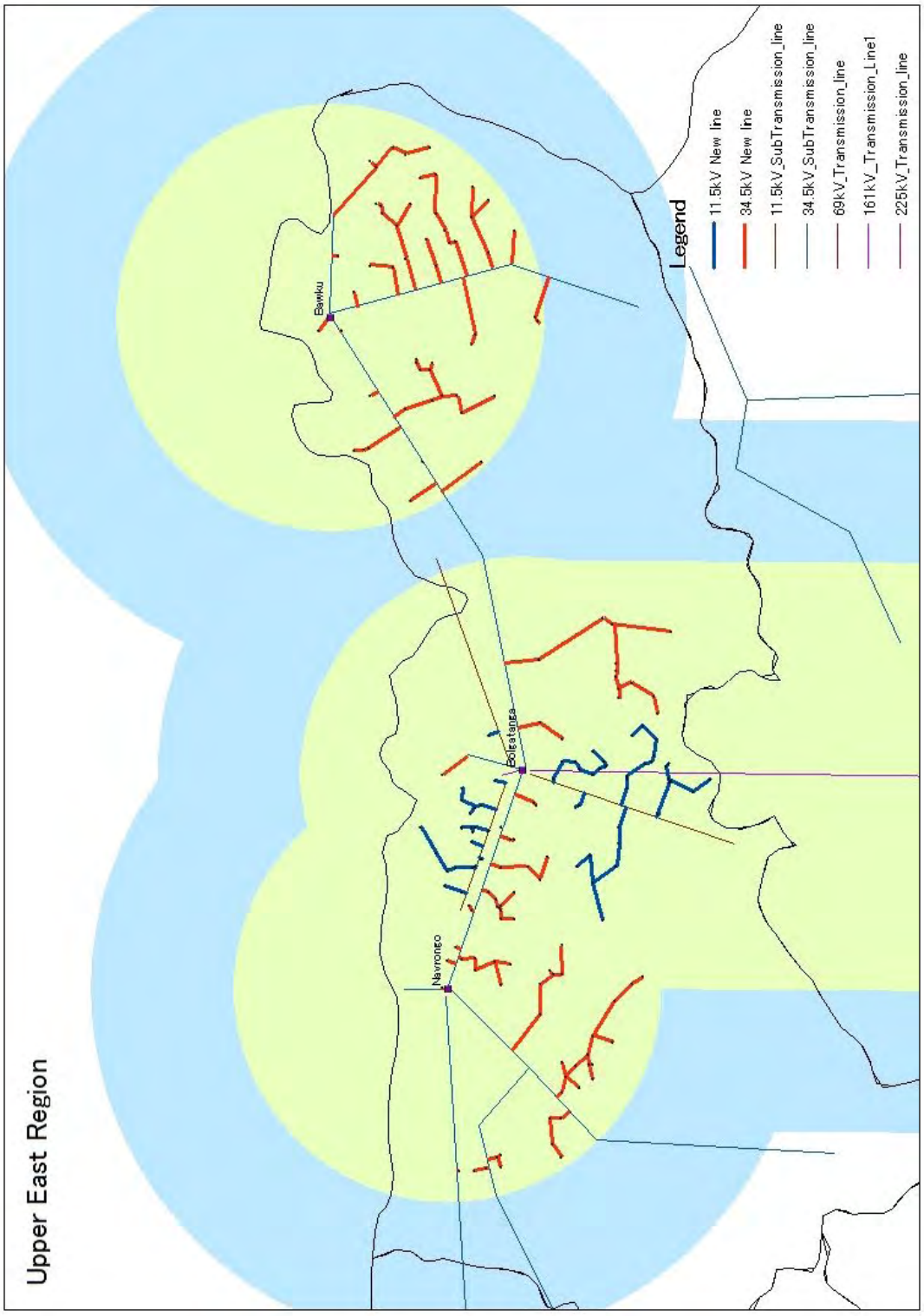
Northern Region



Brong Ahafo Region



Upper East Region



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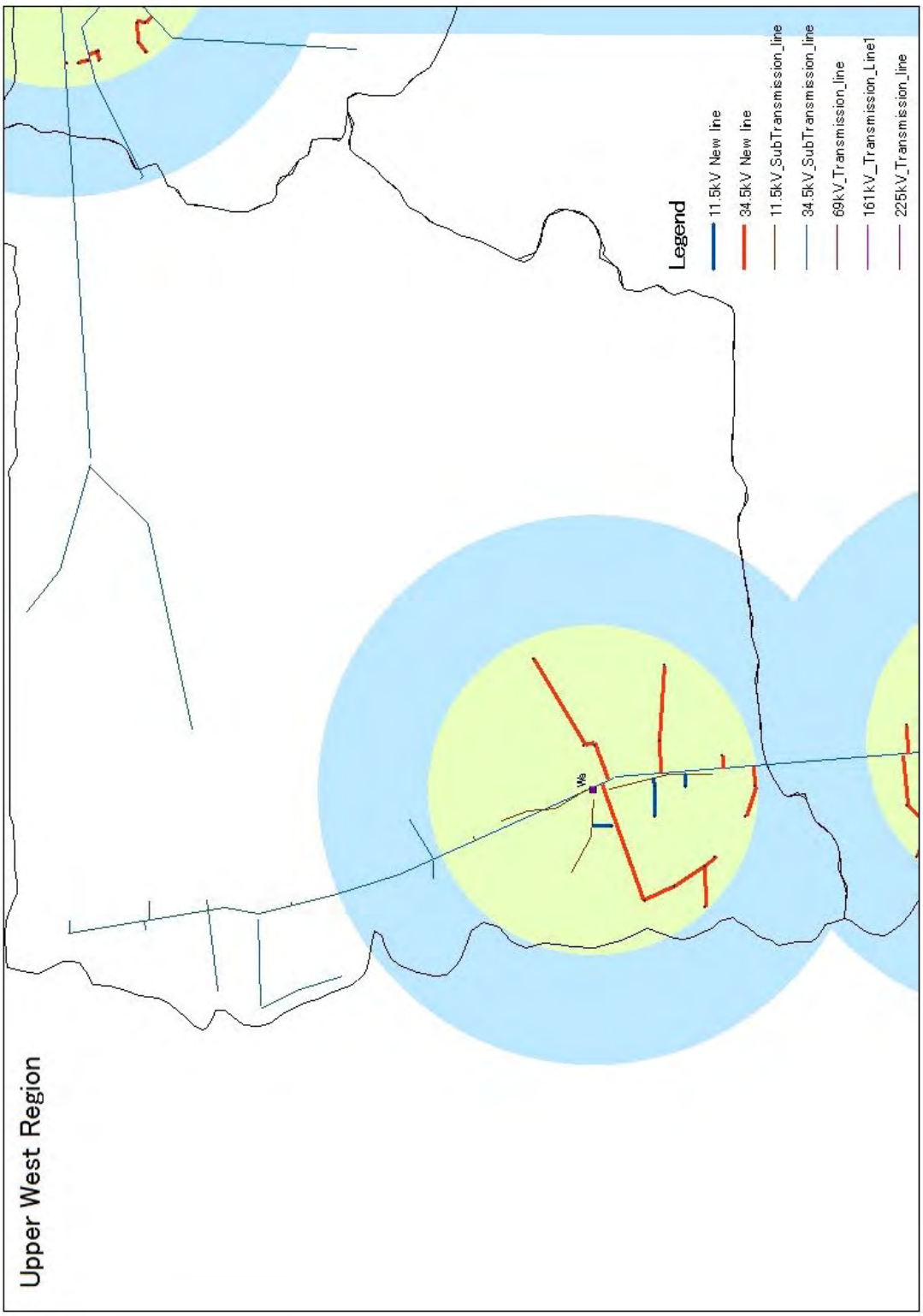


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