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ENHANCED EMERGENCY CONTROL SYSTEM FOR THE GEORGIA STATE ELECTROSYSTEM

July 19, 2012

This report was produced for review by the United States Agency for International Development. It was prepared by Tetra Tech, Inc.

Foreword

This report was prepared by USAID’s Georgia Power and Gas Infrastructure Project (PGIP) under Contract Number AID-EDH-I-00-08-00027-AID-114, Task Order 10-00003. Tetra Tech, Inc. is the prime contractor on PGIP.

The authors gratefully acknowledge the support of the United States Agency for International Development’s Georgia Mission (USAID/Georgia) for this project. [redacted]

This report was made possible through the support of the American people through USAID/Georgia. Its contents are the sole responsibility of Tetra Tech, Inc. and do not necessarily reflect the views of USAID or the United States Government.

PGIP

USAID / GEORGIA POWER AND GAS INFRASTRUCTURE PROJECT (PGIP)

Table of Contents

1. Background

The Georgia Power and Gas Infrastructure Project (PGIP) provides resident professional engineering and other technical services to support power and gas transmission improvements that USAID is undertaking on behalf of the Government of Georgia. PGIP's activities support USAID's objectives of promoting energy security through greater access to electricity and natural gas supplies for households in western Georgia, promoting the development of the Poti Free Industrial Zone on the Black Sea, and securing power exports through domestic reliability-related infrastructure improvements. The activities under the PGIP task order support USAID's larger goal of fostering sustainable development.

This report was prepared in support of USAID's third objective of securing power exports through domestic reliability-related infrastructure improvements. It traces the evolution of the Enhanced Emergency Control System from the summer of 2011 to the present. It is supplementary to a separately submitted document, "The Letter of Consent to Subcontract."

The section titles in this report reflect specific questions USAID has asked about the control system.

The initial version of this equipment, called the Emergency Control System (ECS), was installed in the summer of 2010 in nine GSE substations and its dispatch center in Tbilisi. The ECS was designed for and is used for events along the backbone 500 kV transmission system from Enguri, to Zestaponi, to Ksani, and on to Gardabani.

The existing ECS measures voltages, currents and monitors the status of the switching equipment (circuit breakers and disconnect switches) in Ksani and Zestaponi for detection of events (e.g. tripping of Kartli 2 and/or Imereti) and to calculate the load shedding level. No synchrophasor measurements are performed in the existing ECS.

The ECS needs to be enhanced to handle the new transmission lines that are coming into service now: (a) 500 kV from Zestaponi to Akhaltsikhe to Gardabani (paralleling the Zestaponi – Ksani – Gardabani route), (b) the 400 kV line to Borchka (Turkey), (c) the 154 kV line to Muratli (Turkey), and (d) the transit energy (over the 500 kV and 330 kV lines) from Azerbaijan to Georgia to Turkey.

Neither the Black Sea Transmission Network (BSTN) project, nor any other Georgian project, includes an ECS or EECS implementation.

The Enhanced Emergency Control System (EECS) monitors power, currents, voltages and phase angles in the Georgia State Electrosystem (GSE) transmission system, and takes rapid corrective actions to prevent system-wide blackouts. The EECS is an on-line measurement and control system that acts automatically and within a reaction time of milliseconds, far faster than an operator/dispatcher could react.

The simplified flow chart below shows the principles of the ECS process. The EECS process is remarkably more complex, especially due to the non-local interdependencies.

The Project includes field units, central equipment, training, installation, and support.

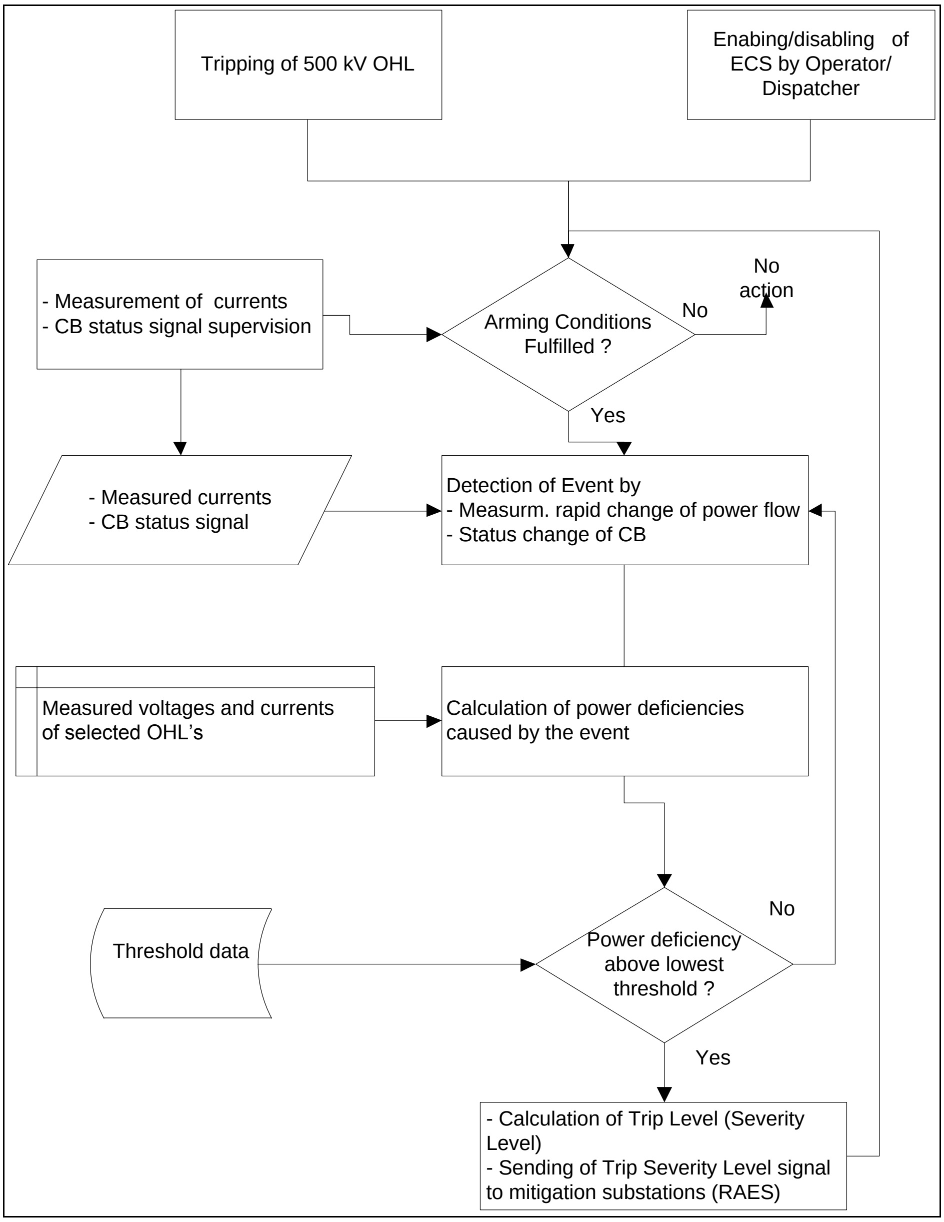

Figure: Schematic Process Flow Chart

A system architecture figure (schematic) of the proposed system is in Annex E. The process is described in Section 7.1.4 through 7.1.5.3, pages 25 through 33, of Attachment A Technical Specification of the tendering documents.

2. Smart Grid Technology Sub-component

Page 5 of the PGIP Task Order presents the rationale for the project's smart grid component:

> Smart grid technology sub-component: USAID/Georgia intends to provide assistance to GSE in identifying and installing smart grid technologies that will increase the reliability and efficiency of the Georgia power transmission grid. Smart grid technologies optimize the integration of electrical (towers, lines, switches, transformers, etc.) and information infrastructures (computerized remote control network) by incorporating new automation and information technologies into the existing network. Such technologies can eliminate redundancies in power production and dispatch that cause waste and overload/disrupt networks, and can optimize the routing of power from production to demand.

The EECS is a smart grid application for transmission systems, and is particularly appropriate in situations where typical distribution-related smart grid technologies – such as demand control – are not effective. The EECS was developed to fulfill the smart grid technology sub-component of the PGIP Task Order.

3. The Choice of the EECS

The ECS was designed by Schweitzer Engineering Laboratories of Pullman, Washington, USA, and installed in the summer of 2010. On July 12, 2011, GSE and PGIP staff met. During the meeting the expansion of the EECS was identified as a possible project. A consensus was reached at that meeting that expanding the emergency control system would increase the transmission system's efficiency, increase revenues by minimizing the extent of load shedding during outages, and improve customer satisfaction. Annex A presents a copy of the notes of this meeting, which were published on July 14, 2011.

To help validate their decision on the system's expansion, GSE and a consultant from Fichtner who specializes in power system stability analysis traveled to the United States to discuss the extension and enhancement with experts from Schweitzer.

The EECS supports the stability of the power flow from Enguri to Zestaponi, to Ksani and on to Gardabani over the 500 kV transmission backbone of Georgia, and the parallel 220 kV backbone (Figure 1). The 220 kV backbone (Enguri – Vardnili – Vectori – Menji – Kutaisi – Zestaponi – Khashuri – Gori – Ksani – Lisi – Gardabani, and Ksani – Gldani – Navtlughi/Rustavi – Gardabani) is not presented in Figure 1, but this 220 kV backbone is evident in the diagram of Annex C.

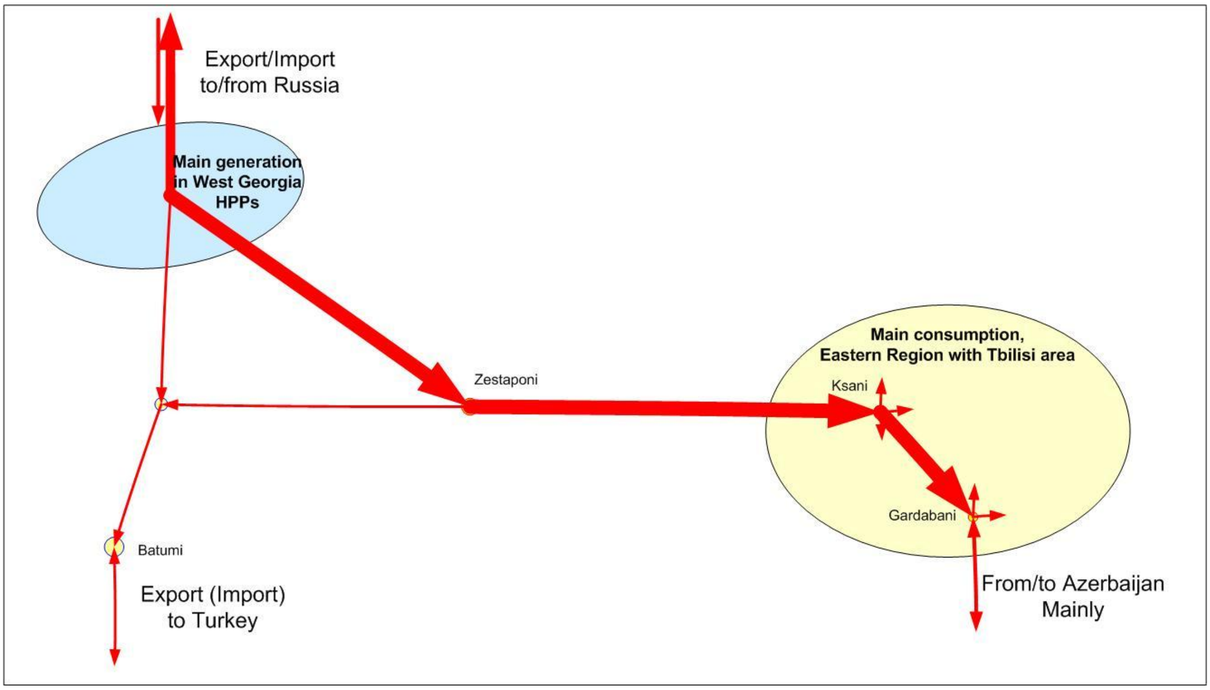

Figure 1: Present main power flow in summertime in the Georgian power transmission system

With the implementation of the Black Sea Transmission Network the following new transmission facilities will be operational.

- Zestaponi – Akhaltsikhe – Gardabani 500 kV transmission lines
- 500/400 kV substation and back-to-back DC/DC converter at Akhaltsikhe
- 400 kV transmission line to Turkey

With the new 500 kV and the existing 330 kV transmission lines to Azerbaijan, the new 154 kV transmission line from Batumi to Turkey, and the back-to-back DC/DC converter station, an additional step is being taken toward the development of the GSE power transmission system as a central part of the South Caucasus regional power hub. At this point, the power flow within the GSE power system will become remarkably more complex (Figure 2).

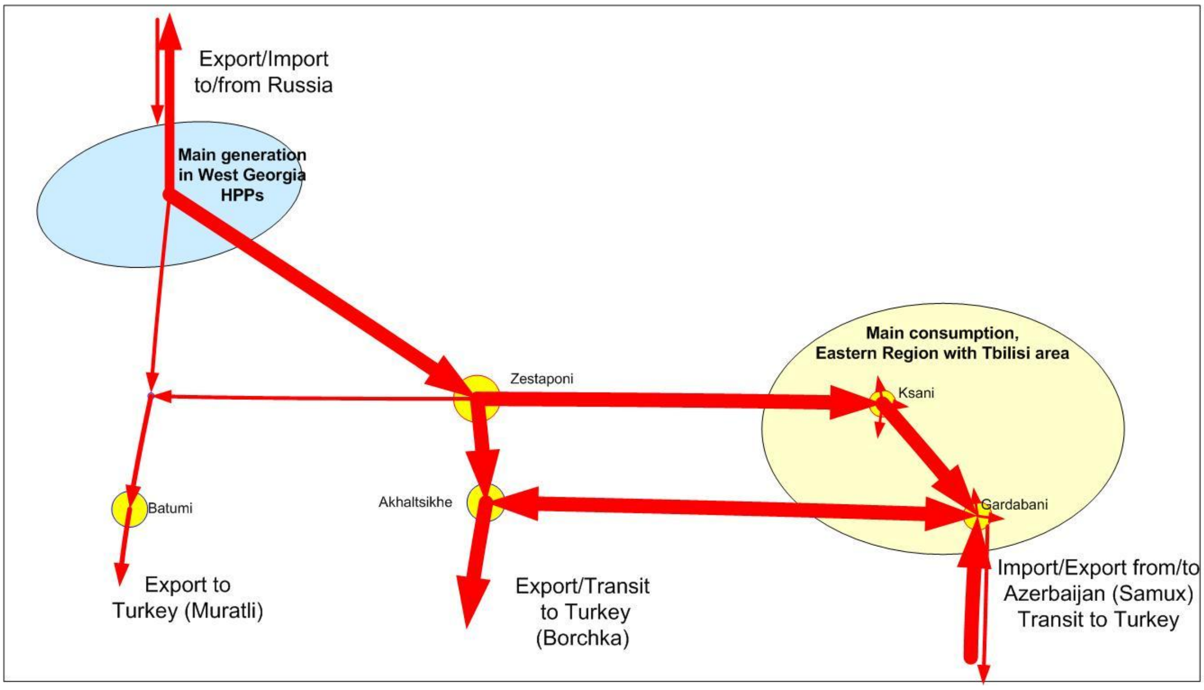

Figure 2: Future main power flows in the Georgian power transmission system

The current ECS needs to be extended and enhanced to cover the more complex power flows on the new 500 kV and 400 kV transmission lines as well as the international power trade terms and conditions necessary both to secure the Georgian power system's stability and cross-border power exchanges (export, transit). The enhancement involves more lines, transformers and reactors are monitored than in the existing ECS, and phasor (also called synchrophasor) measurements are added. Also, see the two right hand columns of the tables in Annexes D-1 and D-3. Moreover, the non-local interdependencies and constraints of the export/transit contracts have to be considered by the EECS.

Neither the Black Sea Transmission Network (BSTN) project, nor any other Georgian project, includes an ECS or EECS implementation.

The decision to proceed with the EECS's expansion and enhancement is reported as Item 1 of the notes of the November 21, 2011 Steering Committee Meeting, which were published on November 25 (Annex B).

GSE chose to proceed on the smart grid, and selected two related options to proceed with the smart grid:

- Expansion of the emergency control system (item 2 in the table in Annex A)
- Installation of voltage angle measurements across the system (item 4 in the table in Annex A).[1]

[1] The voltage and phase angle measurements mentioned in this report are described as synchrophasor measurements in the EECS internal documentation.

Four other projects were considered to be worthwhile, but were not felt to be the most beneficial at this time:

- *Circuit Switchers:* This would be part of a larger program to implement remote controls within GSE's existing SCADA system. To begin using remote control in a utility requires several procedural changes within GSE in addition to adding hardware at a substation. (See Item 1 from the table in Annex A.)

- *Under-Frequency Relays*: This is a well-established technology that does not need a smart grid to advance its use. Also, under-frequency relays may be better implemented at the 35 kV and 11 kV levels, which are the responsibilities of the distribution utilities, rather than GSE's responsibility. (See Item 3 from the table in Annex A.)

- *Digital Protection and Control:* This is a well-established technology that does not need a smart grid to advance its use. GSE is already in the middle of a digital replacement program. (See Item 5 from the table in Annex A.)

- *Dissolved Gas Analyzers:* This option is for the installation of *more* dissolved gas analyzer field units. The Dissolved Gas Analyzer Project will not be completed until the end of October 2012. It is premature to consider expanding the use of Dissolved Gas Analyzer field units until the basic system is operational. (See Item 6 from the table in Annex A.)

4. Benefits to GSE and Georgia

The EECS will benefit GSE and Georgia by maintaining the dynamic stability of both the GSE transmission system and regional network because it will react quickly and take corrective actions when conditions exist that would otherwise lead to the instability of the regional power system and subsequent blackouts. The people of Georgia are inconvenienced by such blackouts. Exports sales of electrical energy stop during a blackout, and this negatively affects the Georgian economy. Also, the envisaged power transfer from Azerbaijan through Georgia to Turkey would be interrupted by blackouts.

The EECS contributes to assuring the neighboring Turkish and Azerbaijani transmission system operators of Georgia's intent and efforts to operate a stable power system.

A requirement of the interconnection between Georgia and Turkey regarding the 400 kV line is that phase angle measurements are to be provided. The EECS system measures, collects, reports, displays, and archives phase angle measurements across the Georgian power system and at the Samux (Azerbaijan), Borchka (Turkey) and Muratli (Turkey)

Substations.[2] Thus, the EECS will help Georgia comply with one of the requirements of the Georgia-Turkey 400 kV interconnection agreements.

5. Portions of the GSE Transmission Network Covered

The EECS stations consist of (please see Annex 3 for more detail):

- Central systems at the National Control Centre.
- EECS node substations in the 500 kV, 330 kV, and 220 kV transmission networks in which measurement, control, and telecommunications equipment for the EECS has been or will be installed. Five of the 18 substations in GSE's transmission network, as well as one hydropower plant (Enguri) and three substations – two in Turkey and one in Azerbaijan – are also included.
- Eight substations are or will be remedy action execution system substations, where control and telecommunication equipment for EECS mitigation measures are or will be installed.
- Three substations where only telecommunication equipment is or will be installed.

This information is presented in Annex D:

- Table D-1, EECS Substations with Measurement Control and/or Telecommunications Equipment (page 19)
- Table D-2, Substations with Telecommunications Equipment (page 20).

The GSE lines, transformers and reactors supervised by the EECS for event detection and the loads (mainly 110 kV and 10 kV lines), generators and other facilities involved in the mitigation measures are presented in Annex D, page 19.

The EECS covers the complete highest voltage power grid of Georgia, which consists mainly of 500 kV transmission lines. In the South-West region, with Batumi as the Georgian cross-border connecting point, the function of this primary interconnecting grid is taken over by the 220 kV grid.

[2] An open question is how the Turkish transmission system operator wants to receive the phase angle measurements. The EECS will be collecting phase angle measurement in compliance with international standard ANSI C37.118, so it is likely that the Georgian and Turkish transmission system operators will agree on the communication method.

Annex A
July 12, 2011 GSE-PGIP Meeting Minutes

This annex contains the notes of the GSE-PGIP meeting of July 12, 2011. The minutes were published on July 14, 2011.

Possible Smart Grid Projects

Consensus points from meeting of July 12, 2011

- The dissolved gas analyzer project should proceed independent of the Senaki I and II 220 kV line project.
- The team of GSE and Tt sees the advantages of installing monitoring points on the existing transformers when the transformers are out of service for schedule or unscheduled maintenance.
- The funds available for the project will limit the scope and extent of what smart grid work can be done at this time.

The second and third columns report possible smart grid projects which were identified at the GSE – Tt meeting of July 12, 2011. The four right hand columns indicate the benefits and were added by Tt after the July 12 meeting.

Nr.	Title	Description	Benefits			
			Reduce Technical Losses	Increased Efficiency	Increase Revenue (reduce commercial losses)	Improve Customer Satisfaction
1	Circuit switchers (also known as disconnectors)	Replace circuit switchers (disconnectors) at substations so that they status (open or closed) of the circuit switchers is reported via the SCADA system; and to control (open or close) the disconnector remotely via the SCADA system.		Yes, by decreasing the amount of substation operator involvement in system restorations.	Yes, by enabling rapid restoration of the system after an outage.	Yes, by enabling rapid restoration of the system after an outage.
2	Emergency Control System	Expand the emergency control system recently installed on the backbone 500 kV lines from west to east Georgia to adjacent lines.		Yes, be decreasing the amount of manpower required in system restoration.	Yes, by minimizing the extent of load shedding when there is outage.	Yes, by minimizing the extent of load shedding when there is outage.

Possible Smart Grid Projects

Nr.	Title	Description	Benefits			
			Reduce Technical Losses	Increased Efficiency	Increase Revenue (reduce commercial losses)	Improve Customer Satisfaction
3	Under Frequency Relays	Replace the existing under frequency relays with fixed thresholds with new relays that allow such features as (a) trip on *rate of frequency change*, (b) remotely programmable threshold, and (c) changeable daily schedules (so that the same district or feeder is not affected each time).		Yes, initiating load shedding based on rate of frequency change should reduce the magnitude of large system outages.	Yes, by avoiding system failure due to potential large system outage	Yes, since the same districts will not be subject to load shedding time after time.
4	Voltage Angle Measurements across the system.	Install measurement devices in substations that measure the voltage angle across the transmission system (say, Batumi to Gardabani). This angle is a measure of the stress on the transmission system.			Yes, fewer system wide outages, that is, increased sales.	Yes, fewer system wide outages.
5	Digital Projection and Control Equipment	Replace the existing electro mechanical relays in a substation with modern digital relays, measurement and control systems.		Yes, more reliable operation of relay protection systems and subsequently less damage to substation equipment and lines.	Yes, fewer system wide outages, that is, increased sales.	Yes, few outage, and outages of less magnitude.

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Possible Smart Grid Projects

Nr.	Title	Description	Benefits			
			Reduce Technical Losses	Increased Efficiency	Increase Revenue (reduce commercial losses)	Improve Customer Satisfaction
6	Dissolved Gas Analyzers	Install more real-time Dissolved Gas Analyzers (DGA) on major system power transformers than is presently planned and funded in the companion DGA Project.			Avoid potential long term outages due to transformer failures.	Yes, fewer outages, and smaller outages.

File: Smart Grid Possible Projects 14 July 2011 v03.docx 3 of 3 July 14, 2011 12:00

Annex B
November 21, 2011 Steering Committee Meeting Minutes

This annex contains the minutes of the November 21, 2011 GSE/USAID/Tetra Tech Steering Committee meeting. The minutes were published on November 25, 2011.

Meeting Notes for Discussion Topics
Meeting of Monday, November 21, 2011; 15:00 hours

Attendees:

GSE	*USAID*	*Tetra Tech*
[redacted]		

Location: At GSE

Topics below are listed randomly; there is no significance to the order or sequence of the topics below.

The table begins on the next page.

Meeting Note for Discussion Topics
Meeting of Monday, November 21, 2011; 15:00 hours

Discussion Leader	Nr.	Component of PGIP	Issue or Update for this Meeting	Expected Outcome from this Meeting.	Results of Meeting (filled in after the meeting)
[redacted]	**1**	Smart Grid	1. Did the trip to SEL go well? 2. Deciding what technology GSE wishes to pursue (that is, emergency response system / SEL, dissolved gas monitoring, a mix of both, etc.). 3. Outline the scope of work in general terms and a schedule. 4. Confirmation / buy-in from USAID of the way forward.	1. Identify which technologies / project GSE wishes to pursue for the smart grid component. 2. Oral outline of the work to be done (scope, budget, schedule). 3. USAID support to proceed with the scope of work budget, and schedule.	1. Two technologies will be pursued: a) Emergency control system, with phasor measurements; and, b) Dissolved gas in transformer oil analysis capability. 2. Tt and GSE technical members to meet at 2:30 PM on Tuesday, 22 November, 2011 at GSE. Plan is to send EOIs or RFPs to bidders by end of December 2011 for their response at end of January 2012. 3. USAID indicated that they are supportive of the above plans.
[redacted]	**2**	Senaki 1 and 2 transmission lines	Tetra Tech requests for a short description of the land resettlement and compensation *methodology* for the environmental assessment document being prepared for the US Government.	GSE to describe / summarize the methodology and Tt will take notes. Draft text will be sent by Tt to GSE for review before the text goes into the EA.	1. Tetra Tech provided draft text at the meeting. 2. GSE to respond with edits on Tuesday. 3. Tt to submit EA document to USAID by COB Tuesday.
	3	Etc.	Other topics as may be discussed at the meeting.		USAID invites GSE's comments on whether one or two contracts; see item 3 on the page 3.

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25 Nov 2011, 13:05 hours

Meeting Note for Discussion Topics
Meeting of Monday, November 21, 2011; 15:00 hours

Discussion Leader	Nr.	Component of PGIP	Issue or Update for this Meeting	Expected Outcome from this Meeting.	Results of Meeting (filled in after the meeting)
	4	Next meeting	Next meeting.	Set the date and time for the next meeting.	Friday, December 2, 2011, at 15:00 hours at GSE.

Meeting Notes for Discussion Topics
Meeting of Monday, November 21, 2011; 15:00 hours

Text below expands upon the summary table above.

1 Smart Grid

Two technologies will be pursued in parallel.

a) Expansion of the existing emergency control system including phasor measurements (ExpECS); funding of about USD 1.2 million; and,
b) Dissolved gas in transformer oil analysis capability (DGOA); funding of about USD 1 million.

Tt and GSE technical members to meet at 2:30 PM on Tuesday, 22 November, 2011 at GSE. (Comment: the meeting was held on Tuesday as planned. Meeting notes will be issued for that meeting.)

The expansion of the present ECS around the functionality of the present Schweitzer Engineering Laboratories (SEL) ECS system will be the model for the scope of work for this ExpECS work. Competitive bids will be sought; the basis of award should be "best evaluated cost" and not "lowest price".

GSE's present oil analysis laboratory, along with the purchase of some portable field dissolved gas oil analysers will be the focus of this component. At this time it appears that on-line, real-time dissolved gas oil analysers using gas chromatographs installed at the transformers or at the substations may not be pursued. (Comment, the Technical Department of GSE was not present at the meeting, and their views will be sought.)

Plan is to send EOIs or RFPs to bidders by end of December 2011 for their response at end of January 2012.

USAID indicated that they are supportive of the above plans.

2 Senaki 1 and 2 Transmission Line Project Land Issues

Tetra Tech needs text that describes the land settlement methodology for the Environmental Assessment being developed for the US Government. Draft text was provided by Tetra Tech to GSE; GSE is to respond with edits to the draft text on Tuesday. The plan is for Tt to submit the EA with the finalized text to USAID by the end of the day, Tuesday. (Comment: GSE provided the text at the close of the day on Tuesday, and Tt submitted the revised EA document to USAID late Wednesday.)

3 One or Two Contracts

USAID solicited GSE's view on whether to have one or two contracts for the Senaki project.

1. The "one contract" approach would be for the combined substation and transmission line works.
2. The "two contracts" approach would be for (a) one contract for the substation work, and (b) anther contract for the transmission line works.

Additional bids and insight would be obtained by obtaining bids from all countries (not just the US and CIS), except for the sanctioned countries.

GSE was supportive of whichever way gets the new lines into service as quickly as possible, consistent with law and regulations.

The suggested way forward it to have one RFP with three "lots"; bidders could choose to bid on as many of the lots as they want. The one RFP would then generate either one or two contracts, depending upon the outcome of the bid evaluation process. This produces bone fide bids for the three options, and avoids future discussion of "what would have happened if….".

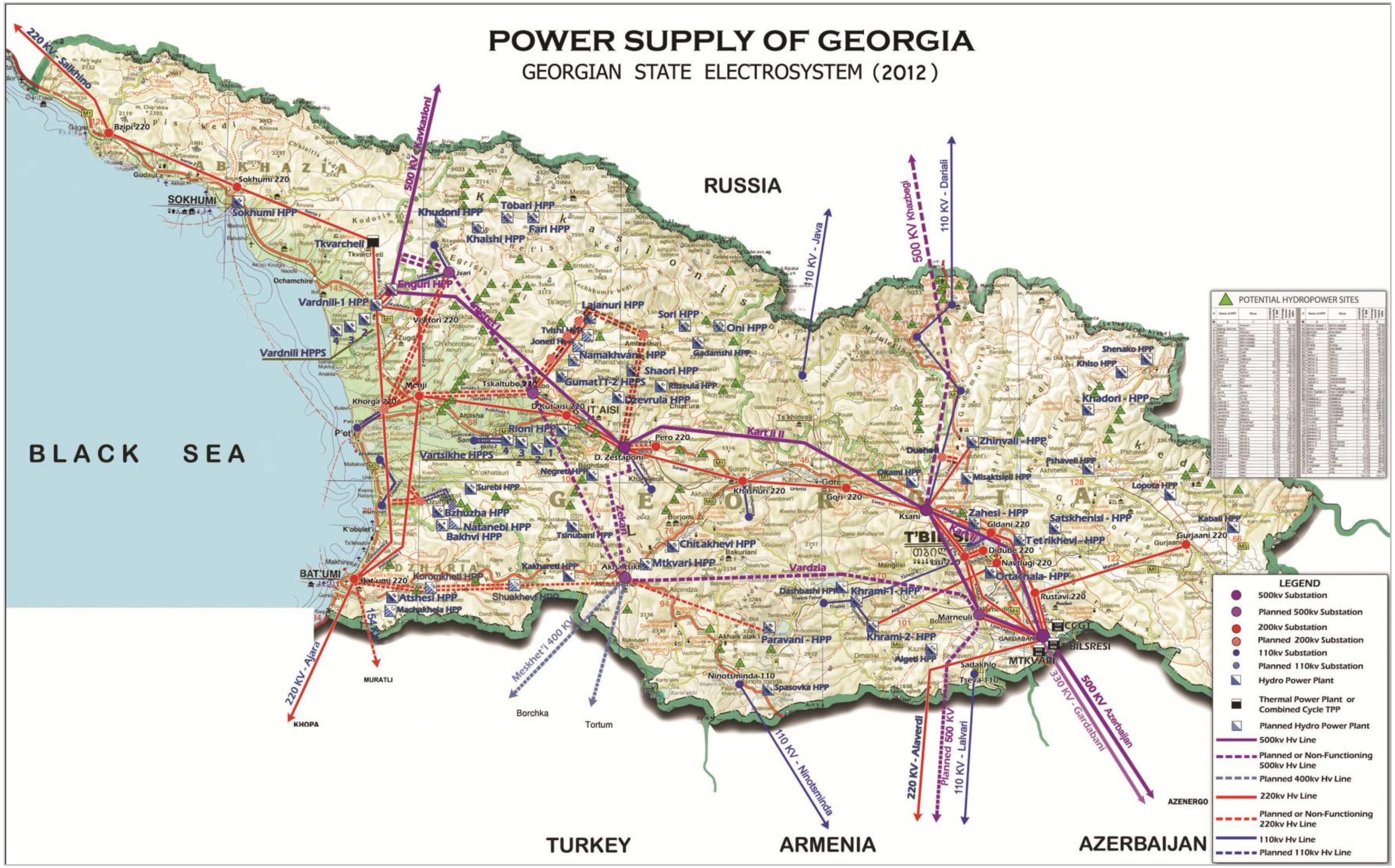
Lot 1	Combined transmission line and substation works
Lot 2	Just the transmission line works
Lot 3	Just the substations works

Also, bids would be invited from all countries (except the sanctioned five), with the RFP stating that bids from the US (Code 000) and the former CIS (Code 110) were preferred, but that USAID could at its discretion award the contract to other countries if the pricing was appropriate and a 'source – origin' waiver was granted to the project.

4 Next Meeting

The next meeting of the steering committee is scheduled for Friday, December 2, 2011, at 15:00 hours at GSE.

Annex C
GSE Transmission Network


POWER SUPPLY OF GEORGIA
GEORGIAN STATE ELECTROSYSTEM (2012)
RUSSIA
BLACK SEA
TURKEY
ARMENIA
AZERBAIJAN
LEGEND
500kv Substation
Planned 500kv Substation
200kv Substation
Planned 200kv Substation
110kv Substation
Planned 110kv Substation
Hydro Power Plant
Thermal Power Plant or Combined Cycle TPP
Planned Hydro Power Plant
500kv Hv Line
Planned or Non-Functioning 500kv Hv Line
Planned 400kv Hv Line
220kv Hv Line
Planned or Non-Functioning 220kv Hv Line
110kv Hv Line
Planned 110kv Hv Line
POTENTIAL HYDROPOWER SITES

Annex D
Tabulation of GSE Network Facilities Involved in EECS

This annex lists the GSE network facilities that are involved in EECS. Three tabulations are presented.

- Substations where measurements, control, and telecommunications equipment are involved in EECS
- Facilities where only telecommunications equipment is involved in EECS
- Lines and reactors involved in EECS.

Table 1 lists the substations involved in EECS. Substations are included in EECS when information from that substation is needed by the algorithms to determine whether or not a disturbance has occurred that required immediate action or when remedy actions are executed in the station. The information here includes measurements of power, voltage, current, phase angles, and status (open or closed) of circuit breakers.

If a substation is in the existing ECS then it will be in the proposed EECS. If a substation is in the existing ECS then it may be upgraded in the proposed EECS, as indicated below. Rows 6, 14, and 16 in the table below are not involved in EECS, but the substation is included in the list to show the complete set of GSE substations. Showing all substations of the GSE transmission system and the indication whether they are involved in the EECS shall demonstrates how comprehensive the new EECS will be.

Table D-1. EECS Substations, Substations with Measurement, Control, and/or Telecommunications Equipment

	Substation Name and HV Voltage Levels (110 - 500 kV)	In EECS	EECS Node Station	Mitigation Station Only	Telecommun. Station Only	Alrady in ECS	New in EECS
GSE Grid Substatons							
1	S/S Akhaltsikhe (Energotrans) 500/400/220 kV	yes	yes				yes
2	S/S Batumi 220/110 kV	yes	yes				yes
3	S/S Didube 220/110 kV	yes		yes		yes	
4	S/S Gardabani 500/330/22/110 kV	yes	yes			yes	upgrade
4	S/S Gldani 220/110 kV	yes		yes		yes	
5	S/S Gori 220/110 kV	yes		yes		yes	
6	S/S Gurjaani 220/110 kV	no					
7	S/S Khashuri 220/110 kV	yes		yes		yes	
8	S/S Ksani 500/220/110 kV	yes	yes			yes	upgrade
9	S/S Kutaisi 220/110 kV	yes			yes	yes	
10	S/S Lisi 220/110 kV	yes		yes		yes	
11	S/S Marneuli 220/110 kV	yes		yes		yes	
12	S/S Menji 220/110 kV	yes			yes	yes	
13	S/S Navtlugi 220/110 kV	yes		yes		yes	
14	S/S Pero 220/110 kV	no					
15	S/S Rustavi 220/110 kV	yes		yes		yes	
16	S/S Tskaltubo 220/110 kV	no					
17	S/S Zestaponi 500/220/110 kV	yes	yes			yes	upgrade
18	S/S Zugdidi 220/110 kV	no			yes	yes	
	Totals	**15**	**5**	**8**	**3**	**14**	**5**
Additional in Georgia							
1	Enguri HPP 500/220 kV	yes	yes			yes	upgrade
Additional in Neighbor Countris							
1	S/S Borchka and HPP (Turkey)	yes	yes				yes
2	S/S Samux (Azerbaijan)	yes	yes				yes
3	Muratly HPP (Turkey)	yes	yes				yes
	Totals	**19**	**9**	**8**	**3**	**15**	**9**

Table D-2 lists facilities where only telecommunications equipment is involved in EECS.

Table D-2. Substations with Telecommunications Equipment

Nr.	Substation
1	S/S Kutaisi 220
2	S/S Menji 220
3	S/S Zugdidi 220 (Vectori)
Total	3

Table D-3 lists the lines, transformers, and reactors involved in EECS.

Lines, transformers and reactors are included in EECS when information from a device is needed by the algorithms to determine whether or not a disturbance has occurred that required immediate action. The information here includes measurements of power, voltage, current, phase angles, and status (open or closed) of circuit breakers.

The table also lists the load connections (mainly 110 kV and 10 kV lines), generators and other facilities that are involved in the mitigation actions.

Table D-3. Lines, Transformers and Reactors Involved in EECS

If a substation is in the existing ECS then it will be in the proposed EECS. If a substation is in the existing ECS then it may be upgraded in the proposed EECS, as indicated below.

	Substation Name and HV Voltage Levels (110 - 500 kV)	Transmission Lines ≥ 220 kV Supervised	ECS	EECS	Transformers and Reactors ≥ 220 kV Supervised	ECS	EECS	Other Facilities Supervised	ECS	EECS	Lines to be Tripped for Mitigation	ECS	EECS
GSE Grid Substatons													
1	S/S Akhaltsikhe (Energotrans) 500/400/220 kV	500 kV OHL Zekari		yes	AT 500/220/10 kV		yes	HV/DC Conv. Block 1 500 kV	yes		Ramp down HVDC Δ Level 1		yes
		500 kV OHL Vardzia		yes	Synchron. Condensors		yes	HV/DC Conv. Block 2 500 kV	yes		Ramp down HVDC Δ Level 2		yes
		400 kV OHL Meshketi		yes				HV/DC Conv. Block 1 400 kV	yes		Ramp down HVDC Δ Level 3		yes
								HV/DC Conv. Block 2 400 kV	yes		Single Pole blocking		yes
											Double Pole blocking		yes
2	S/S Batumi 220/110 kV	220 kV OHL Paliastomi 1		yes	AT1 220/110 kV	no		Batumi HVDC 220/154 KV		yes	110 kV OHL Erge 1		yes
		220 kV OHL Paliastomi 2		yes	AT1 220/110 kV	no					110 kV OHL Erge 2		yes
		220 kV OHL Adjara		yes							110 kV OHL Adlia 1		yes
		220 kV OHL to Akhaltsikhe		yes							110 kV OHL Adlia 2		yes
		154 kV OHL to Muratli		yes							110 kV Bypass Feeder		yes
											35 kV OHL Peria		yes
											35 kV OHL Chorokhi		yes
3	S/S Didube 220/110 kV	220 kV OHL Didube 3	no		220/110 kV AT 1	no					110 kV OHL Didube 1	yes	
		220 kV OHL Didube 4	no		220/110 kV AT2	no					110 kV OHL Digomi 101	yes	
											110 kV OHL Digomi 102	yes	
											110 kV OHL Grma-Gele	yes	
											110 kV Bypass	yes	
											35 kV Dinamo 1	yes	
											35 kV Dinamo 2	yes	
											35 kV Vera 1	yes	
											35 kV Vera 2	yes	
											35 kV Saburtalo 1	yes	
											35 kV Saburtalo 2	yes	
											35 kV Saburtalo 3	yes	
											2 blocks of 6 kV feeders with total 15	yes	
												yes	
4	S/S Gardabani 500/330/22/110 kV	500 kV OHL Kartli 1		yes	500/220 kV AT		yes				330 kV OHL Gardabani (to Azerbaijan)	yes	
		500 kV OHL Vardzia		yes	500 kV Reactor		yes				220 kV OHL Alaverdi (to Armmenia)	yes	
		500 kV OHL to Samux (Azerbaijan)		yes	220/110 kV AT	no					110 kV OHL Archi 1	yes	
		330 kV OHL Gardabani (to Azerbaijan)		yes							110 kV OHL Archi 2	yes	
		220 kV Alaverdi (to Armenia)	no								110 kV OHL Udabno	yes	
		220 kV OHL Veli 1	no								110 kV OHL Marani	yes	
		220 kV OHL Veli 2	no								110 kV Bypass	yes	
		220 kV OHLKoda 2	no										
		220 kV OHL Lomtagora	no										
		220 kV OHL Navtlugi	no										

	Substation Name and HV Voltage Levels (110 - 500 kV)	Transmission Lines ≥ 220 kV Supervised	ECS	EECS	Transformers and Reactors ≥ 220 kV Supervised	ECS	EECS	Other Facilities Supervised	ECS	EECS	Lines to be Tripped for Mitigation	ECS	EECS
5	S/S Gldani 220/110 kV	220 kV Aragvi	no		220/110/10 kV AT1	no					110 kV OHL Armazi 1	yes	
		220 kV Varketili	no		220/110/10 kV AT2	no					110 kV OHL Armazi 3	yes	
											110 kV OHL Avchala 102	yes	
											110 kV OHL Avchala 103	yes	
											110 kV OHL Kenisi 1	yes	
											110 kV OHL Avshniani 1	yes	
											110 kV OHL Avshniani 2	yes	
											110 kV OHL Mukhiani 1	yes	
											110 kV OHL Mukhiani 2	yes	
											110 kV OHL Elia 2	yes	
											110 kV Bypass	yes	
											35 kV Norio	yes	
											1 block of 10 kV feeders with total 6	yes	
6	S/S Gori 220/110 kV	220 kV Liakhvi	no		220/110 kV AT 1	no					110 kV OHL Skra	yes	
		220 kV Urbnisi	no								111 kV OHL Gorijvari	yes	
											35 kV T3	yes	
											35 kV T4	yes	
											1 10 kV feeder	yes	
7	S/S Gurjaani 220/110 kV	220 kV OHL Manavi	no		220/110 kV AT 1	no					none		
					220/110 kV AT 2	no							
8	S/S Khashuri 220/110 kV	220 kV Urbnisi	no		220/110 kV AT 1	no					110 kV OHL Tseva 1	yes	
		221 kV Surami	no		220/110 kV AT 2	no					110 kV OHL Tseva 2	yes	
		220 kV Bypass	no								110 kV OHL Tezeri	yes	
											110 kV Bypass	yes	
											35 kV T1	yes	
											35 kV T2	yes	
											1 10 kV feeder	yes	
9	S/S Ksani 500/220/110 kV	500 kV OHL Kartli 1		yes	500/220 kV AT		yes				110 kV OHL Ksani 1	yes	
		500 kV OHL Kartli 2	yes		500 kV Reactor		yes				110 kV OHL Kani 2	yes	
		500 kV OHL Mukhrani		yes							110 kV OHL Khandaki	yes	
		220 kV Liakhvi	yes								110 kV OHL Narakhtari	yes	
		220 kV Aragvi	no								110 kV Bypass	yes	
		220 kV OHL Didgori 1	no								1 block with 3 feeders 10 kV	yes	
		220 kV OHL Didgori 2	no										
		220 kV Bypass	yes										

	Substation Name and HV Voltage Levels (110 - 500 kV)	Transmission Lines ≥ 220 kV Supervised	ECS	EECS	Transformers and Reactors ≥ 220 kV Supervised	ECS	EECS	Other Facilities Supervised	ECS	EECS	Lines to be Tripped for Mitigation	ECS	EECS
10	S/S Kutaisi 220/110 kV	220 kV OHL Ajameti 1	no		220/110 kV AT 1	no					none		
		220 kV OHL Ajameti 2	no		220/110 kV AT 2	no							
		220 kV OHL Kolkhida 1	no										
		220 kV OHL Sataplia	no										
		220 kV Bypass	no										
11	S/S Lisi 220/110 kV	220 kV OHL Didgori 1	no		220/110 kV AT 1	no					110 kV OHL Didube 1 a	yes	
		220 kV OHL Didgori 2	no		220/110 kV AT 2	no					110 kV OHL Lisi 1	yes	
		220 kV OHL Didube 3	no								110 kV OHL Lisi 2	yes	
		220 kV OHL didube 2	no								110 kV OHL Mtatsminda	yes	
		220 kV OHL Koda 1	no								110,kV Bypass	yes	
		220 kV OHL Koda 2	no								1 block with 3 feeders 10 kV	yes	
		220 kV Bypass	no										
12	S/S Marneuli 220/110 kV	220 kV OHL Koda 1	no		220/110 kV AT 1	no					110 kV OHL Arakhlo 1	yes	
		220 kV OHL Lomtagora	no		220/110 kV AT 2	no					110 kV OHL Arakhlo 2	yes	
		220 kV Bypass	no								110 kV OHL Marabda 1	yes	
											110 kV Bypass	yes	
											1 bloch with the T2 feeders 10 kV	yes	
13	S/S Menji 220/110 kV	220 kV OHL Kolkhida 1	no		220/110 kV AT 1	no					none		
		220 kV OHL Kolkhida 2	no		220/110 kV AT 2	no							
		220 kV OHL Khorga	no										
		220 kV OHL Paliastomi 1	no										
		220 kV OHL Senaki 1	no										
		220 kV OHL Senaki 2	no										
		220 kV Bypass	no										
14	S/S Navtlugi 220/110 kV	220 kV OHL Navtlugi	no		220/110 kV AT 1	no					110 kV OHL Makhata	yes	
		220 kV OHL Kukia	no		220/110 kV AT 2	no					110 kV OHL Kenisi	yes	
		220 kV OHL Algeta	no								110 kV OHL Rustavi 1	yes	
		220 kV Bypass	no								110 kV OHL Rustavi 2	yes	
											35 kV Lilo 1	yes	
											35 kV Lilo 2	yes	
											35 kV Orkhevi 2	yes	
											1 block with 7 feeders 10 kV	yes	
15	S/S Pero 220/110 kV	220 kV OHL Pero 3	no		220/110 kV AT 1	no					none		
		220 kV OHL Pero 4	no		220/110 kV AT 2	no							

	Substation Name and HV Voltage Levels (110 - 500 kV)	Transmission Lines ≥ 220 kV Supervised	ECS	EECS	Transformers and Reactors ≥ 220 kV Supervised	ECS	EECS	Other Facilities Supervised	ECS	EECS	Lines to be Tripped for Mitigation	ECS	EECS
16	S/S Rustavi 220/110 kV	220 kV OHL Veli 1	no		220/110 kV AT 1	no					220 kV OHL Manavi	yes	
		220 kV OHL Veli 2	no		220/110 kV AT 2	no					110 kV OHL Jeostili	yes	
		220 kV OHL Varketili	no								110 kV OHL Gamarjveba 1	yes	
		220 kV OHL Mmanavi	no								110 kV OHL Gamarjveba 2	yes	
											110 kV OHL Gachiani	yes	
											110 kV OHL Metalurgika 1	yes	
											110 kV OHL Metalurgika 2	yes	
											110 kV OHL Rustavi 2B	yes	
											110 kV Bypass	yes	
											1 block with 4 feeders 10 kV	yes	
17	S/S Tskaltubo 220/110 kV	220 kV OHL Sataplia	no		220/110 kV AT 1	no					none		
		220 kV OHL Derchi	no										
		220kV OHL Senaki 1	no										
		220kV OHL Senaki 2	no										
		220 kV Bypass	no										
18	S/S Zestaponi 500/220/110 kV	500 kV OHL Imereti	yes		500/220 kV AT 3		yes				220 kV OHL Pero 3	yes	
		500 kV OHL Kartli 2	yes		220/110 kV AT1	no					220 kV Bypass	yes	
		500 kV OHL Zekari	yes		220/110 kV AT2	no					110 kV OHL Pero 1	yes	
		220 kV OHL Ajameti 1	yes		500 kV Reactor		yes				110 kV OHL Pero 2	yes	
		220 kV OHL Ajameti 2	yes								110 kV OHL Kokhra 2	yes	
		220 kV OHL Surami	yes								110 kV OHL Kokhra 3	yes	
		220 kV OHL Pero 3	yes								110 kV OHL Kokhra 4	yes	
		220 kV Bypass	yes								110 kV OHL Argveta	yes	
		110 OHL Pero 1	yes								110 kV OHL Kvirila 1	yes	
		110 OHL Pero 2	yes								110 kV OHL Kackhi	yes	
		110 kV Bypass	yes								110 kV Bypass	yes	
19	S/S Zugdidi 220/110 kV	220 kV OHL Kolkhida 2	no		220/110 kV AT 1	no					none		
		220 kV OHL Kolkhida 2A	no		220/110 kV AT 2	no							
		220 kV Bypass											
Totals													
Additional in Georgia													
1	Enguri HPP 500/220 kV	500 kV OHL Imereti	yes		500 kV Reactor		yes				Generator 1	yes	
		500 kV OHL Kavkasioni		yes							Generator 2	yes	
		220 kV OHL Egrisi 1		yes							Generator 3	yes	
		220 kV OHL Egrisi 2		yes							Generator 4	yes	
											Generator 5	yes	

	Substation Name and HV Voltage Levels (110 - 500 kV)	Transmission Lines ≥ 220 kV Supervised	ECS	EECS	Transformers and Reactors ≥ 220 kV Supervised	ECS	EECS	Other Facilities Supervised	ECS	EECS	Lines to be Tripped for Mitigation	ECS	EECS
Additional in Neighbor Countris													
1	S/S Borchka and HPP (Turkey)	400 kV OHL Meskheti		yes							none		
		Connecting Line to Turkey grid		yes									
		Connecting Line to Turkey grid		yes									
2	S/S Samux (Azerbaijan)	500 kV OHL to Gardabani		yes							none		
		Connecting Line to Azerbaijan grid		yes									
		Connecting Line to Azerbaijan grid		yes									
3	Muratli HPP (Turkey)	154 kV OHL to Batumi		yes							none		
		Connecting Line to Turkey grid		yes									
		Connecting Line to Turkey grid		yes									
Totals		104	15	26	44	0	9	9	4	1		97	12
			41			9			5			109	

Annex E
System Architecture

[redacted]

The Georgia Power and Gas Infrastructure Project ('PGIP' or 'Project') provides in-country professional engineering and other technical services to support power and gas transmission improvements being undertaken by USAID on behalf of the Government of Georgia. Activities performed under the PGIP will complement and reinforce the activities, project management, and engineering expertise of USAID/Caucasus.

USAID will be undertaking work from 2010 to 2013 in the energy sector in collaboration with the Georgian Oil and Gas Company ('GOGC') and the Georgia State Electrosystem ('GSE') to upgrade, replace, and install critical selected gas and power transmission infrastructure. These companies are state-owned entities charged with the import and transit, and in the case of GSE, dispatch of electricity throughout the country.

The activities under this Project will support USAID's objective of promoting energy security through greater access to electricity and natural gas supplies households in Western Georgia, promote the development of the Poti Free Industrial Zone (FIZ) on the Black Sea, and secure power exports through in-country reliability related infrastructure improvements. The activities assigned are managed by Tetra Tech and support USAID's objective of fostering sustainable development.

The PGIP project includes the following infrastructure projects:

- Construction of a new 31 kilometer, 700 mm gas pipeline from Senaki to the Poti FIZ;
- Construction of a new 76 kilometer, 700 mm gas pipeline from Kutaisi to Senaki;
- Replacement of 58 kilometers of 220 kV transmission lines (referred to as Senaki I and II) which were dismantled in 1992 during Georgia's civil war; and,
- Restoration of the power substations in Tskaltubo and Menji to support the Senaki I and II 220 kV transmission lines.

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