Hydropower Investment Promotion Project (HIPP)

UPDATE ON THE REGIONAL TRANSMISSION TRANSFER CAPABILITY FOR GEORGIAN NEW HPPS ELECTRICITY SALES

FINAL REPORT

Friday, August 02, 2013

This publication was produced for review by the United States Agency for International Development. It was prepared by Deloitte Consulting in collaboration with Black & Veatch and Pierce Atwood Attorneys LLC.

UPDATE ON THE REGIONAL TRANSMISSION TRANSFER CAPABILITY FOR GEORGIAN NEW HPPS ELECTRICITY SALES

FINAL REPORT

USAID HYDROPOWER INVESTMENT PROMOTION PROJECT (HIPP)

CONTRACT NUMBER: EEM-I-00-07-00005-0

DELOITTE CONSULTING LLP

IN COLLABORATION WITH BLACK & VEATCH AND PIERCE ATWOOD ATTORNEYS LLC.

USAID/CAUCASUS OFFICE OF ENERGY AND ENVIRONMENT

FRIDAY, AUGUST 02, 2013

This document was prepared by:

Author	Organization	Contact Details
Ruben Abrahamyan	Deloitte Consulting LLP	Abrrub@gmail.com
Reviewer	**Organization**	**Contact Details**
Jake Delphia	Deloitte Consulting LLP	jdelphia@deloitte.com

TABLE OF CONTENTS

1.0 BACKGROUND

During the last 5-6 years a number of companies performed studies concerning the development of energy sector of Georgia.

These studies, in general, addressed two interrelated directions:

- Development of hydropower considering substantial hydro potential of Georgia;
- Georgia's electricity export potential to countries of the region and projects for development of transmission interconnections.

Interconnection of these processes is obvious, as far as to attract private investors into construction of HPPs it is necessary that in addition to availability of relatively low construction costs the investor has a clear idea on how he will sell the generated power.

It should be noted that the above mentioned studies have one common disadvantage: assessment of profitability of sales from Georgia is implemented without consideration of priorities of the neighboring countries, their domestic needs and possibilities both in terms of transfer capabilities of their power grids and in terms of the internal development of these systems. This may make it impossible in certain cases to ensure the desired results and, as a consequence, may cause changes in sale conditions from new HPPs of Georgia.

The purpose of this work is to provide detailed information to the potential investors of HPPs construction in Georgia on possibilities to realize the generated power and in particular, possibilities to export.

The period 2013 to 2022 was under consideration for this work. In this regard the following was needed:

- Analysis of the results of studies carried out earlier from the viewpoint of the present situation (since completion of many of those studies significant time has passed) and of the plans for development of regional power systems;
- Defining the transfer capabilities of interconnection lines (considering their expansion) taking into account possible limitations conditioned by internal grids and power system development plans of the regional countries.
- Defining the potential of economically justified export of power from Georgia by seasons and by time of the day with the assessment of possible prices for new HPPs of Georgia in the directions of Turkey, Russia, Armenia and Iran based on applicable prices of import and volumes of purchases by power systems of the region's countries.

2.0 EXECUTIVE SUMMARY

The priority of Georgia in the power sector is development of hydro energy, namely construction of new HPPs with attraction of private investors.

One of the important preconditions of attracting private investors is to have possibility of efficient sale of electricity in order to guarantee return on investments to private investors.

Sale of electricity is possible both for the domestic market and for export to neighboring countries.

Sale of electricity for the domestic market may be implemented in winter, all the more that, according to the rule the Georgian generators, are obliged within three winter months to sell the electricity to the domestic market. Sale of electricity is limited by low prices during the most favorable period for generation by new HPPs from April to October.

This work is dedicated to the analysis of the possibilities of export to the countries of the region from the perspective of new HPPs of Georgia.

The following issues are addressed in this work:

Analysis of results of earlier studies from the perspective of the current reality (Chapter 1)

Several years have passed since issuance of the last studies on this subject and it became necessary to supplement them with the effects of changes occurred since then within the Georgian and Armenian power systems, as well as within other regional power systems.

Critical analysis of these works revealed the following shortcoming, which are addressed in this current work:

- The Georgian export potential by years based on realistic deadlines for commissioning of new generation capacities and based on domestic consumption growth rates is not assessed;
- Impacts of internal limitations inside Turkey (the main priority direction of the Georgian export) both by prices and by transfer capabilities of the network for deliveries from Georgia are not addressed;
- Possible changes in the export policy of Azerbaijan towards Turkey (gas or electricity), what may dramatically reflect the power flow Georgia-Turkey are not considered;
- The possibility of Russia's interest in deliveries of electricity to Turkey is not considered;
- The suggested scheme of trading Georgia-Armenia-Iran is wrong in terms of possible mutual deliveries (volumes and prices) and in terms of operation conditions (a synchronous operation is suggested, which is impossible).

Calculations of transfer capabilities of regional networks considering power systems development plans (Chapter 2)

In this Chapter, the allowable power flows are calculated from Georgia to the countries of the region (Turkey, Armenia, Iran, Russia, Azerbaijan) taking into account the internal network capabilities of these countries.

The detailed calculations (load flow, steady-state and thermal stability) for normal and post-accident regimes performed based on former soviet methodologies and ENTSO-E requirements provided the following results:

Georgia-Turkey

- Summer regimes are the most unfavorable from the perspective of limitations on the power flow from Georgia due to overloading of HPPs of Turkey and transfer capability of the internal transmission interface comprising of two 400 kV lines and two 154 kV lines (in 2013) and later on with addition of the third line of 400 kV due to commissioning of new Yusufeli and Artvin HPPs;
- Under a normal scheme of operation, the allowable power flow from Georgia will be 650 MW in 2013 and 560 MW in case of construction of the new third line of 400 kV together with construction of new HPPs within the period 2017-2022. With disconnection of the Deriner-Erzurum line these power flows will not exceed 270 and 420 Mw, respectively.
- To increase the power flow from Georgia, the possible changes in the connection scheme Georgia-Turkey were analyzed (options for construction of the second 400 kV line, changing the place of the connection point for that line).

Georgia-Armenia (synchronous operation with disconnection of the Armenian power system from Iran)

- The power flow to Armenia allowable by steady-state stability requirement via the existing line 220 kV Gardabani-Alaverdi reaches 295-330 MW in normal and post-accident regimes
- Transfer capability of that line is limited by thermal stability requirement (in summer not more than 250 MVA)
- Analysis of options to upgrade the transmission interface was performed for the case with availability of the Armenia-Iran line, i.e. for the case of potentially big power flow from Georgia.

Georgia-Armenia-Iran (asynchronous operation through B2B converter)

- The allowable power flow through the existing transmission interface 220 kV Gardabani-Alaverdi is defined by the thermal stability requirement (250 MVA or about 220 MW).
- Upgrading of the transmission interface by means of constructing a new 220 kV Gardabani-Vanadzor line increases the allowable power flow up to 440-470 MW depending on the section of the new line.
- Upgrading of the transmission interface by means of constructing a new 400 kV transmission line even with disconnection of 220 kV Gardabani-Alaverdi line will allow having no limitations via that line for possible

deliveries from Georgia, whereas the allowable power flow will be determined only by the capacity of the B2B converter.

Georgia-Russia

Availability of 500 kV "Kavkasioni" line may ensure power flow of 500 MW from Georgia with a high margin; there is also 220 kV "Salkhino" line and two 220 kV "Dariali" and "Dzhava" lines, which allow stating that this transmission interface may have limitation only in case of disconnection of "Kavkasioni".

Georgia-Azerbaijan

In 2012 a new line of 500 kV will be put into operation, which will allow together with the existing one of 330 kV transferring possible deliveries from Georgia, if required.

Sale of electricity from new HPPs of Georgia to the countries of the region (Chapter 3)

In this Chapter the possible directions of export (by countries), export volumes and prices, at which electricity from the new HPPs of Georgia can be sold, are defined.

To solve this issue the following aspects were addressed:

Analysis of the potential export from new HPPs based on the following:

- Dynamics of the Georgian domestic consumption growth;
- Existing surplus of generation and the Georgian power system development plans;
- Electricity import requirement by the countries of the region and potential of the existing HPPs of Georgia.

Possibility of sales to Turkey, including:

- Impacts of processes in Turkey on the Georgian export, namely:
  - Development of the northeast part of the Turkish power system.
  - Prices on the wholesale market of Turkey and probability of splitting into price zones.
  - Technical limitations.
  - Competition by countries of the region.
  - Regulatory base
- Possible prices of energy purchases from Georgia by a participant of the Turkish wholesale market.
- Calculation of marginal price and delivery schedules fro new HPPs of Georgia by seasons and by day zones with consideration of the necessity to pay transmission charges;
- Analysis of possible ways to increase the price of delivery from new HPPs.

Analysis of limitations to possibilities of sales to Russia and Azerbaijan, including:

- Low level of wholesale electricity prices on markets of these countries (in Russia prices in the Northern Caucasus are subsidized)
- Their export-oriented strategy (Azerbaijan intents to export electricity to Turkey through Georgia).

Possibility of electricity sales to Armenia (synchronous operation with Armenia without Iran), including:

- Defining the required volumes of import from Georgia by seasons and by day zones with consideration of the domestic consumption growth dynamics and the structure of generation capacities;
- Calculation of possible prices of delivery from new HPPs of Georgia.
- Impact of the upgrade options for the Georgia-Armenia interconnection on prices of delivery from new HPPs.

Possibility of electricity sales to Armenia-Iran, including:

- Defining the required volumes of import from Georgia by seasons and by day zones with consideration of the existing Armenian-Iranian swap contract “electricity for Iranian gas”.
- Calculation of prices for new HPPs of Georgia under the condition of assuring profit for the Armenian part as well.

The main results of this Chapter are as follows:

- Export of electricity to Turkey could be limited for new HPPs of Georgia within the period from April to June, which is conditioned by the reduction of Turkey’s demand for the Georgian electricity;
- Based on the current prices being formed on the Turkish wholesale market, the price of delivery from new HPPs of Georgia for export to Turkey with transmission charges and “costs of business” of the Turkish partner will not exceed $58/MWh, but may reduce to $$49/MWh. Growth of these prices is possible in case of growth of the wholesale prices on the Turkish market, which can occur, for example, with cancellation of subsidies for gas for TPPs;
- These prices may be higher by $15/MWh in case of selling only day-time and night-time electricity and by $3-4/MWh in case of using transmission methodology, which is based on a reasonable differentiation of costs of transmission for certain exporters;
- Export from new HPPs to Russia is inefficient given the relatively low level of prices on the wholesale market (about $40/MWh) and the price subsidization policy implemented in the Northern Caucasus;
- For new HPPs of Georgia, Azerbaijan can not be considered as a potential importer, since Azerbaijan itself has the intention to export surplus of its own electricity to Turkey, Iran and Russia;
- Under synchronous operation with Armenia (without Iran) from March till the end of September through the existing connection, Georgia traders can export electricity at the price of generation up to $55-60/MWh practically on a smooth delivery schedule until 2017 and with a necessary range of control up to 100 MW until 2022 under the existing structure of generation in Armenia;
- In those seasons, when daily exchange of electricity is being realized between Armenia and Georgia, prices for the Georgian HPPs may increase up to $70-80/MWh as well, depending on the exchange volumes;

- Shut-down of the Armenian NPP after the year 2016 and its substitution with a thermal unit (construction of the new NPP within the review period is hardly possible) will define the price of import from Georgia to be $50/MWh with the price for the Russian gas on the border Georgia-Armenia amounting to $180/MWh;
- Growth of Russian gas prices (unavoidable, though could be moderate) will bring the growth of the sale prices for electricity from HPPs of Georgia;
- Considering that the priority for Armenia is the electricity delivery to Iran in exchange forIranian gas, the HPPs of Georgia, under the existing structure of generation in Armenia, may supply the following volumes of electricity allowing the Armenian TPPs to operate only on Iranian gas:
  - 250GWh –in 2013
  - 750 GWh – in 2017
  - 1550 GWh – in 2022
- The price of delivery from HPPs of Georgia even with the current prices of substituted Russian gas for TPPs of Armenia will be not more than $57/MWh;
- The main advantage of deliveries to Armenia while operating with Iran is the opportunity to export actually on a smooth delivery schedule, which solves the problem with realization of the night-time electricity for run-of-river HPPs. In this case the deliveries could be regulated and use the most favorable periods for HPPs of Georgia;
- Substitution of the retiring Armenian NPP with thermal units will result in an increase of export from Georgia; the annual deliveries will exceed 2000 GWh;
- The impact of options for upgrading the Georgia-Armenia interconnection on the level of possible prices of the Georgian HPPs (towards reduction) is demonstrated herein, and it justifies the assumption that such an upgrade is necessary only at the time it becomes required from the viewpoint of increased power flows.

3.0 ANALYSIS OF RESULTS OF EARLIER RESEARCHES ON ELECTRICITY EXPORT FROM GEORGIA TO THE COUNTRIES OF THE REGION

This Chapter addresses the issue of critical analysis of proposals of various companies from the viewpoint of efficiency of electricity sale from new HPPs.

Since issuance of these research works significant time has passed, during which certain changes happened in the region; and the results need to be adjusted from the point of view of the current situation.

Here is the analysis of results of the previous studies.

The study performed by Fichtner [1] in 2007 can be considered the main work on evaluation of sales opportunities from Georgia to Turkey. As it is stated therein, today Georgia is carrying out considerable network construction to connect to Turkey (Fig.1.1), in particular:

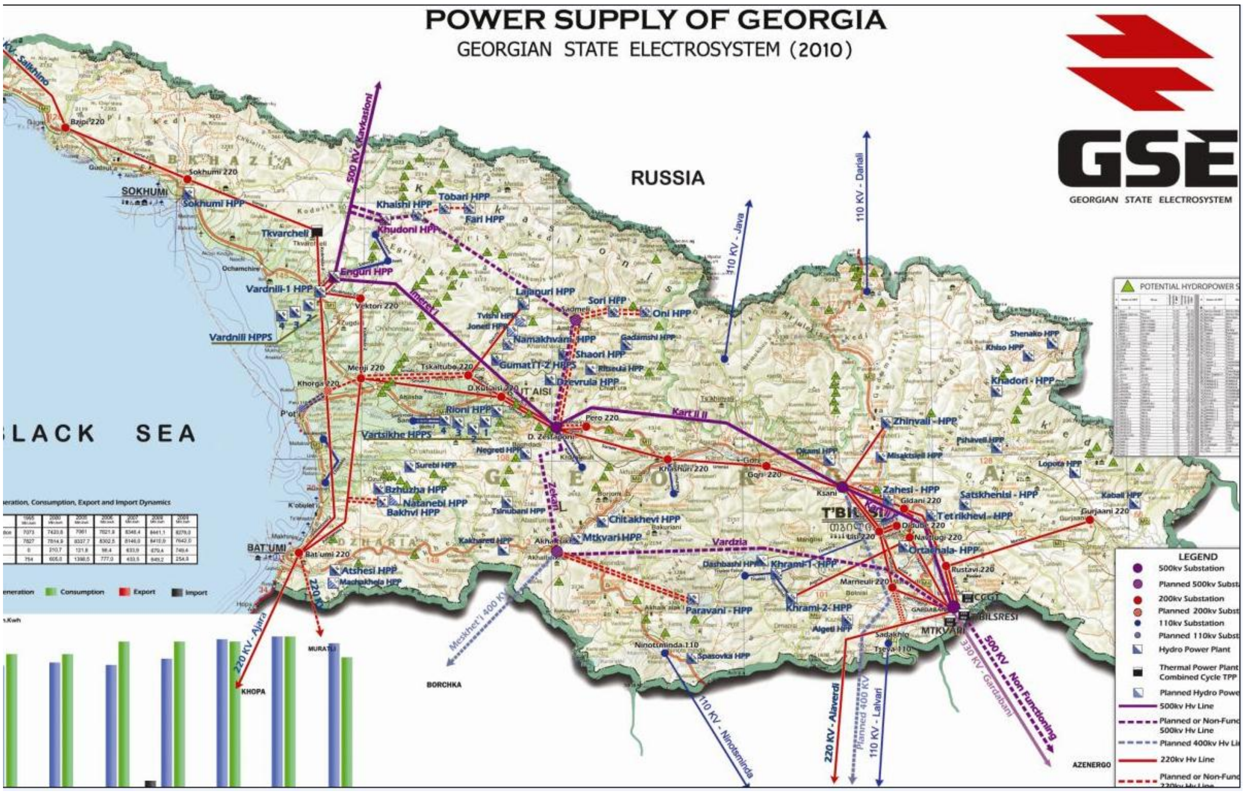
- Transmission line (TL) 500 kV Zestafoni-Akhaltsikhe
- TL 500 kV Gardabani-Akhaltsikhe;
- Substation 500/400/220 kV Akhaltsikhe with 2x350 MW back-to-back converter (B2B) to be expanded for additional 350 MW;
- TL 400 kV Akhaltsikhe-Borchka (Turkey).

Cost of the project, which, as well, substantially increases the reliability of the Georgian power system, is assessed to be €265-300 M [2].

The study assumes that export of power in 2013 will amount to 650 MW with the perspective to grow up to 1000 MW after the year 2017.The study also assumes that Turkey will be purchasing all the power transferred through the territory of Georgia, including 80% of that power from Azerbaijan.

Even in case of the assumed electricity export to be about 3500 GWh annually, the transmission price in Georgia, according to the Fichtner's approach, amounts to $20 /MWh(if all costs of the above mentioned network construction are incurred by exporters). Because that transmission service price is rather high, the option of decreasing it on account of domestic consumers is also considered. Taking into account the current tariff for domestic consumers, which is rather high even today (for residential consumers it is about $105/MWh), it is hardly acceptable. Currently the government of Georgia evaluates the additional price of transmission to $18/MWh, which together with the current transmission and dispatch charge will amount up to $23/MWh.

Fig. 1.1. Transmission map of Georgia



The studies [1,3] did not analyze the economic benefits of electricity export to Turkey for Azerbaijan. In the case when exports decrease, the supposed volumes of export to Turkey could actually be significantly less than forecasted.

Let's make the possible situation clearer.
The economic benefits for Azerbaijan to export power to Turkey are addressed in the study of ECON [4], where it is fairly noted that at the existing prices of 2008 for the Azerbaijan gas supplied to Turkey, which amounts to $120/tcm, export of electricity is quite profitable (specific estimates are not provided).

However, today Azerbaijan exports gas to Turkey at the price of about $260 /tcm and intends to double delivery volumes (currently it is 6 bln.m^3 annually). In such conditions, **trading of electricity may appear to be less profitable than direct export of natural gas**.

Considering the fact that, according to Fichtner, the major part of export (80%) is supplied by Azerbaijan, as well as the present decrease of the average price on the wholesale market of Turkey and uneven prices by day zones, this may bring to decrease of power flow from Georgia, which, in its turn, will increase theprice of transmission services.

Moreover, the ECON study didn't address the development of the northeast part of Turkey both in terms of new generating capacities and in terms of transfer capabilities of transmission lines.

However, as it will be demonstrated herein after, this is quite important factor in defining export potential from Georgia by seasons, especially for new HPPs. Currently, while negotiating trading agreement, the Turkish side discusses the issue of limiting deliveries from Georgia for the period from April to June by 350-500 MW.

The other directions of export, according to Fichtner, are Armenia and Iran. Unfortunately, in this part of their study, this fact was not initially taken into consideration, such was for the case with Turkey, the Georgian power system cannot function synchronously with Armenia and Iran, since it has an agreement on parallel operation with Russia that is not going to be synchronized with Iran in the foreseeable future. Even in that case, the proposed construction of a new connection 400 kV Ksani-Hrazdan (Fig.1.1) is estimated to €69 M.

Today, the scheme of this connection is changed into Marneuli-Hrazdan making it a shorterline. However, the necessity in B2B converter of 350 MW will considerably increase the budget of that project (only the cost of B2B converter is about €60 M).

With respect to the power flows, it is assumed in the study that Georgia will be delivering 350 MW at a smooth delivery schedule to Iran within 6 summer months and within the other 6 months, it will be receiving 350 MW from Armenia (these are just the conditions, under which the annual volume of power flows via that connection is calculated). Acceptance of these values demonstrates that the daily load curves are not considered at all.

Another fact that was not taken into account is that Armenia does not have such capacity in winter to be of economic benefit for Georgia, and prices of the potential Armenian export that were accepted while assessing the economic efficiency, are at least 1.6 times lower than the current prices (note: even the accepted low prices do not assure proper economic efficiency for the project).

One of the main deficiencies of the above mentioned studies is that the limitation of the existing export potential of Georgia and its actual rate of growth, which will be significantly lower than it was planned to be, was completely disregarded.

Instead of the planned 700 MW of new capacities, the actual new Georgian HPPs capacities by 2015 will sum to 200-250 MW. One of the main factors resulting in delay of HPP construction projects is uncertainty as to volumes and prices of realization of electricity.

The common drawback of those studies is absence of the analysis of relationship of processes in the countries of the region, for example, impact of export/import in one direction on the other direction, provision of advantageousness of the integration process for all participants given priorities in the development of regional power systems.

As an example, both Fichtner [1] and GSE [3] in their calculations just assume the power flow to Turkey to be on the level of 700 MW in 2013 and 1000 MW in 2017 absolutely without considering either the transmission interface Northeast-Center of Turkey, or hydro generation development plans near the connection point of the line Georgia-Turkey. This may significantly result in decrease of power flow from Georgia with all related negative aftereffects.

Irrespective of the fact that in Georgia the new 400 kV line Borchka-Ispir-Keban in Turkey is considered as upgrading of the Turkish transmission interface, the efficiency of this line is not discussed from the viewpoint of the growth of the allowable power flow, although it is already several years that in the studies of Turkish companies [5,6 etc.] this line is directly associated with construction of hydro power plants in that part of Turkey (Yusufeli, Artvin), and therefore, it is quite possible this line will not ensure necessary increase of transfer capability.

Moreover, if we take into consideration that development of hydropower in Turkey is envisaged in this region of the country [7], it becomes obvious that serious problems may occur with power transfer to the central part of Turkey.

The fact that the development of transmission network of Turkey will be directly connected with new generating capacities is confirmed also by studies of the company Deloitte [8], in which it is stated, based on the Turkey development programs, that the estimated investments required for the period 2010-2030 is between $193-225 billion, which comprises $180-210 billion for generation, $6-7 billion for transmission and $7-8 billion for distribution.

Even taking more moderate numbers for development of generation provided in the study of the Turkish company Tubitak [6], according to which new generation requirement makes 3000 MW per year at average cost of $1 million per MW, it is obvious that development of transmission will be carried out mainly to support generation from their own (Turkish) new power plants.

It is clear that only when results are based on a complex research of realistic volumes of export from Georgia, which include both technical and economic aspects, may give a real idea to the private investors of HPPs in Georgia on issues concerning power sales and therefore, on return on investments.

Chapter 2 will address the analysis of transfer capabilities of the regional countries under integration, considering both ongoing and planned projects.

Chapter 3 will be dedicated to the definition of volumes of export from new HPPs of Georgia that may be in-demand considering the growing electricity needs in the countries of the region, as well as to applicability of prices by seasons and by daily schedules of deliveries.

4.0 2. ANALYSIS OF TRANSFER CAPABILITIES OF THE NATIONAL GRIDS OF THE REGION WITH A VIEW TO EXPORT POSSIBILITIES FROM GEORGIA FOR YEARS 2013-2022

The purpose of this Chapter 2is to define the potential of transfer capabilities of national grids of the region considering export of electricity from Georgia and possible limitations in terms of regimes and power systems development options.

Availability of limitations on transfer capabilities will represent certain barriers for realization of power from new HPPs of Georgia.

The period from 2013 to 2022 is taken as a settlement period. Turkey and Armenia (with and without deliveries to Iran) are taken as main export directions.

In principle, electricity export to Turkey is supposed to be in two directions - Batumi-Muratli and Akhaltsikhe-Borchka, however, with the purposes of this report only export to Borchka will be under consideration, since the first direction with the B2B converter of 2x175 MW implemented by the company Energo-Pro will be supplying the domestic load in the Eastern part of Turkey and will not cause significant technical problems.

To assess the technical potential of exporting both to Turkey and to Armenia and Iran summer regimes were taken for calculations considering that Turkey and Iran have their maximum demand especially in summer just during the period when Georgia has real export possibilities.

This Chapter does not address in details the capabilities of transfer to Russia and Azerbaijan due to their sufficiency for deliveries from Georgia (in Chapter 3 these issues are addressed from the economic perspective).

Russia is connected with Georgia (Fig.1.1) through the lines 500 kV “Kavkasioni”, 220 kV “Salkhino” and 110 kV “Dariali” and “Dzhava”. The 220 kV line can hardly be considered as a line for export to Russia, since through this line power supply of Abkhazia is realized. Only the “Kavkasioni” line can transfer 500 MW with a high margin, which is quite sufficient for possible deliveries to Russia.

Georgia is connected with Azerbaijan through a330 kVline, and in this year the other line of 500 kV will be commissioned (Fig. 1.1) to allow for any delivery from Georgia.

However, Azerbaijan currently discusses as a priority the evaluation of options for delivering of its own electricity to Georgia, Turkey, Russia and Iran during all seasons of the year.

4.1 Analysis of Regimes and Transfer Capabilities of the Transmission Interface Georgia-Central Turkey Through the Interconnection Akhaltsikhe-Borchka for the Period 2013-2022

Calculation conditions

- Summer regimes are taken as calculation regimes since summer is the period of maximum demand in Turkey.
- The demand of Turkey is taken in a manner that transformers of 400/154 kV be loaded no more than for 50-60% of their nominal capacity.

- Relating to development of new generation capacities, it is scheduled that before 2015, the Deriner HPP of 670 MW will be put into operation, and within the period 2017-2022, the Yusufeli HPP of 540 MW and the Artvin HPP of 330 MW will be commissioned.
- The transmission interface Georgia-Central Turkey is presented by a 400 kV transmission line (TL) from the Akhaltsikhe substation 500/400/220 kV with B2B converter of 2x350 MW (with a perspective of adding another 350 MW) to Borchka, from which two 400kV transmission lines (Borchka-Tirebolu-Karsamba-Kayabashi and Borchka-Deriner-Erzrum-Keban) and two 154kV transmission lines are extended (Fig.2.1).

Fig. 2.1. Georgia-Northeast Turkey interconnection (2013-2017)

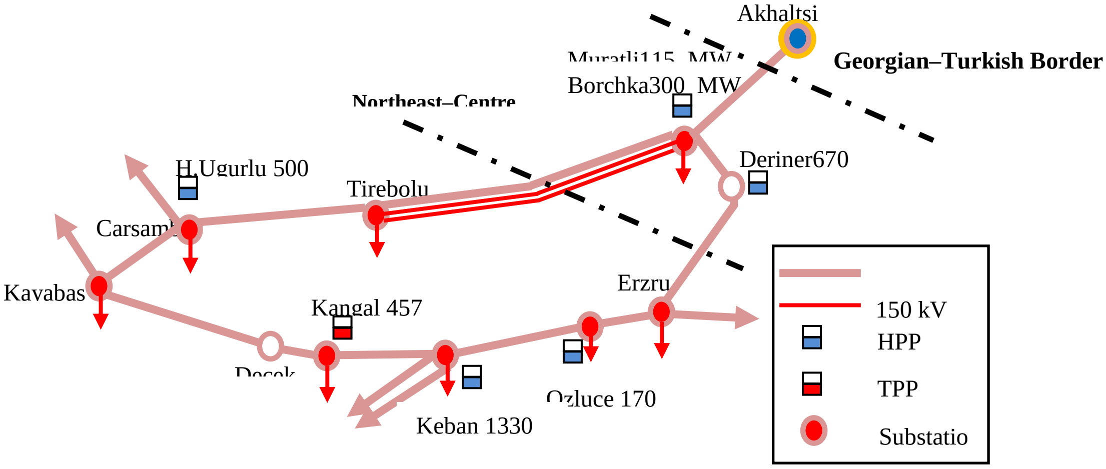
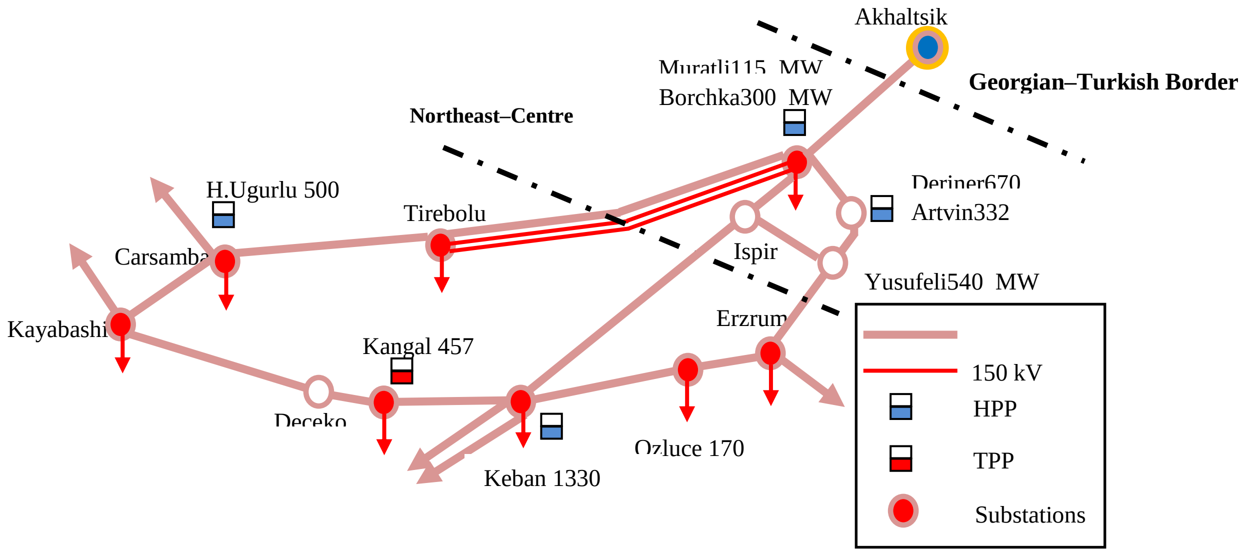


Fig. 2.2. Georgia-Northeast Turkey interconnection (2017-2022)



1. Another 400 kV line to Keban is planned to be built in the future (Fig. 2.2).
2. In order to define allowable power flows both the standards of the former Soviet Republics (Georgia, Azerbaijan, Armenia and Russia) being still used therein to calculate the steady-state stability margin of 20% for long-term allowable flows and a margin of 8% for short-term allowable flows in post-fault regimes, and the ENTSO-E requirements were used in calculations, specifically the requirement of10 % margin while disconnecting one (main) element, which is being analyzed from the viewpoint of steady-state stability of the given transmission interface.

Calculation Results

The calculations are implemented for the case when HPPs on the northeast part of Turkey are maximally loaded. This situation causes the highest limitations on export from Georgia.

According to the former Soviet standards each of the emergency regimes is characterized by its allowable power flow both the long-term flow and the short-term flow. Therefore, the power flows should be different and the results are provided for both cases.

To define the allowable power flow, pursuant to the ENTSO-E requirements, the largest single contingency regime is chosen and out of the conditions of that regime the allowable power flow is defined.

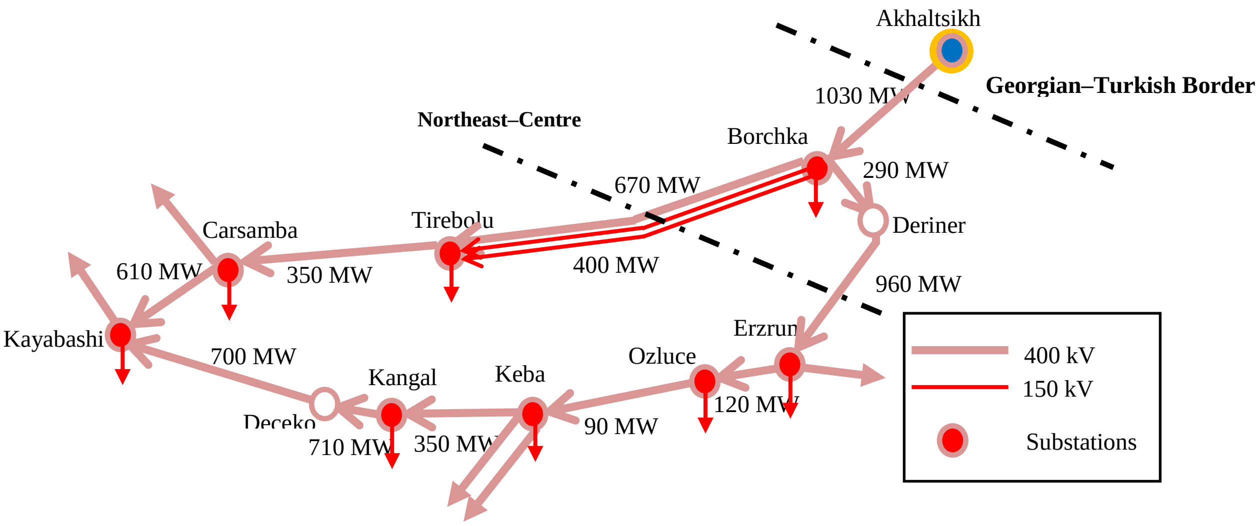
4.2 Scenario for the year 2013 (the existing scheme of the transmission interface Northeast – Center of Turkey)

Normal scheme

The maximum export from Georgia through B2B converter is up to 1030 MW (the key requirement for this case is voltage stability), where as the transfer capacity margin of the Turkish power system via transmission interface northeast-center is 2030 MW (Fig. 2.3), including 1070 MW in the direction Borchka-Tirebolu (aggregate for 400 kV and 154 kV lines) and 960 MW in the direction Deriner-Erzrum (via 400 kV).

Thus, the transfer capability (for a long-term flow) through the Turkish transmission interface will be 2030*0.8=1625 MW; therefore, the power flow from Georgia will not exceed 655 MW.

Fig. 2.3. The limit of transmission capacity (steady-state stability) of Northeast-Centre transmission interface. Normal scheme 2013.



Transmission line Deriner-Erzrum 400 kV is tripped

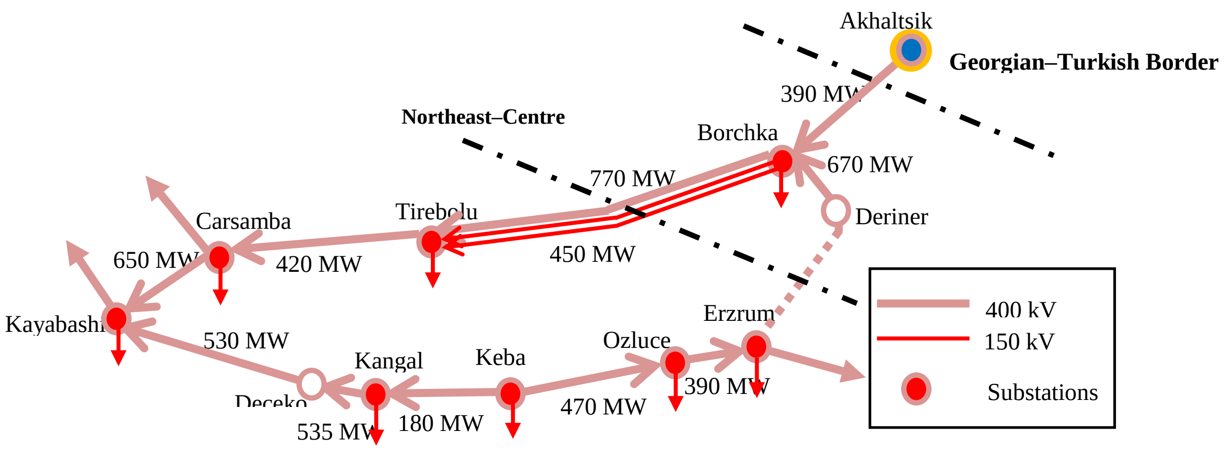
The maximum export from Georgia through B2B converter is 390 MW, whereas the transfer capacity margin of the Turkish power system via the transmission interface northeast-center is 1220 MW (Fig.2.4).

Transfer capability of the Turkish transmission interface under post-fault regime for short-term flows will be 1220*0.92=1120 MW and for long-term flows will be 1220*0.8=980 MW.

Thus, according to calculations the possibility of export from Georgia to Turkey through B2B converter in case if 400 kV TL of Deriner-Erzrum is tripped, should be 390- (1220-1120)= 290 MW for short-term export (up to 20 min) and 390-(1220-980)=150 MW for long-term export.

This case is the worst case from the viewpoint of transfer capability and limitations on the Georgian power flow.

Fig. 2.4. The limit of transmission capacity (steady-state stability) of Northeast-Centre transmission interface. 400kV line Deriner-Erzrum is tripped (2013).



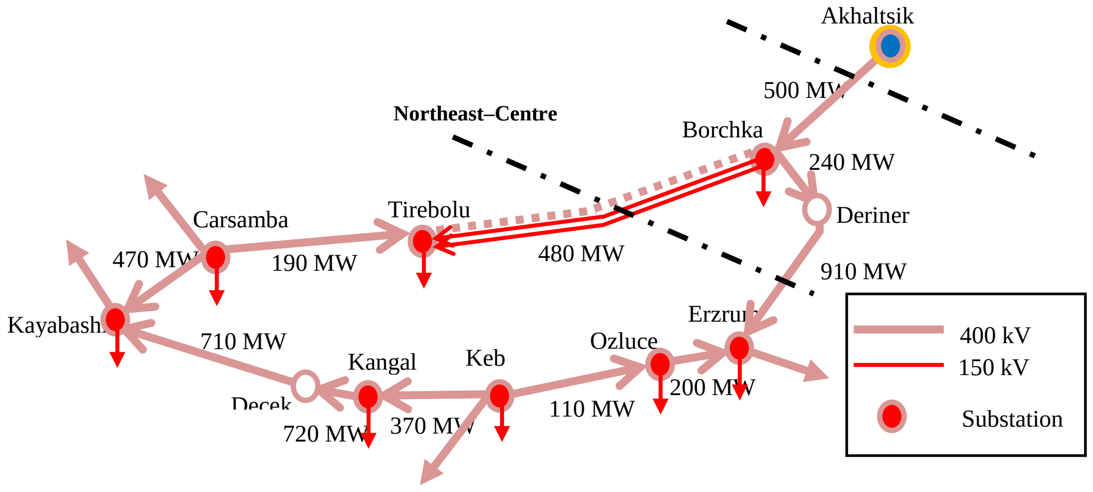
Transmission line Borghka-Tirebolu 400 kV is tripped

The maximum export from Georgia through B2B converter is 500 MW, whereas the transfer capacity margin of the Turkish power system via the northeast-center transmission interface is 1390 MW (Fig. 2.5), including 480 MW in the direction Borchka-Tirebolu (154 kV lines) and 910 MW in the direction Deriner-Erzrum (via 400 kV).

Transfer capability of the Turkish transmission interface under post-fault regime for short-term flows will be 1280 MW and for long-term flows will be 1110 MW. Power flow from Georgia will be 390 and 220 MW, respectively.

Fig. 2.5. The limit of transmission capacity (steady-state stability) of Northeast-Centre transmission interface. 400kV line Borchka-Tirebolu is tripped (2013).

.



The largest single contingency case out of the above described cases is option 2 (Fig.2.4), which is chosen as a base option for assessment of acceptability pursuant to the ENTSO-E requirements. Therefore, the allowable power flow from Georgia will be 390 -1220 *0.1=270 MW.

Conclusions for the year 2013

Despite the fact that under normal operation scheme, export from Georgia to Turkey through the existing transmission interface with B2B converter could be up to 650 MW with a rather high stability margin, the possible accidents without application of anti-emergency automation will allow for a long-term flows not exceeding 290 MW, whereas under emergency disconnection of 400 kV Deriner-Erzrum line, the System Operator will have to restrict the export flow down to 150 MW for a period of 20 minutes.

Upon the ENTSO-E requirements, the allowable power flow will be 270 MW.

Considering that the majority of faults are caused by single-phase short circuits, phase-by-phase disconnection with a subsequent one-phase automatic reclosing will be rather efficient and actually will allow removing limitations on the Georgian export.

Another alternative is the projected upgrade of the Turkish transmission interface by means of constructing the third line of 400 kV (Borchka-Ispir-Keban).It is obvious that **availability of such a line will remove all limitations on power flows from Georgia**.

However, the construction of this line will probably depend on connection schemes of new HPPs– Yusufeli (540 MW) and Artvin (330 MW) – planned to be commissioned after 2015 (Fig.2.2) and this is the option under consideration, since certain limitations may occur therein.

4.3 Scenario for years 2017-2022 (upgrading the transmission interface by means of

Constructing Borchka-Ispir-Keban 400 kV transmission line)

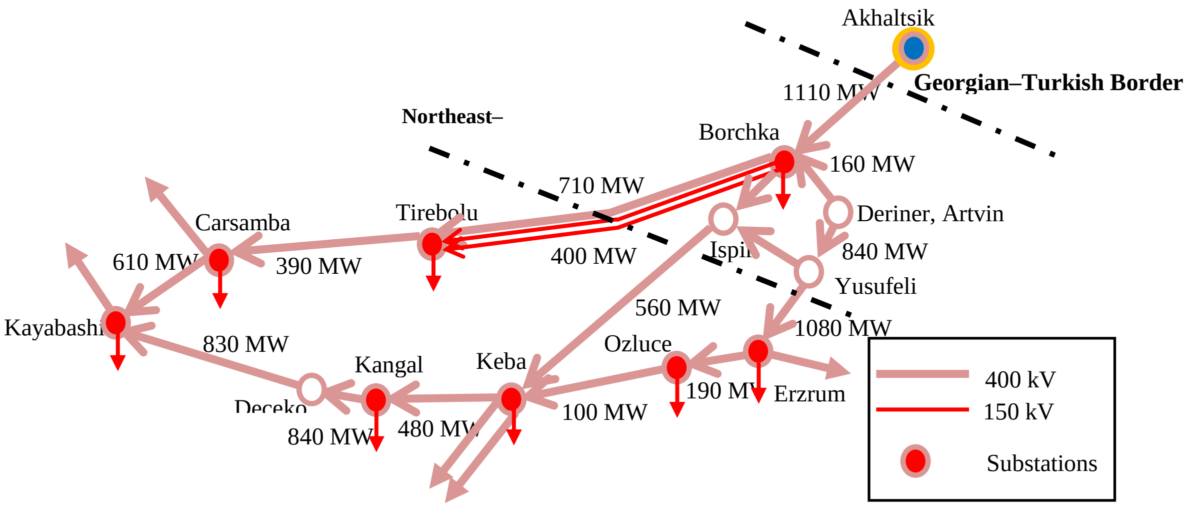
Normal scheme

Export potential from Georgia is up to 1110 MW. The transfer capacity margin of the Turkish power system via the northeast-center is 2750 MW (Fig. 2.6), including 1110 MW in the direction Borchka-Tirebolu (400 kV+154 kV lines), 560 MW in the direction Ispir-Keban (400 kV) and 1080 MW in the direction Yusufeli-Erzrum (via 400 kV).

Under conditions of maximal loading of Borchka, Muratli, Deriner, Artvin and Yusufeli HPPs, the long-term allowable flow will be 2200 MW. Thus, the export from Georgia to Turkey through B2B converter under normal operation scheme can be no more that 560 MW.

Fig. 2.6. The limit of transmission capacity (steady-state stability) of Northeast-Center transmission interface. Normal scheme 2017-2022.

.

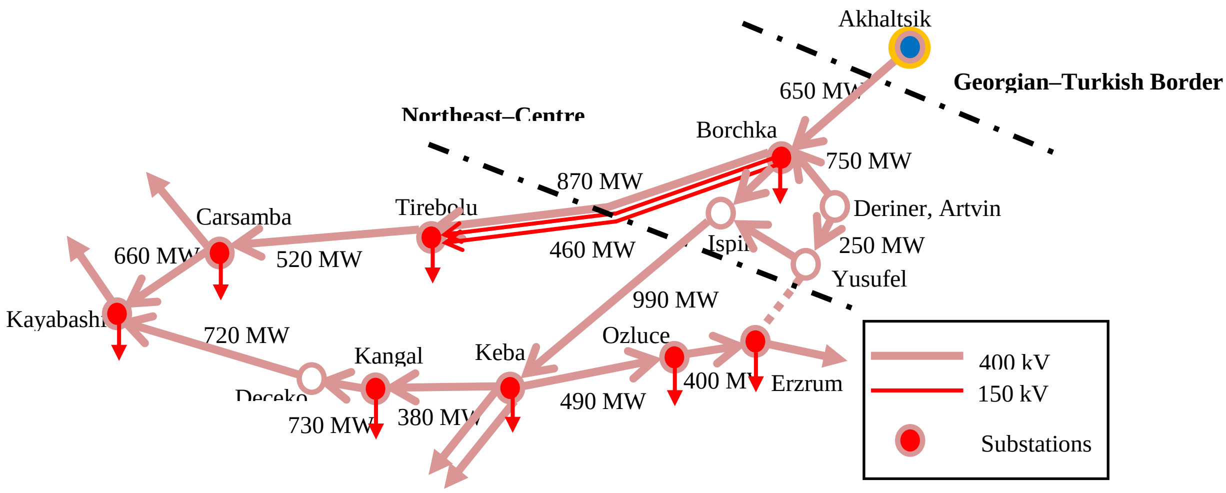


Transmission line Yusufeli-Erzrum 400 kV is tripped

The maximum export from Georgia is 650 MW. The transfer capacity margin of the Turkish power system via the northeast-center transmission interface is 2320 MW (Fig.2.7), including 1330 MW in the direction Borchka-Tirebolu (400 kV + 154 kV lines) and 990 MW in the direction Ispir-Keban (via 400 kV).

The short-term allowable power flow via the Turkish transmission interface is 2135 MW and the long-term flow is 1860 MW. Georgia is able to export 465 MW for a short-term period and 190 MW for a long-term period.

Fig. 2.7. The limit oftransmission capacity (steady-state stability) of Northeast-Centertransmission interface. 400kV line Yusufeli-Erzrum is tripped (2017-2022).



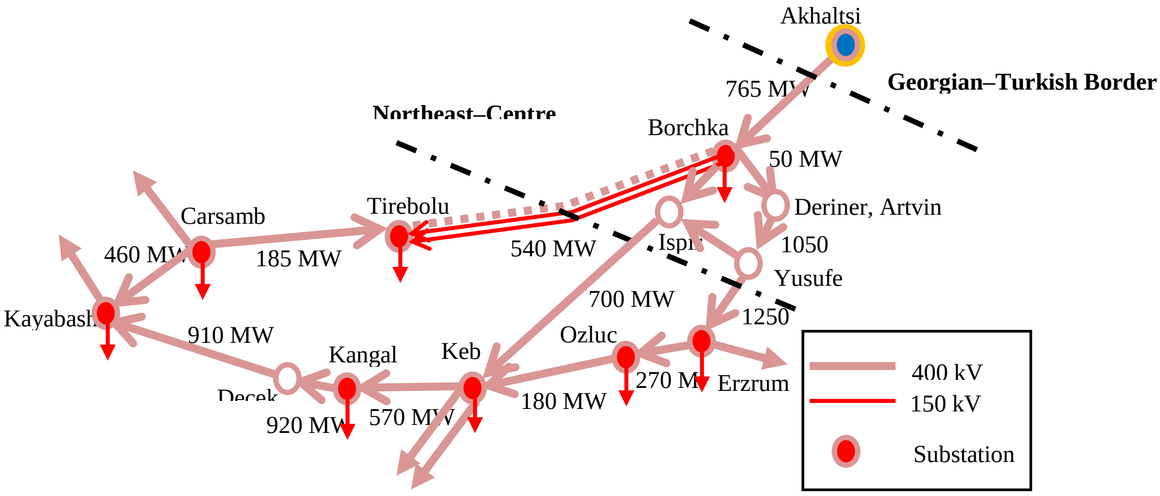
Transmission line Borchka-Tirebolu 400 kV is tripped (2017-2022)

The maximum export from Georgia is 765 MW. The transfer capacity margin of the Turkish power system via the northeast-center is 2490 MW (Fig. 2.8), including 540 MW

in the direction Borchka-Tirebolu (150 kV), 700 MW in the direction of Ispir-Keban (400 kV) and 1250 MW in the direction Yusufeli-Erzrum (via 400 kV).

The short-term allowable power flow via the Turkish transmission interface is 2290 MW and the long-term flow is 1990 MW. Georgia is able to export 565 MW for a short-term period and 265 MW for a long-term period.

Fig. 2.8. The limit of transmission capacity (steady-state stability) of Northeast-Centre transmission interface. 400kV line Borchka-Tirebolu is tripped (2017-2022).



Transmission line Ispir-Keban 400 kV is tripped

The maximum export from Georgia is 800 MW.

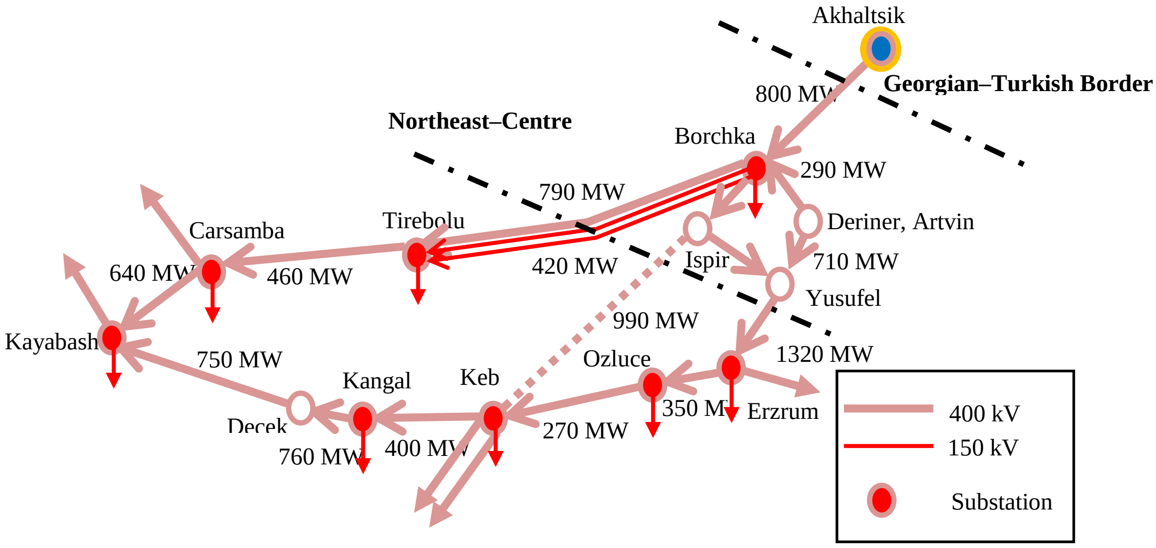
The transfer capacity margin of the Turkish power system via the northeast-center is 2530 MW (Fig. 2.9), including 1210 MW in the direction Borchka-Tirebolu (400+150 kV), and 1320 MW in the direction Yusufeli-Erzrum (via 400 kV).

The short-term allowable power flow via the Turkish transmission interface is 2330 MW and the long-term flow is 2030 MW. Georgia is able to export 600 MW for a short-term period and 300 MW for a long-term period.

The hardest case out of the above described cases is option 2, which is chosen as a base option for assessment of acceptability pursuant to the ENTSO-E requirements, according to which the allowable power flow from Georgia will be 420 MW.

Fig. 2.9. The limit of transmission capacity (steady-state stability) of Northeast-Centre transmission interface. 400kV line Ispir-Keban is tripped (2017-2022).

.



Conclusions for the period 2017-2022

Analyzing the options for years 2017-2022 one can conclude that without use of anti-emergency automation the long-term export from Georgia to Turkey would be no more than 460 MW, where as under emergency disconnection of 400 kV Yusufel-Erzrum line (the worst case), the System Operator will have to restrict the export to 190 MW for 20 minutes.

According to the ENTSO-E requirements the allowable power flow will be 420 MW.

Thus, to export through B2B converter the scheduled power flow of 650-1000 MW (2017-2022) it is necessary to additionally upgrade the connection on the northeast-center transmission interface of the Turkish power system. Otherwise, under maximal loading of HPPs of Turkey export will be limited to 560 MW and application of appropriate anti-emergency automation will be needed.

The calculation results are provided in Table 2.1.

Table 2.1. Calculation of Transfer Capability Georgia-Turkey (2013-2022)

				Former Soviet Standards		ENTSO-E requirements
Number of 400 kV lines in transmission interface	Option (scheme)	Maximal flow in Turkey MW	Maximal flow from Georgia MW	Short –term allowable export from Georgia MW	Long-term allowable export from Georgia MW	Allowable export from Georgia, MW
2	Normal	2030	1030		655	270
2	400kV line Deriner-Erzrum tripped	1220	390	290	150	
2	400kV line Borchka-Tirebolu tripped	1390	500	390	220	
3	Normal	2750	1110		560	420
3	400kV line Yusufeli-Erzrum tripped	2320	650	465	190	
3	400kV line Borchka-Tirebolu tripped	2490	765	565	265	
3	400kV line Ispir-Keban tripped	2530	800	600	300	

4.4 Strengthening of the transmission interface Georgia-Turkey

Currently Georgia is reviewing the issue of construction of the second line 400 kV from Akhaltsikhe to Turkey.

Below is provided the analysis of the necessity and possible options of that interconnection line.

Obviously, the second line will considerably increase the reliability of supply and at the same time will increase costs of transmission, which is not desirable fro new HPPs of Georgia.

The analysis will address the scheduled power flow of 650 MW, since if supply is increased up to 1000 MW, this issue will have to be solved together with capacity increase of the B2B converter up to 1050 MW, given availability of the abovementioned limitations inside Turkey.

Let’s evaluate the effect of the second line on the volume of power flows. The most discussed option is the line Akhaltsikhe-Tortum.

Tortum is located at a distance of 100 km from Erzrum to the Deriner HPP (Fig. 2.10).

As it is shown above, at a normal scheme of operation in case of two lines of 400 kV of the internal transmission interface of Turkey, the hardest case in terms of the necessity to reduce power flow from Georgia, appears to be the case with disconnection of the line Deriner-Erzrum. With availability of the line Akhaltsikhe-Tortum liberalization of this requirement is possible only in case of disconnecting the section Deriner-Tortum, which is about 70 km (40 % of the length of the line Deriner-Erzrum).

With disconnection of Erzrum-Tortum results differ by about 80 MW compared to the case without the Akhaltsikhe-Tortum line (Table 2.1 and Table 2.2).

Table.2.2. Calculation of Transfer Capability Georgia-Turkey with 400 kV lines Akhaltsikhe–Borchka and Akhaltsikhe–Tortum

According to [1,3] assuming the number of disconnections as 0.4 per 100 km per year we have the annual number of disconnections of 0.4 resulting in limitation of the

Georgian export with availability of the new line as compared to 0.68 in case without the line.

If we take into consideration that phase-by-phase disconnection of the line is possible, then it could be stated that the impact of disconnection on limitation of the Georgian export is small.

We come to nearly the same conclusions in case of constructing the third line 400 kV in Turkey with a simultaneous commissioning of the Yusufeli and Artvin HPPs.

				Former Soviet Standards		ENTSO-E requirements
Number of 400 kV lines Georgia-Turkey	Option (scheme)	Maximal flow in Turkey MW	Maximal flow from Georgia MW	Short -term allowable export from Georgia MW	Long-term allowable export from Georgia MW	
2	400kV line Deriner -Tortum tripped	1670	800	665	465	355
1	400kV line Tortum -Erzrum tripped	1315	490	385	225	

Thus, **construction of 400 kV line Akhaltsikhe-Tortum results in inconsiderable reduction of the limitation for the Georgian export**, although it, undoubtedly, improves the reliability of deliveries.

However, from the Turkey's perspective such a line worsens conditions of capacity transfer from the Deriner HPP (later from the Yusufeli and Artvin HPPs) to the center of Turkey.

The **most beneficial option both for Turkey and Georgia is construction of 400 kV line Akhaltsikhe-Erzrum** (Fig. 2.11a), which will allow liberalization at the key transmission interface Deriner-Erzrum both for the Georgian export and for generation from new large HPPs of Turkey (operation for the expanded network and availability of domestic load).

The calculation results demonstrating significant increase of the power flow are provided in Table 2.3.

Table.2.3. Calculation of Transfer Capability Georgia-Turkey with 400 kV lines Akhaltsikhe–Borchka and Akhaltsikhe–Erzrum

This line would be 100 km longer and more expensive. The question is who is going to finance this line. Without Georgia's participation, Turkey will hardly start it. Participation of the Georgian party will result in additional growth of transmission tariff for the Georgian exporters to Turkey, having a negative effect on potential investors of new HPPs of Georgia.

Probably the best solution could be substitution of the line Akhaltsikhe-Borchka, which is already in the process of construction, by the line Akhaltsikhe-Erzrum (Fig. 2.11b) and application of phase-by-phase disconnection in case of one-phase short circuits.

				Former Soviet Standards		ENTSO-E requirements
Number of 400 kV lines Georgia-Turkey	Option (scheme)	Maximal flow in Turkey MW	Maximal flow from Georgia MW	Short -term allowable export from Georgia MW	Long-term allowable export from Georgia MW	
2	400kV line Deriner - Erzrum tripped	1690	830	695	490	660

This option will twice increase the allowable power flow from Georgia compared to the implemented construction of the Akhaltsikhe-Borchka; at the same time this power flow will be less just by 120 MW than in the case of constructing two lines (Table 2.2.-2.4).

Table.2.4. Calculation of Transfer Capability Georgia-Turkey with 400 kV line Akhaltsikhe–Erzrum

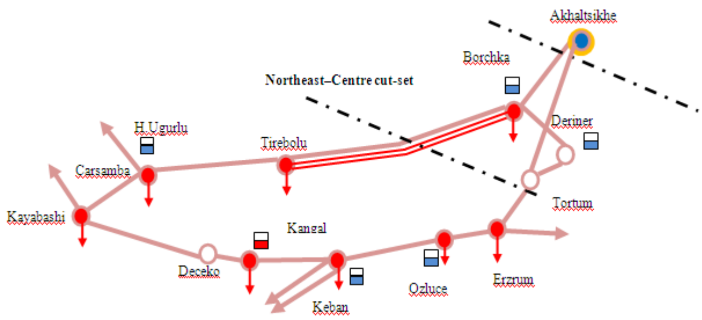
				Former Soviet Standards		ENTSO-E requirements
Number of 400 kV lines Georgia-Turkey	Option (scheme)	Maximal flow in Turkey MW	Maximal flow from Georgia MW	Short -term allowable export from Georgia MW	Long-term allowable export from Georgia MW	
1	400kV line Deriner -Erzrum tripped	1505	540	540	540	540

Such a solution would increase costs of on-going project realization of interconnection Georgia-Turkey; however, in general, construction of the second line Georgia-Turkey would be cheaper.

The carried out analysis could not be considered a comprehensive one; a separate investigation of this issue is required.

Fig. 2.10. Second line Georgia-Turkey

a)



b)

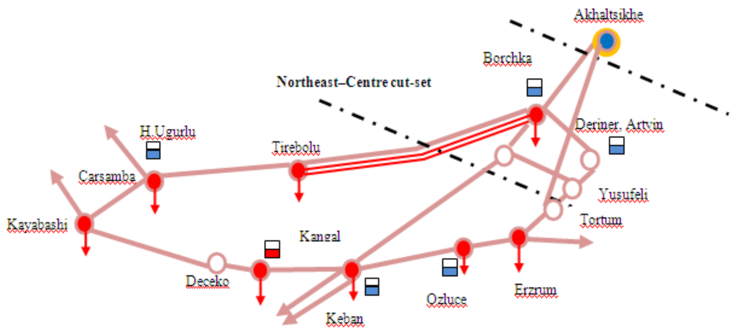
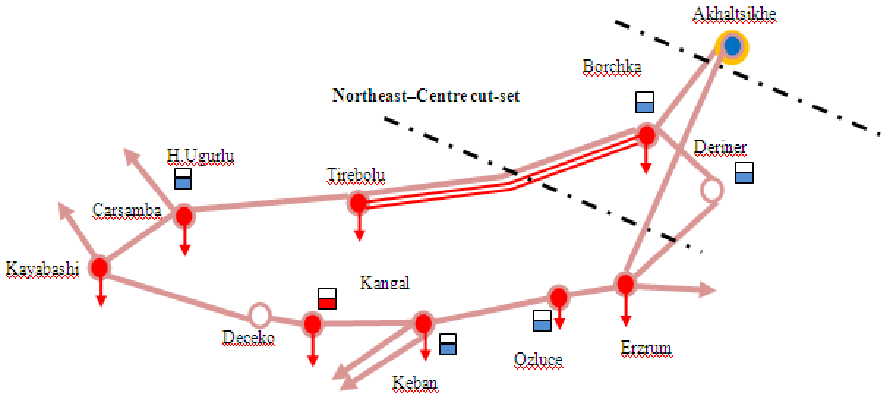
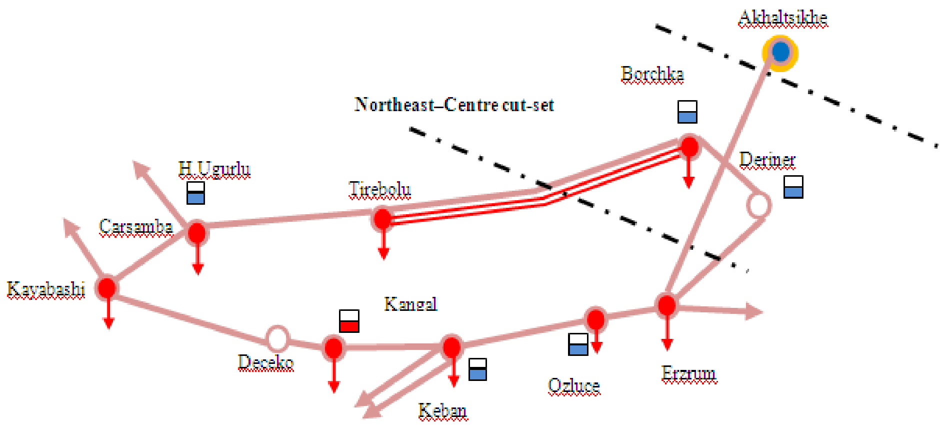


Fig. 2.11. Alternative options for strengthening of the transmission interface Georgia-Turkey

a)



b)

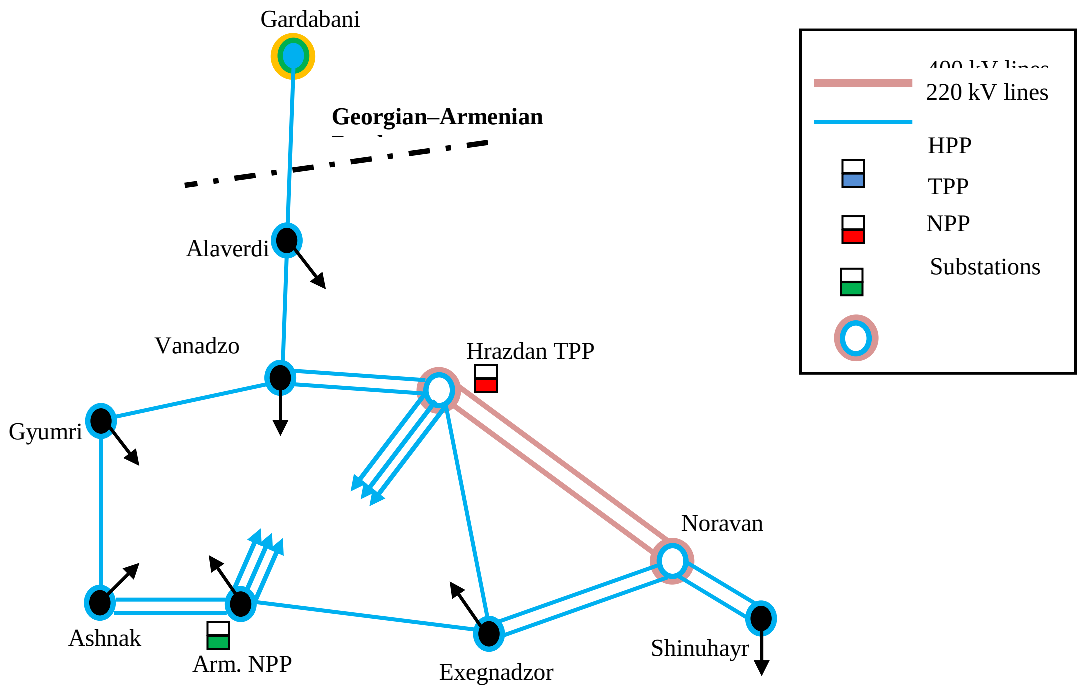


4.5 Analysis of Regimes and Transfer Capabilities of Transmission Interfaces Georgia-Armenia and Georgia-Armenia-Iran for the Period of 2013-2022

Calculations conditions

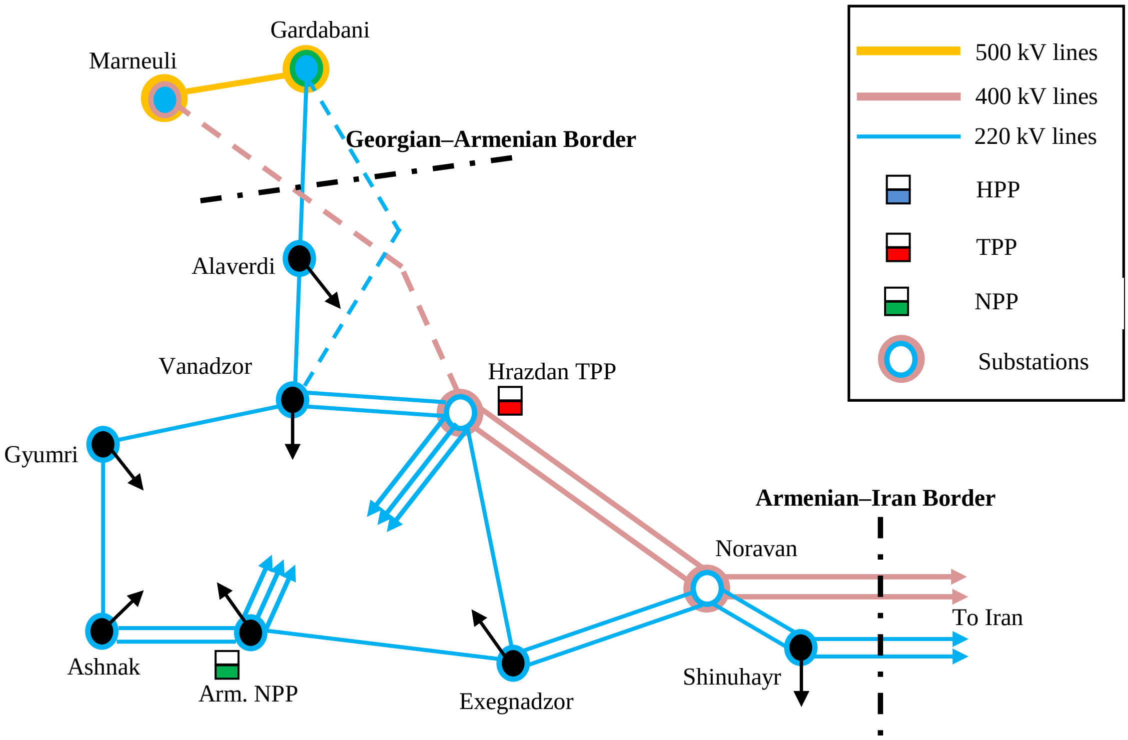
1. Summer regimes are taken as base regimes, considering that the maximal demand in Iran is observed in summer, and summer is a favorable season for Armenia to import electricity from Georgia.
2. In options under consideration, within the period 2017-2022, either the Armenian NPP will be shut-down and an equivalent capacity power plant will replace it, or operation of the existing nuclear plant will continue. The option of replacing the existing NPP by a new NPP of 1000 MW (according to the program of the RoA Ministry of Energy and Natural Resources) is considered in the Chapter 3. It is worth mentioning that appearing of such a plant within the given period is hardly probable, however, if that plant appears, it will practically minimize the possibility of export of the Georgian power to Armenia (Iran).
3. Two scenarios are envisaged:
   - ✓ Scenario 1 – the Georgian power system operates synchronously with the Armenian power system, which is isolated from the Iranian power system;
   - ✓ Scenario 2 – the Georgian power system is connected to the Armenian power system via B2B converter, whereas the Armenian system operates synchronously with Iran.
4. Under Scenario 1 the transmission interface Georgia-Armenia is presented by 220 kV transmission line from Gardabani substation of 500/330/220/110 kV to Alaverdi substation of 220/110/35 kV (Fig. 2.12).

Fig. 2.12. Georgia-Armenia interconnection. Existing scheme.



5. Under Scenario 2 the transmission interface Georgia-Armenia-Iran is presented by 220 kV transmission line from Gardabani substation of 500/330/220/110 kV with the B2B converter to Alaverdi substation of 220/110/35 kV (upgrading of the interface Georgia-Armenia is also provided for either by means of one more line of 220 kV from Gardabani substation of 500/330/220/110 kV to Vanadzor substation of 220/110/35 kV, or by means of 400 kV transmission line from Marneuli substation of 500/400/220/ kV to Hrazdan substation of 400/220 kV, and then connection with Iran is presented by two 400 kV transmission lines (Noravan-Kheris-Julfa) and two lines of 220 kV (Shinuhayr-Agarak-Agar)(Fig. 2.13).

Fig. 2.13. Georgia-Armenia-Iran interconnection. Different options.



6. Both the standards a) of the former Soviet Republics (Georgia, Azerbaijan, Armenia and Russia) being still used therein to calculate the static stability margin of 20 % for long-term allowable flows and a margin of 8% for short-term allowable flows in post-fault regimes, and b) the ENTSO-E requirements, will be used in calculations.

Calculation results

Scenario 1. The Armenian power system is disconnected from the Iranian system and operates synchronously with Georgia

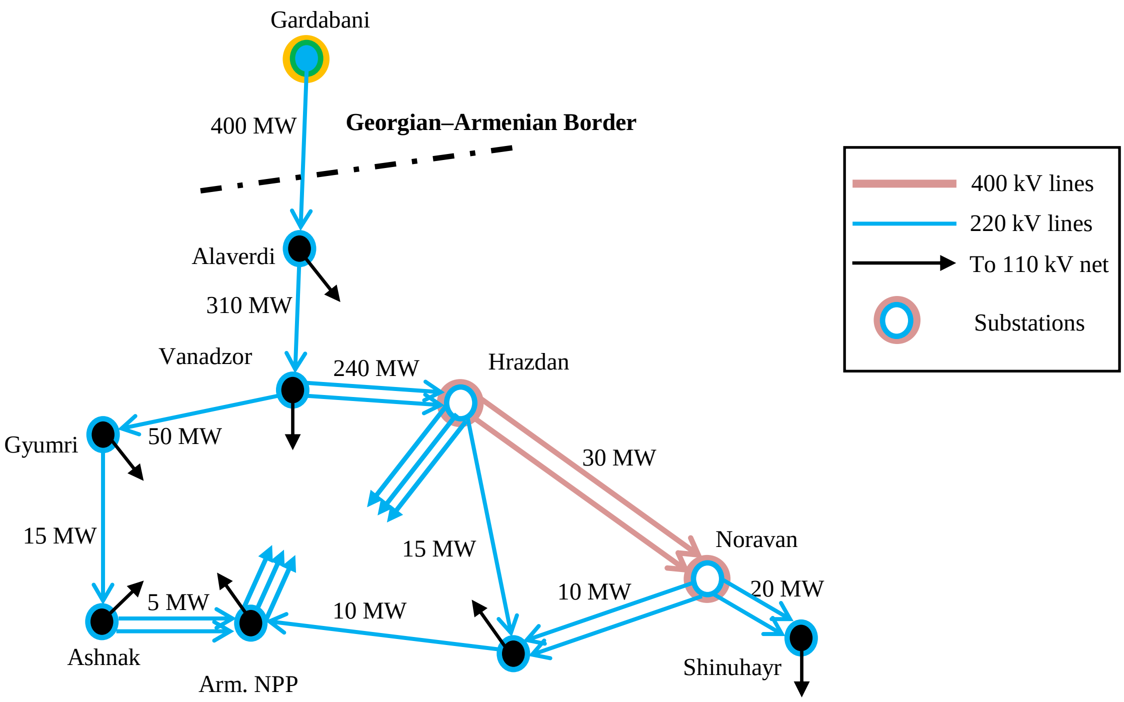
The calculations are given for the case when thermal power plants of Armenia are switched off, because only in that situation Armenia, while operating in the isolated from Iran regime, will be able to import significant volumes of power from Georgia.

Normal scheme

The transfer capacity margin by static stability at the interface Georgia-Armenia is 400 MW (Fig.2.14). Based on the requirement of static stability, under the normal scheme of operation via 220 kV transmission line of Gardabani-Alaverdi the possible long-term export makes up to 400*0.8=320 MW and the short-term export under the post-fault regime makes up to 400*0.92=370 MW.

Based on the ENTSO-E requirements, the allowable flow is 330 MW.

Fig. 2.14. The limit oftransmission capacity (steady-state stability) of Georgia-Armenia transmission interface.Normal scheme (Scenario 1).



Taking into consideration that the transmission line of 220 kV has a cross-section of 300 mm^2 and that summer regimes are being analyzed (high temperature both in Georgia and in Armenia), we need to define the thermal stability for these conditions. In these conditions, the maximum rating would be about 250 MVA, therefore 220 MW will be accepted as a margin.

The following emergency regimes are considered:

- ✓ Disconnection of 220 kV Vanadzor-Gyumri transmission line, or one out of two 220 kV lines of Vanadzor-Hrazdan;
- ✓ Disconnection of both 220 kV lines of Vanadzor-Hrazdan (Double-circuits line).

Calculation results are provided in Table 2.5.

Table 2.5 Calculation results for Georgia Armenia Transfer Capability

			Former Soviet standards		ENTSO-E requirements	
Cross-section Georgia-Armenia	Option (scheme)	Maximal flow from Georgia to Armenia MW	Short -term allowable export from Georgia to Armenia MW	Long-term allowable export from Georgia to Armenia MW	Allowable export from Georgia to Armenia MW	Thermal stability in summer MW
220kV line Gardabani-Alaverdi	Normal	400	-	320	330	220
	Off 220kV line Vanadzor-Gyumri or Vanadzor-Hrazdan	390	360	310		
	Off 2x220kV line Vanadzor-Hrazdan	370	340	295		

It is obvious that the key limitation here is thermal stability. Upgrading the interface by means of, for example, construction of a new 220 kV line of Gardabani-Vanadzor, it is possible to increase the transfer capability up to 400 MW, but for that we need to have increased demand in import of summer power by Armenia (this is discussed in Chapter 3). If such a demand appears, then the transmission interface will need to be upgraded from the viewpoint of economic power flow, otherwise, the necessity of upgrade will be justified only in terms of ensuring reliability.

In this respect, at this stage, the issue of upgrading the given transmission interface will be discussed below while analyzing scenario 2 - when Iran appears.

Scenario 2.1 .The Armenian power system operates synchronously with Iran and through B2B converter with Georgia via the existing 220 kV line of Gardabani-Alaverdi

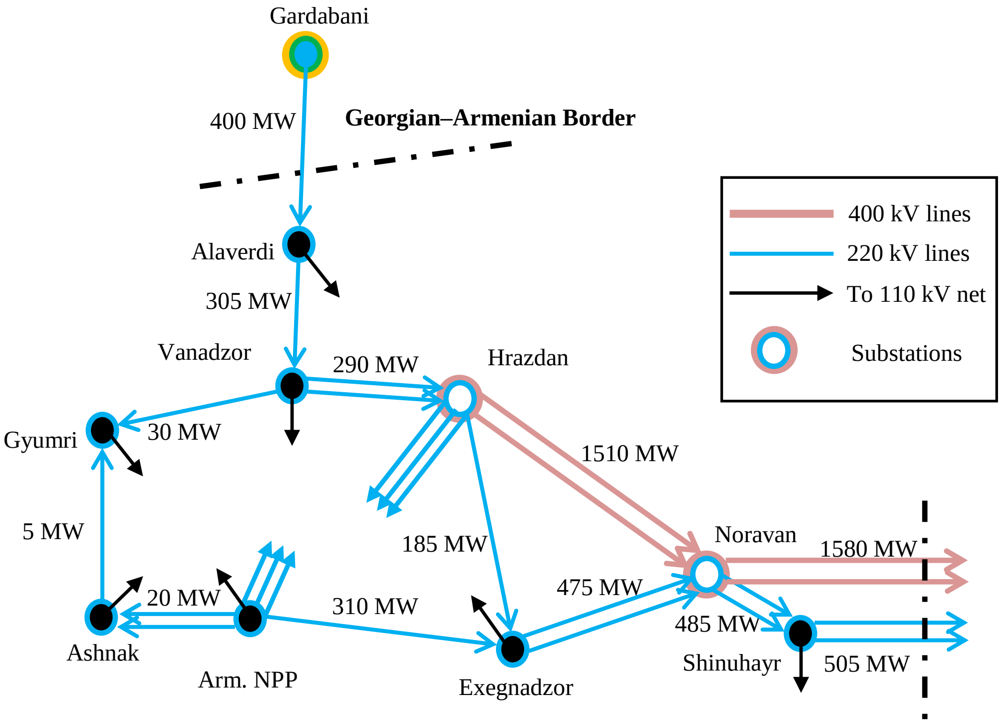
The calculations are done for cases with fully loaded Hrazdan TPP (new unit) and Yerevan TPP in Armenia. It should be noted that the export potential of the Armenian power system in summer regimes for the period from 2013 to 2022 will not exceed 700 MW.

All the following calculations provide for availability of B2b converter on Gardabani substation.

Normal scheme

The maximum long-term export from Georgia through B2B converter is 400 MW, whereas the transfer capacity margin through the transmission interface Armenia-Iran is 2085 MW (Fig.2.15), including 1580 MW via 400 kV interconnection lines and 505 MW - via 220 kV lines.

Fig. 2.15. The limit of transmission capacity (steady-state stability) of Georgia-Armenia transmission interface. Normal scheme (Scenario 2.1).



Obviously, the transfer capability at the transmission interface Georgia-Armenia will be limited by the thermal stability of 220 kV transmission line of Gardabani-Alaverdi (in summer up to 220 MW).

The following regimes are considered **as emergency regimes**:

- ✓ Disconnection of 400 kV line Noravan-Kheris
- ✓ Disconnection of both 220 kV lines Vanadzor-Hrazdan.

Calculation results are presented in Table 2.6.

Table 2.6.Calcution results – Georgia- Armenia with B2B substation

Cross-section Georgia-Armenia	Option (scheme)	Maximal flow from Georgia to Armenia MW	Maximal flow to Iran MW	Allowable export to Iran (former Soviet standards) MW	Allowable export to Iran (ENTSO-E requirements) MW	Available transmission capacity of transmission interface Armenia-Iran (Armenian export 700MW) MW	Long-term allowable export from Georgia to Armenia MW
1	2	3	4	5	6	7 (col.5-700MW)	8
220kV line Gardabani-Alaverdi	Normal	400	2085	1620	1485	920	220
	Off 400kV line Noravan-Heris	400	1705	1320		620	
	Off 2x220kV line Vanadzor-Hrazdan	300	2060	1610		910	

Given the fact that in summer regimes the export potential of Armenia will not exceed 700 MW and the transfer capability of the Armenia-Iran transmission interface is no more than 1320 MW, the Armenia-Iran transmission interface will allow exporting approximately 600 MW from Georgia to Iran. Under the normal scheme it is possible to transfer up to 300 MW of long-term power flow at a sufficient stability margin through the existing transmission interface from Georgia to Armenia by means of an appropriate B2B converter without using anti-emergency automation. Whereas the thermal stability of 220 kV line Gardabani-Alaverdi in summer will allow transferring only up to 220 MW as a long-term flow.

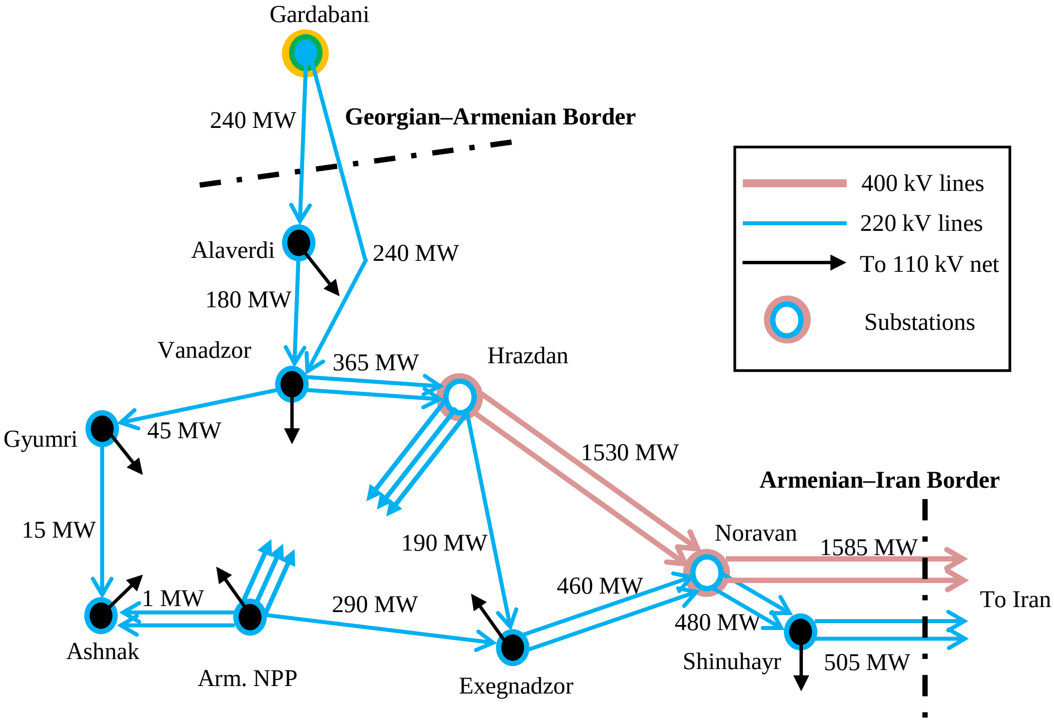
Scenario 2.2. The Armenian power system operates synchronously with Iran and through B2B converter with Georgia via 220 kV Gardabani-Vanadzor and Gardabani-Alaverdi transmission lines

The export potential of Georgia in the direction of Armenia and Iran will be higher than the transfer capability of the transmission interface Georgia-Armenia (the Iranian direction is disconnected). Upgrade of the transmission interface Georgia-Armenia is possible only by means of constructing a new line between Georgia and Armenia. Either a second line of 220 kV Gardabani-Vanadzor, or a new 400 kV line Marneuli-Hrazdan may serve for that purpose. The analysis of regimes and transfer capabilities of Georgia-Armenia and Armenia-Iran transmission interfaces under various options of upgrading is given below.

Normal scheme

It is possible to have a long-term export of up to 480 MW from Georgia through B2B converter, where as the transfer capacity margin at the Armenia-Iran transmission interface is 2090 MW (Fig.2.16), including 1585 via 400 kV ties and 505 MW via 220 kV ties.

Fig. 2.16. The limit of transmission capacity (steady-state stability) of Georgia-Armenia transmission interface.Normal scheme (Scenario 2.2).



Therefore, the transfer capability of the Georgia-Armenia interface will be limited by the thermal stability of 220 kV transmission lines of Gardabani-Alaverdi and Gardabani-Vanadzor (in summer up to 500 MW), and the transfer capability of the Armenia-Iran transmission interface will be 2090*0.8-40=1620 MW.

The following regimes are considered **as emergency regimes**:

- ✓ Disconnection of 400 kV Noravan-Kheris transmission lines;
- ✓ Disconnection of both 220 kV Vanadzor-Hrazdan transmission lines;
- ✓ Disconnection of 220 kV Gardabani-Vanadzor transmission line.

Calculation results are presented in Table 2.7.

Table 2.7 Calculation results, Georgia-Armenia Transfer Capability with B2B

Cross-section Georgia-Armenia	Option (scheme)	Maximal flow from Georgia to Armenia MW	Maximal flow to Iran MW	Allowable export to Iran (former Soviet standards) MW	Allowable export to Iran (ENTSO-E requirements) MW	Available transmission capacity of transmission interface Armenia-Iran (Armenian export 700MW) MW	Long-term allowable export from Georgia to Armenia MW
1	2	3	4	5	6	7 (col.5-700MW)	8
220kV lines Gardabani-Alaverdi+ Gardabani-Vanadzor	Normal	480	2090	1620	1500	920	440
	Off 400kV line Noravan-Heris	480	1670	1495		595	
	Off 2x220kV line Vanadzor -Hrazdan	400	2070	1615		915	
	Off 220kV line Gardabani-Vanadzor	400	1880	1620		920	

With availability of two 220 kV lines of Gardabani-Alavedi and Gardabani-Vanadzor under normal scheme of operation it is possible to export from Georgia to Armenia through B2B converter up to 400 MW with a sufficient stability margin without application of anti-emergency automation.

As far as the transfer capability of the Armenia-Iran transmission interface is not less than 1295 MW, then this transmission interface allows in principle exporting almost 600 MW from Georgia to Iran.

Scenario 2.3. The Armenian power system operates synchronously with Iran and through B2B converter with Georgia via 400 kV Marneuli-Hrazdan transmission line, whereas the Gardabani-Alavedi line of 220 kV is disconnected.

Normal scheme

It is possible to have a long-term export of up to 560 MW from Georgia through B2B converter, whereas the transfer capacity margin at the Armenia-Iran transmission interface is 2235 MW (Fig.2.17), including 1685 via 400 kV ties and 550 MW via 220 kV ties. Therefore, the transfer capability of the Georgia-Armenia transmission interface will be 560 MW, and the transfer capability of the Armenia-Iran transmission interface will be 2235*0.8-40=1750 MW. Disconnection of 400 kV Noravan-Kheris is considered as an emergency regime.

Calculation results are presented in Table 2.8.

Fig. 2.17. The limit of transmission capacity (steady-state stability) of Georgia-Armenia transmission interface.Normal scheme (Scenario 2.3).

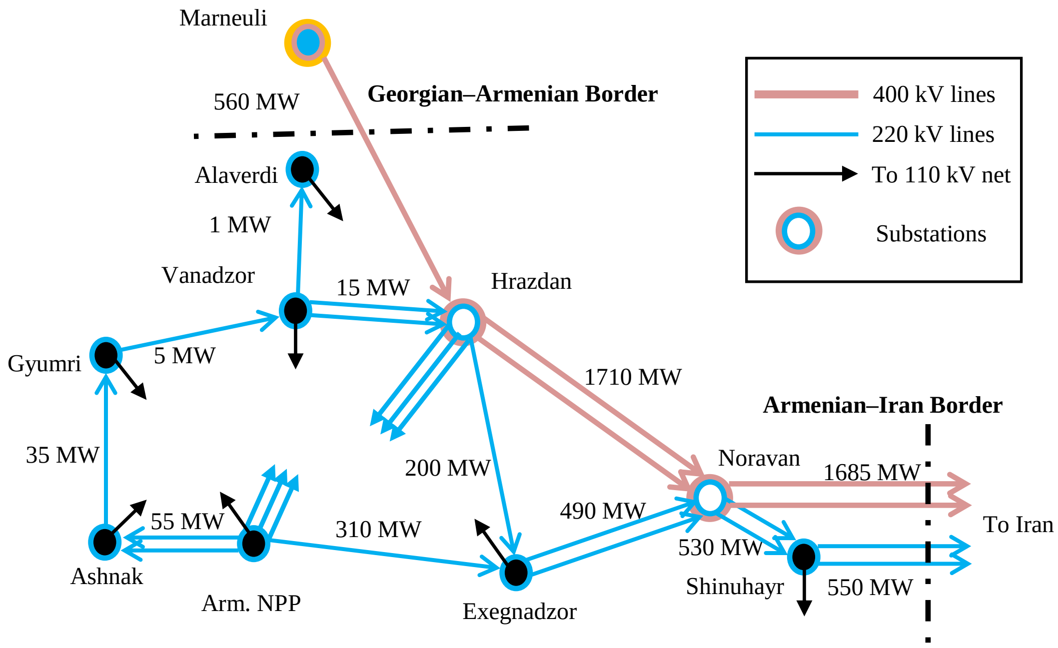


Table 2.8. Transfer Capability, Georgia- Armenia, 400 kV connection and B2B S/S

Cross-section Georgia-Armenia	Option (scheme)	Maximal flow from Georgia to Armenia MW	Maximal flow to Iran MW	Allowable export to Iran (former Soviet standards) MW	Allowable export to Iran (ENTSO-E requirements) MW	Available transmission capacity of transmission interface Armenia-Iran (Armenian export 700MW) MW	Long-term allowable export from Georgia to Armenia MW
1	2	3	4	5	6	7 (col.5-700MW)	8
400 kV line Marneuli-Hrazdan	Normal	560	2235	1745	1580	1050	Capacity of B2B
	Off 400kV line Noravan-Heris	560	1760	1370		670	

With availability of 400 kV Marneuli-Hrazdan and with disconnected Gardabani-Alavedi220 kV line it will be possible to export from Georgia to Armenia through the B2B converter up to 560 MW with a sufficient stability margin and without application of anti-emergency automation.

As far as the transfer capability of the Armenia-Iran transmission interface is not less than 1370 MW, this transmission interface allows exporting up to 670 MW from Georgia to Iran.

5.0 POSSIBILITIES OF NEW HPPS OF GEORGIA TO ELECTRICITY SALES TO THE COUNTRIES OF THE REGION

The purpose of this Chapter is to define all possible options of export of power from the new HPPs of Georgia by seasons and day zones based on the following:

- Needs of the neighboring countries in import of power and their national power systems development programs;
- Prices that are forming on the wholesale markets of the neighboring countries and their dynamics;
- Ensuring availability of alternative directions of export;
- Ensuring competitiveness with the export from neighbor countries by export directions.

As a result, possible volumes of export by directions and their mutual influence and prices should be defined considering technical feasibility of regimes in conditions of minimizing new network construction, as well as the impact of the development of interconnection lines on decrease in prices of offers for export from new HPPs of Georgia should be assessed.

5.1 Possibilities of export from new HPPs of Georgia

It is obvious that the volumes of export from the new Georgian HPPs will directly depend on availability of capacity excess at the existing power plants, which is currently deviating in the large range subject to the season. Let's analyze the main factors that have an influence on that excess.

5.2 Domestic consumption

First of all, it is the level of domestic consumption.

Table 3.1 shows the comparative assessment of the consumption forecast provided by ECON [4] and based on actual data from ESCO.

Table 3.1 Domestic demand in Georgia

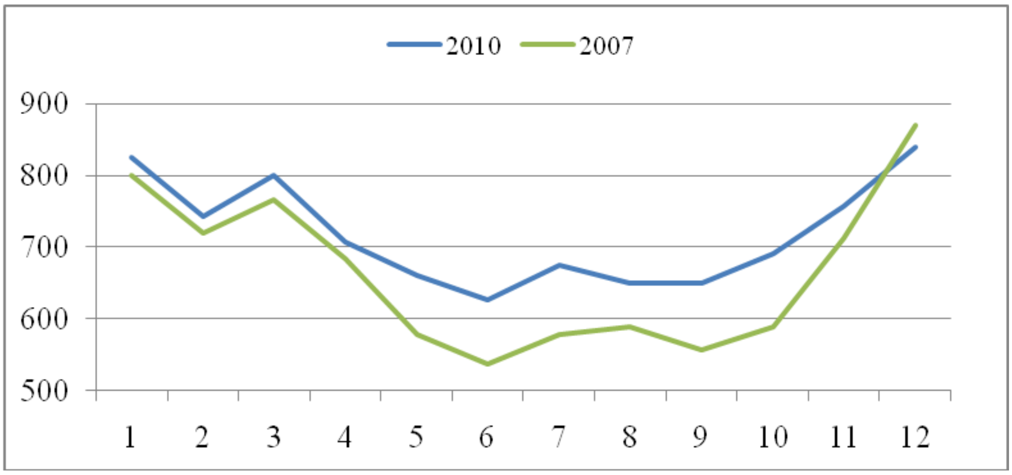
	ECON (2008 forecast)		ESCO
Year	Growth 3%	Growth 6%	Actual
2008	8504	8752	8074
2009	8759	9277	7642
2010	9022	9834	8441
2011	9293	10424	9256
2012	9572	11049	
2013	9859	11712	

At first sight the actual consumption growth for the period 2009-2011 is very high (10.4 and 9.7% annually), but this fact should not be considered as the dynamics for the future, since the global financial-economic crisis resulted in drastic reduction of consumption at the end of 2008 and 2009, after which the consumption growth is stipulated by rehabilitation and not by development of the economy.

To assess the excess of existing capacities in Georgia for the future it is necessary to apply a 3% growth rate at the most, all the more that forecast numbers and actual numbers (Table 3.1.) for the year 2011 coincide. In case of higher increase of consumption, the situation from the viewpoint of export possibilities of new HPPs will be more favorable.

If for several years there was a significant growth of summer consumption (April-September) compared to winter consumption (October-March) (Fig. 3.1), then for the last two years the relation of the summer to the winter volumes remained approximately on the level of 85%. This fact should also be considered while analyzing the export potential by seasons.

Fig. 3.1. Electricity consumption in Georgia by months inGWh



5.3 Generation

The generation potential in Georgia and, therefore, the exporting possibilities depend to a large extent on climatic conditions, namely on “surplus water” of the given year, considering that 85% of electricity on average is generated at hydro power plants. The two last years, which differ by their climatic conditions, are demonstrative in this regard. During the “high water” year 2010, the portion of HPPs in the generation structure made 93%, and the next year 2011 it made only 78%, whereas the difference in absolute values is 1482 GWh that negatively affected the export, which reduced from 1524 GWh in 2010 to 930 GWh in 2011(reduction by 39%).

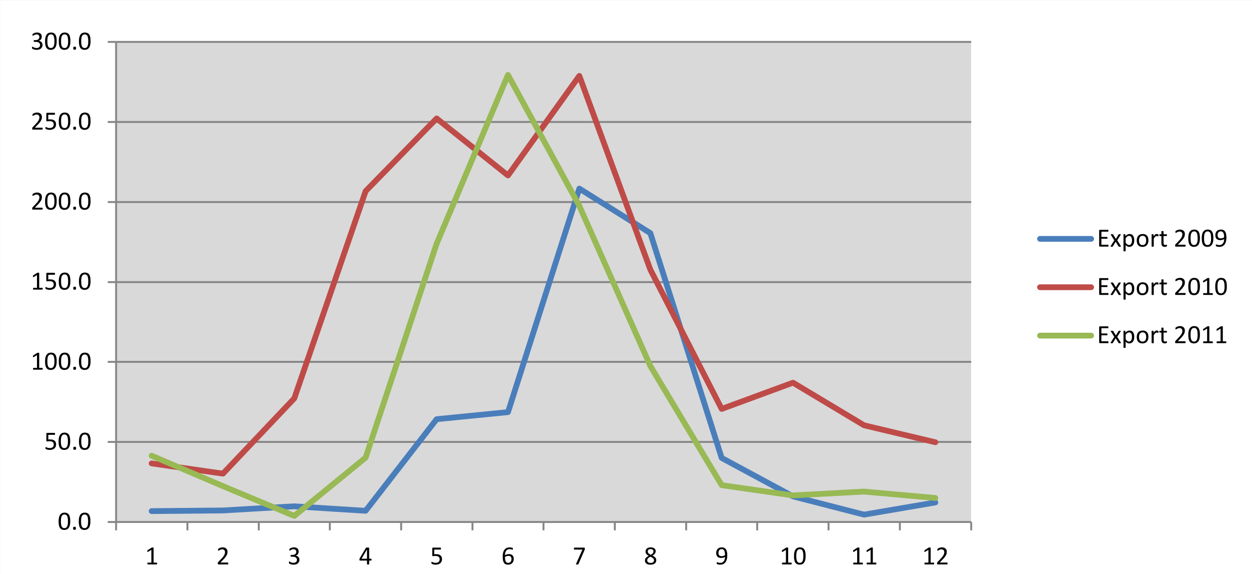
Currently, the export potential depends to a large extent on the generation output of Enguri and Vardinili HPPs, which in 2011 have generated 3846 GWh compared to 5033 GWh in 2010 (reduction by 23.6 %).

It should be mentioned that thermal power plants cannot delivery competitive electricity or export (they are used to cover only domestic consumption in winter time, while burning gas delivered from Azerbaijan at reduced price $143/tcm) due to necessity of using gas at commercial price.

5.4 3.1.3. Required export volumes and actual possibilities

Volumes of actual export for 2009-2011 are presented on Fig 3.2,where it

Fig. 3.2. Georgian export by months in GWh



is demonstrated that from September to March the monthly export is not significant (this is actually the export to Turkey implemented by the company EnergoPro via 220 kV Batumi-Khopa line in the volume of 70-75 MW).Thus, even considering only the scheduled power flow to Turkeythe new HPPs will not be restricted by internal competition in Georgia.

While analyzing the remaining period of time, when Georgia has considerable potential of export, quite interesting statistics of export appears for the last three years of 2009-2011.

These years are characterized by the following main factors:

- 2009 – a drastic reduction in consumption
- 2010 – high-water year
- 2011 – rehabilitation of economy and significant growth of consumption

Figures 3.3 and 3.4 present daily schedules of export by years for June and August.

Fig. 3.3.Georgian export hourly shapes in June in MW

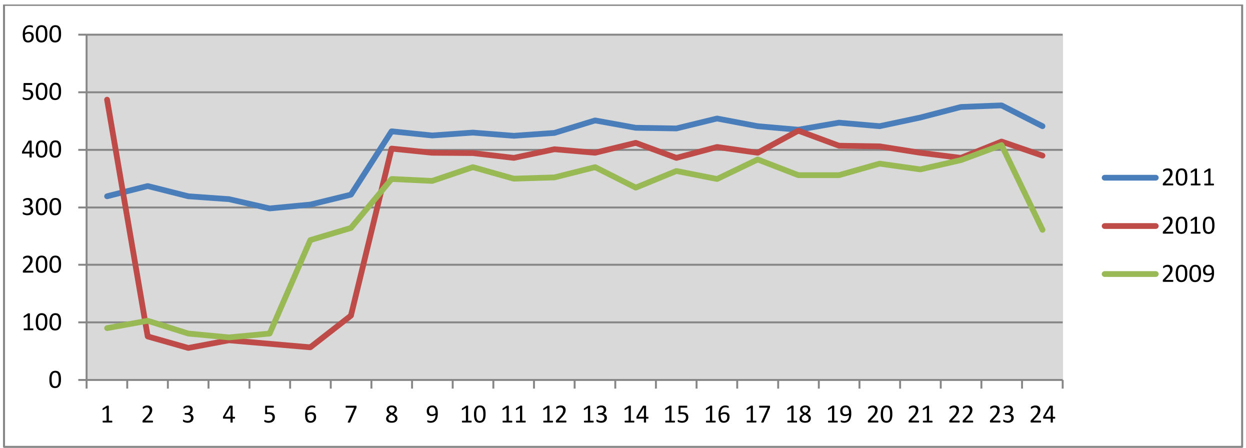
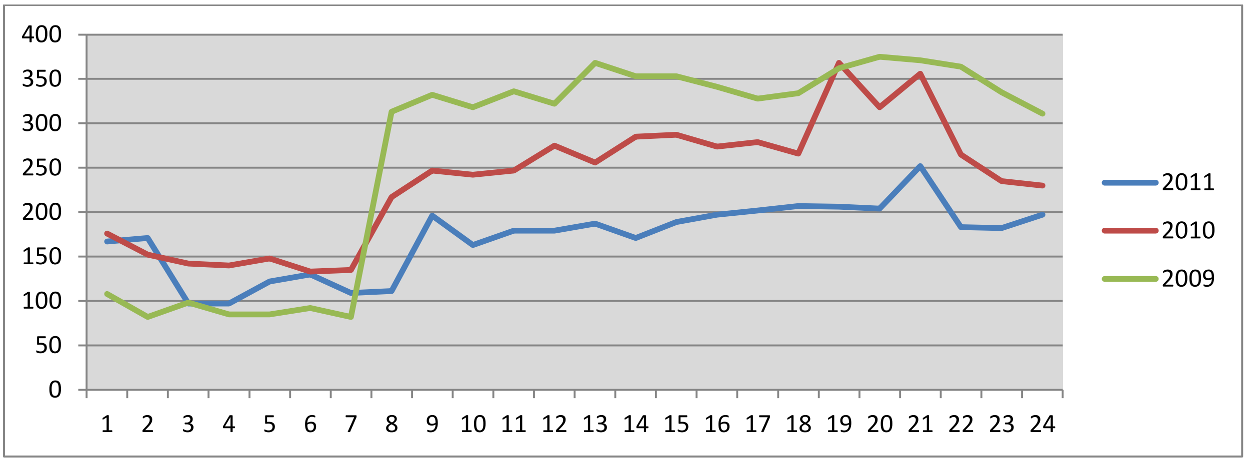


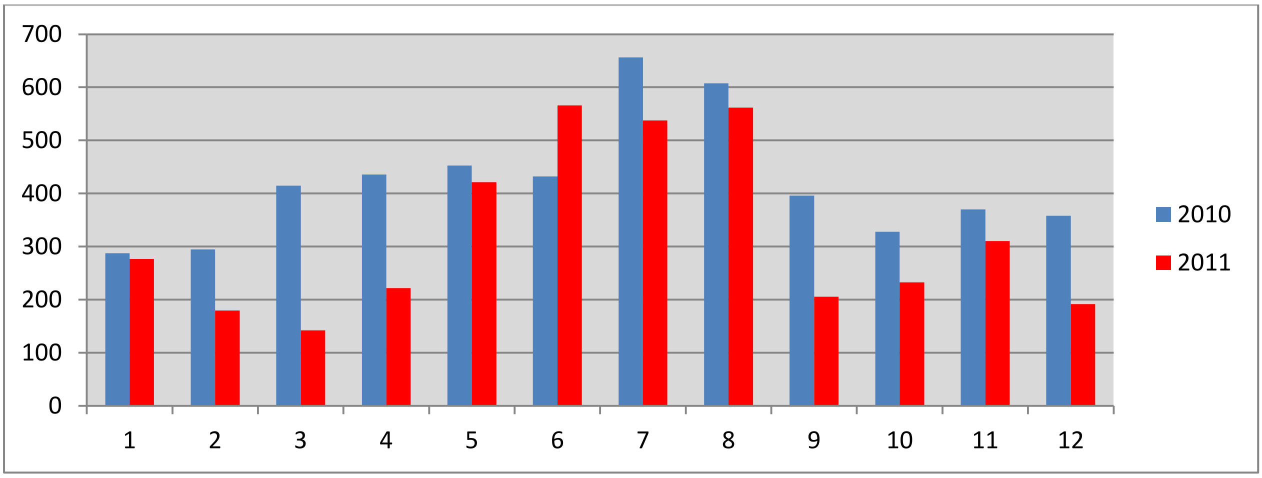
Fig. 3.4.Georgian export hourly shapes in August in MW



The maximum export in June was registered in 2011 and reached the level of 470 MW (Fig. 3.3.) and the maximum in August was registered in 2009 - 370 MW (Fig. 3.4.). The matter is that despite considerable reduction of generation output of Enguri and Vardinili HPPs in 2011 compared to 2010(fig. 3.5), it is uneven in the yearly profile. Thus, in June 2011 compared to 2010 there was a growth of generation by 31 % on these HPPs, and in August there was a reduction by 7.6%.

It is obvious that upon completion of construction of interconnection line with Turkey, even if export direction is totally re-oriented from the today's main direction, that is, Russia to Turkey (more favorable conditions), the potential of the existing power plants is not sufficient even in summer time, considering also growth of domestic consumption in Georgia.

Fig. 3.5.Monthly generation by Enguri + Vardinili HPPs in GWh



While analyzing the required export of Georgia, it should be noted that it comprises of up to 650 MW – to Turkey, up to 400 MW – to Russia, and plus the Armenian and the Iranian directions. Thus, from the viewpoint of demand of the neighboring countries, there is a big potential. The main requirement here is that the price and delivery conditions be applicable.

In the following paragraphs we well specify in details export possibilities of new Georgian power plants in all directions starting from the Turkish market that is accepted to be the most profitable one.

5.5 3.2. Impact of processes in Turkey on the Georgian export

Here is the analysis of factors that may influence the power flows from Georgia.

5.6 3.2.1. Development of the power system on the northeast part of Turkey

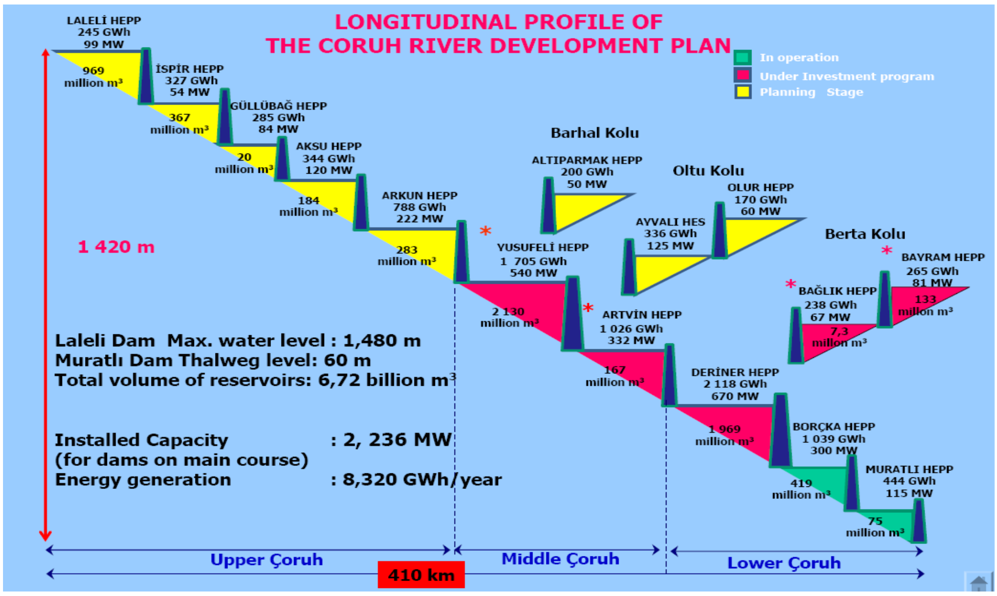
One of the attractive characteristics of the Turkish power market is the rather high consumption growth rate observed during the last years (up to 7.5% annually). In this regard, import of electricity together with the huge plans of developing generation capacities is also being a source to cover growing electricity demand.

Thus, for example, integration of the Turkish power system with Europe allows importing considerable amounts of energy. The agreement signed with Bulgaria provides for import of 4000 GWh per year (in 2010 Bulgaria has exported in total 7500 GWhat average price of €45/MWh, which is quite applicable price for the Turkish market).

However, there is a certain difference between the Bulgarian and Georgian export. Currently consumption growth forecast for Turkey has a tendency to a certain decrease [5,6], and there is a disproportion between growth rates in the western and central parts of the country (higher rate) and the eastern part (lower rate).

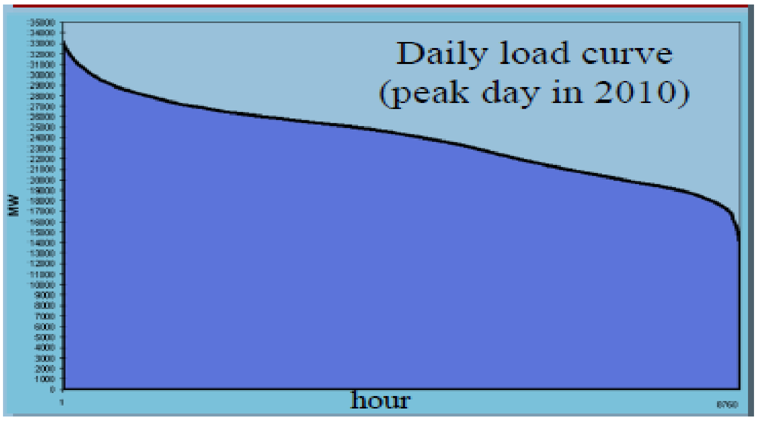
The main hydro potential of Turkey is concentrated in the eastern part of the country and its development will allow not only to cover the demand of that region (commissioning of the Deriner HPP will change the direction of the current flow, which is now from center to east, to opposite direction, see calculations of Chapter 2), but also to transfer power to the center of Turkey. They suppose to have a number of large HPPs on Coruh river, too [7] (Fig 3.6).

Fig 3.6. HPPs on Coruh River in Turkey



Despite the fact that new HPPs in Georgia will be of daily regulated type, it is not certain that power flow from Georgia will be required on a smooth delivery schedule, considering irregularity of the consumption patterns in Turkey. The relation of the maximum load to the minimum load is presented on Fig.3.7according to [6].

Fig. 3.7. Daily demand shape in Turkey



5.7 Prices on the wholesale electricity market of Turkey

In all earlier market research studies high prices on the wholesale market of Turkey are the main justification of advantageousness of the Georgian export to Turkey. The prices are really higher than in other countries of the region, however, the current tendencies do not allow for a definite estimate of the degree of attractiveness of export.

According to reports on the Turkish market [9] issued by Special Studies Group (established within the framework of the USAID-funded Hydropower Investment Promotion Project) the following was observed:

- Decrease of daily average prices on the market for the last two years (Fig.3.8);
- Big difference between the night-time prices and prices for other day zones (Fig. 3.9).

Fig.3.8. Daily average prices decreasing in Turkey [9]

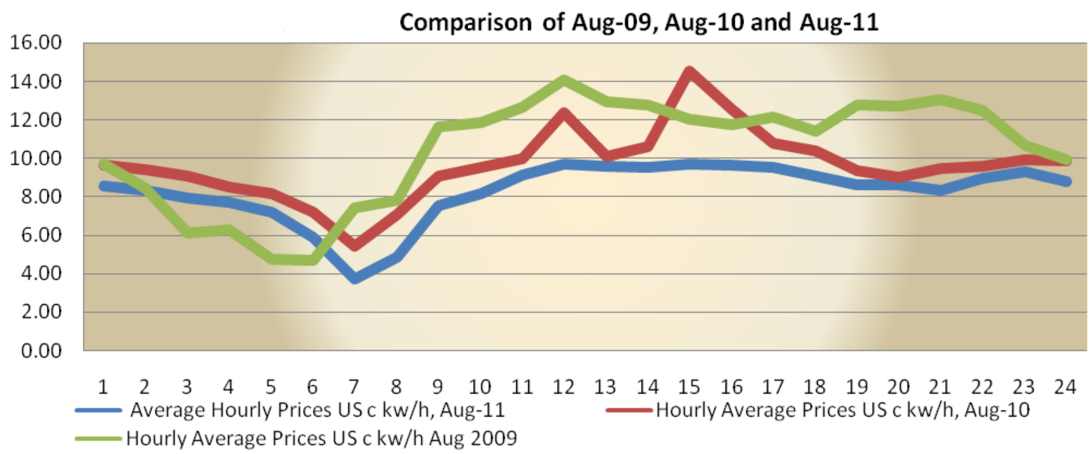
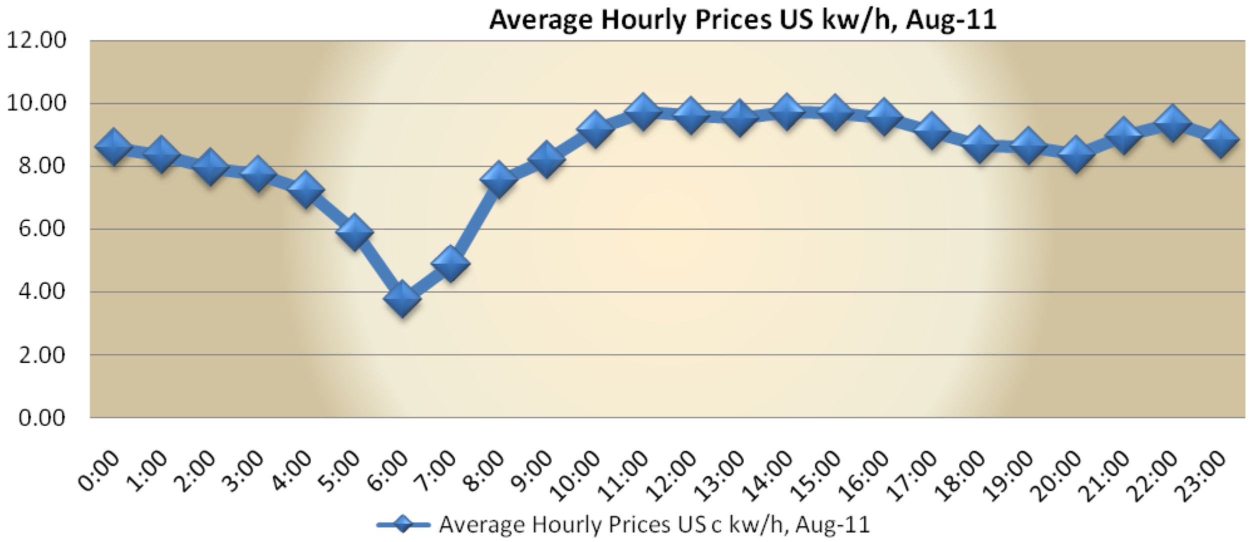


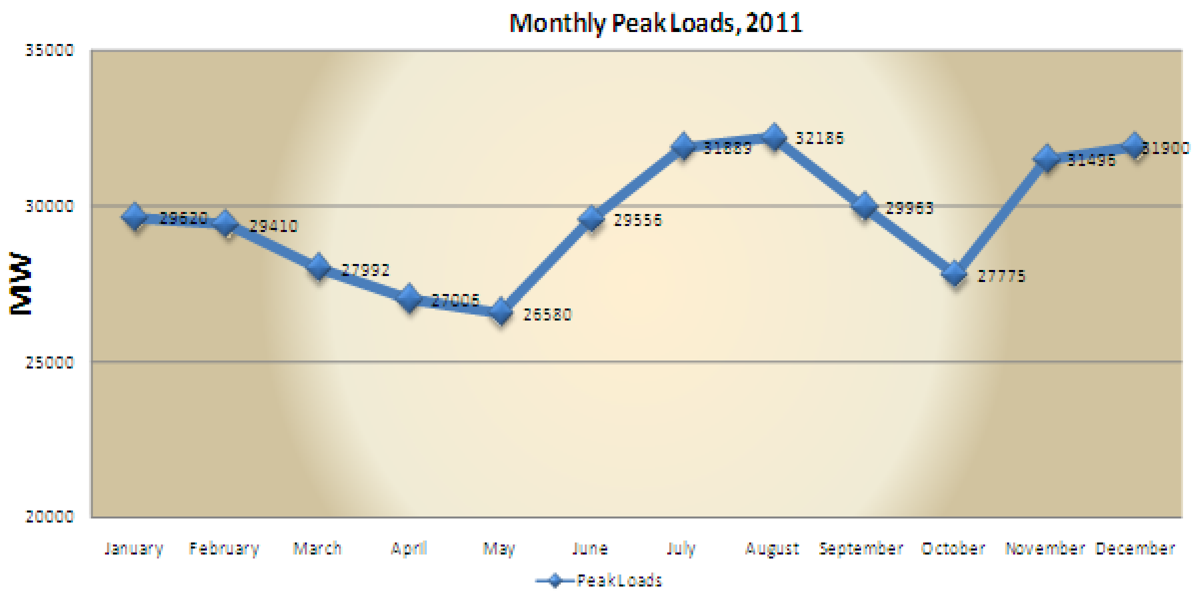
Fig. 3.9. Average hourly prices on Turkish market [9]



The daily average prices deviate in the range of $80-85/MWh reaching $100/MWh at peak-time and decreasing to $40-50/MWh at night

It should be noted that peak load in Turkey as opposed to Georgia occurs in summer (Fig.3.10) at day-time (12-15 pm, Fig. 3.9), having a favorable impact on export possibilities of Georgia.

Fig. 3.10. Seasonal peak loads in Turkey [9]



However, considering the fact that the majority of HPPs in Georgia are “run-of-river”, the potential of selling night-time power could be limited.

It should be mentioned that for a year and a half the Turkish government has been in fact subsidizing prices of gas for the state-owned company BOTAS leaving them unchanged, whereas prices for the imported gas have significantly increased (in certain period up to 40%) [9]. In that situation prices for the wholesale electricity are not growing, moreover they are even slightly decreasing.

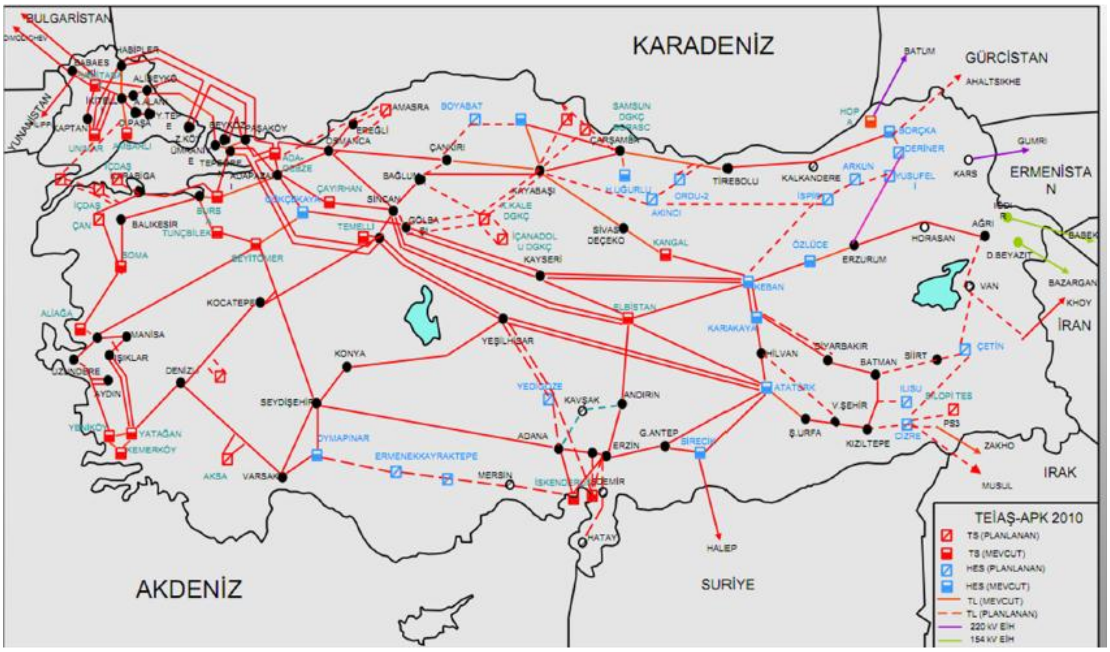
Cancellation of those subsidies is hampered by the unwillingness by the GoT for increase of prices for electricity, which is clear, in general, from the viewpoint of economy development; however, even if this ever happen, it is not for sure that prices for gas and electricity will considerably increase, since during the last period there is a tendency in many countries to reduce gas purchase prices, especially this is true with the Russian gas prices, which sometimes happen to be higher by $120-130/tcm than the spot-market prices. A fresh example: Turkey has been purchasing the Russian gas from “GasProm” under three contracts. Upon expiration of one of those contracts, Turkey requested the reduction of the price so that to prolong the contract, and the supplier agreed.

5.8 Technical limitations on power deliveries

This issue is discussed in details in Chapter 2, which provides the analysis of serious limitations on deliveries of power from Georgia to Turkey in summer time, the most favorable period for new HPPs in Georgia.

It should be noted that strengthening of transmission interface in Turkey (third 400kV line) gives limited improvements, since by TEIAS’s decision to construct new lines is directly associated with new HPPs construction in Turkey (Fig. 3.11.)

Fig. 3.11. 400kV network in Turkey



Limited aggregate power flow together with the competition for delivery by the existing HPPs of Georgia also present a barrier for efficient deliveries of power from new HPPs.

5.9 Competition for deliveries by power systems of neighboring countries

Russia and Azerbaijan can be considered as potential competitors of Georgia. The existing trade between Georgia and Russia implies deliveries of summer power from Georgia to Russia and in winter – in an opposite direction. After commissioning of a link with Turkey the situation may change. Availability of this direction may bring to the situation, when both the Georgian and the Russian power plants will be able to export power to Turkey (if Russia is capable of supplying power to Georgia in winter, it will be as well capable of doing that in summer). The current level of average exchange prices (about $40/MWh) should also be taken into account, while analyzing possibilities of export from new HPPs of Georgia.

The policy of Azerbaijan may have a multi-factor impact in terms of deliveries to Turkey. First of all, these deliveries may cover the lacking volume of the scheduled power flows of 650 MW, since Georgia currently has an excess of about 400MW in summer (about 500 MW in high-water years).

Secondly, increase of the aggregate flow to Turkey will prevent anincrease in the transmission tariff for exporters to Turkey. However, as it was already mentioned, for the last three years the situation with deliveries of gas from Azerbaijan to Turkey has radically changed. This may negatively affect the terms of deliveries of power from new HPPs of Georgia to Turkey (if Azerbaijan significantly reduces deliveries of electricity, the transmission tariff may considerably increase). The matter is the price of gas supplied by Azerbaijan, which has dramatically changed from $120/tcm to about $260/tcm.

Let’s estimate the cost of power generation that will allow selling that power on the Turkish market and what price should be for the burning gas.

If we take the average price of the wholesale market of $85/MW as a purchase price in Turkey and subtract the transmission constituent in Georgia ($23/MWh) and in Azerbaijan itself (no less than $3), then with consideration of losses the maximum possible price of generation at power plants of Azerbaijan will not exceed $55/MWh. In reality a lower price is required.

According to cost estimates provided in [4], even with generation on units with 58% efficiency and with consideration of all expenses, except for fuel, of $18/MWh, in order to ensure $37/MWh for the fuel constituent, we have a gas price of $175-180/tcm.

It is obvious that under any possible prices for transit of gas the direct export of gas through the territory of Georgia, given the purchase by Turkey at $260/tcm, is much more profitable than burning it in Azerbaijan at low price, since for this they will need to construct new efficient steam-gas installations, not to mention the environmental part of this issue.

5.10 Possibility to change conditions of functioning of the wholesale market in Turkey

All studies performed until now assumed high prices on the Turkish wholesale market. This is good for exporters in that direction. Starting December 2011 the “Day Ahead market” was finally introduced in Turkey, which, first of all, means competition, which may result in restriction of price growth.

Irregularity of the economic growth of Turkey (the eastern part is behind) influences the solvency of end-users and it is rather probable that future tariffs in various parts of Turkey may significantly differ from each other.

Reduction or at least restriction of future growth of tariffs is possible by means of reducing prices on the wholesale market. In such cases market split by price zones is usually being applied. However, according to the European rules, this is allowable only if limitation of transfer capability between zones exists.

As it was demonstrated in Chapter 2, there are considerable limitations on the transmission interface Northeast – Center of Turkey, therefore we cannot totally exclude from consideration the potential market split, which means that the wholesale prices on the east of Turkey may reduce.

5.11 Legal Aspects

According to the existing rules, the participating entity of the Georgian market cannot directly participate also on the Turkish market. In order to get a license for export of electricity from Georgia, the entity should sign an agreement with a partner, which is registered in Turkey. That Turkish company should also have the right of work on the Turkish market subject to renewal for each year.

On the one hand, it will allow the Georgian HPPs overcome probable barriers, which may appear due to different rules and principles of market functioning. On the other hand, the Georgian side will have a mediator, which will take the risks of realization of electricity on the Turkish market; it means that the price of delivery from the Georgian HPPs should be reduced by «costs of business» of the partner.

5.12 Export from new HPPs of Georgia to Turkey

As it was demonstrated above, there are possibilities of delivery of electricity to Turkey from the new HPPs of Georgia considering limitations in Turkey of technical character and in terms of prices on the wholesale market of Turkey.

Let’s estimate the possible price of generation in Georgia, which may be required in Turkey.

The price will be defined as a price on the Turkish market minus transmission costs and costs of business of the partner of the Georgian HPP in Turkey, who is the one to participate on the Turkish market as a seller of the Georgian electricity.

5.13 Possible price of purchase of electricity by a participant of the Turkish Market

Most probable is that purchase of electricity will be carried out on the border Turkey-Georgia. Let’s estimate the price exactly for this point.

Conventionally, the price characteristics of the Turkish market can be split into 2 daily zones: 00-08 – low prices zone and 09-23 – high prices zone. However, for the beginning, let’s estimate the applicable price based on the daily average prices. This is justified by the necessity to sell electricity from new HPPs (mainly “run-of-river” plants) practically on a smooth-delivery schedule. Analysis of the level of average prices for DAM by months demonstrates that the prices deviate in the range of $80-85/MWh.

When we speak about transfer of electricity to the Center of Turkey and not about consumption nearby the border, we most probably need to consider also transmission costs inside Turkey [10l], which will be no less than $3/MWh.

Costs of business of the Turkish partner is quite difficult to estimate today, however, they will hardly go below $5/MWh given that all risks associated with realization of electricity, are incurred by that partner.

Thus, on the border with Turkey, the price in the best option will hardly exceed $72-77/MWh depending on the season.

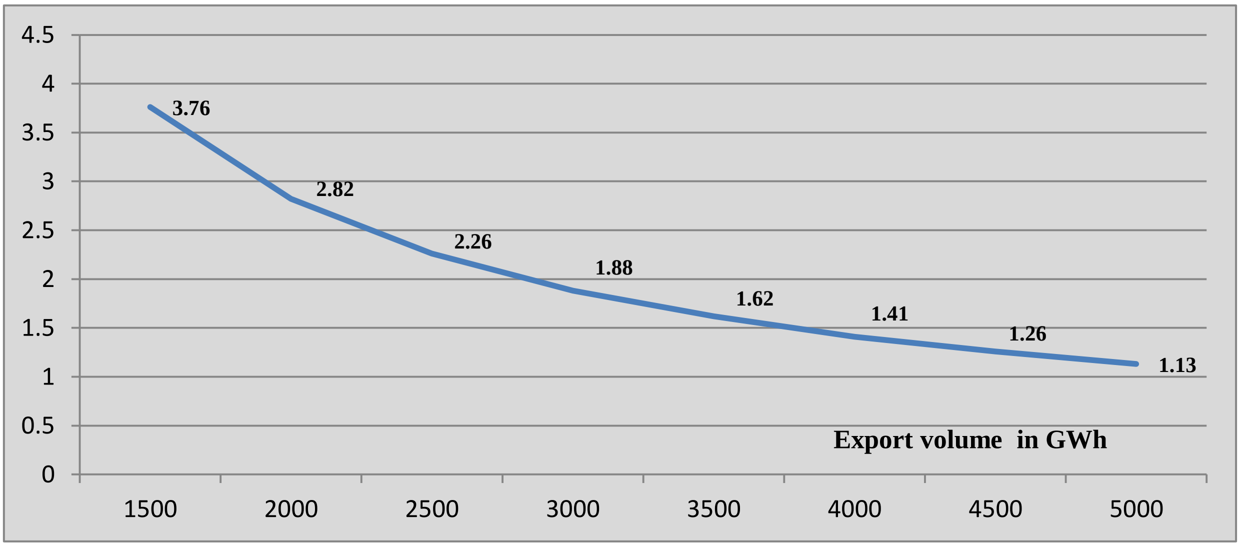
Now let's estimate the transmission constituent in Georgia that should be paid by new HPPs while transferring electricity to the border.

New network construction in Georgia, on the one hand, guarantees entry to the Turkish market, and on the other hand, brings to significant increase of transmission costs conditioned by expensiveness of a project.

Considering that the most reasonable solution is that these costs be covered by exporters, since growth of tariff for the domestic consumers is undesirable due to its already high value, let's assess the transmission tariff, which will mainly depend on the annual flow through the transmission interface Georgia-Turkey. Fig.3.12. presents the results of evaluating the dependence of transmission tariff on the power flow volume, which as carried out under the following calculation conditions:

- Project costs -€265 M (€/$=1.3)
- Interest of 10 years loan with 3 years of grace period – 8%
- Export from Georgia from the Georgian power plants – 1500 GWh p.a.(approximate volume of the total Georgian export in 2010)
- IRR=10% (WACC=9.26%).

Fig. 3.12. Estimation of transmission tariff in USc/kWh



These results show that the tariff estimated by the Georgian side as $18/MWh can be ensured under power flows of about 3200 GWh. This is much higher than the existing potential of Georgia and this proves also the possibility to export electricity from new HPPs.

As of today, the existing aggregate tariff on transmission and dispatch in Georgia amounts to 8.3 GEL/MWh or $5/MWh (transmission – 3.01, Sakrusenergo – 1.08, dispatch – 0.91) at the rate of exchange $1=1.66 GEL.

Thus, the aggregate tariff will be changing within the range from $19/MWh (in case, if the exporter pays only the dispatch charge) to $23/MWh (the exporter pays the tariff in total).

5.14 Price of delivery from new HPPs of Georgia applicable for export to Turkey and ways to support

In the light of the above, it could be stated that the average price of electricity from new HPPs required on the Turkish market should not exceed $85-$8-$19=$58/MWh, but it may decrease to $80-$8-$23=$49/MWh.

In general, considering the price of electricity that is required to ensure return on investments for new HPPs, for many of them the price of offer to the Turkish market may appear to be lower.

To improve the situation the following ways are suggested:

1. Sale of day-time electricity only.

   At these hours prices on the Turkish market will be by approximately $15/MWh higher than the average price and the corresponding prices of delivery from HPPs can be increased up to $64-$73 /MWh.

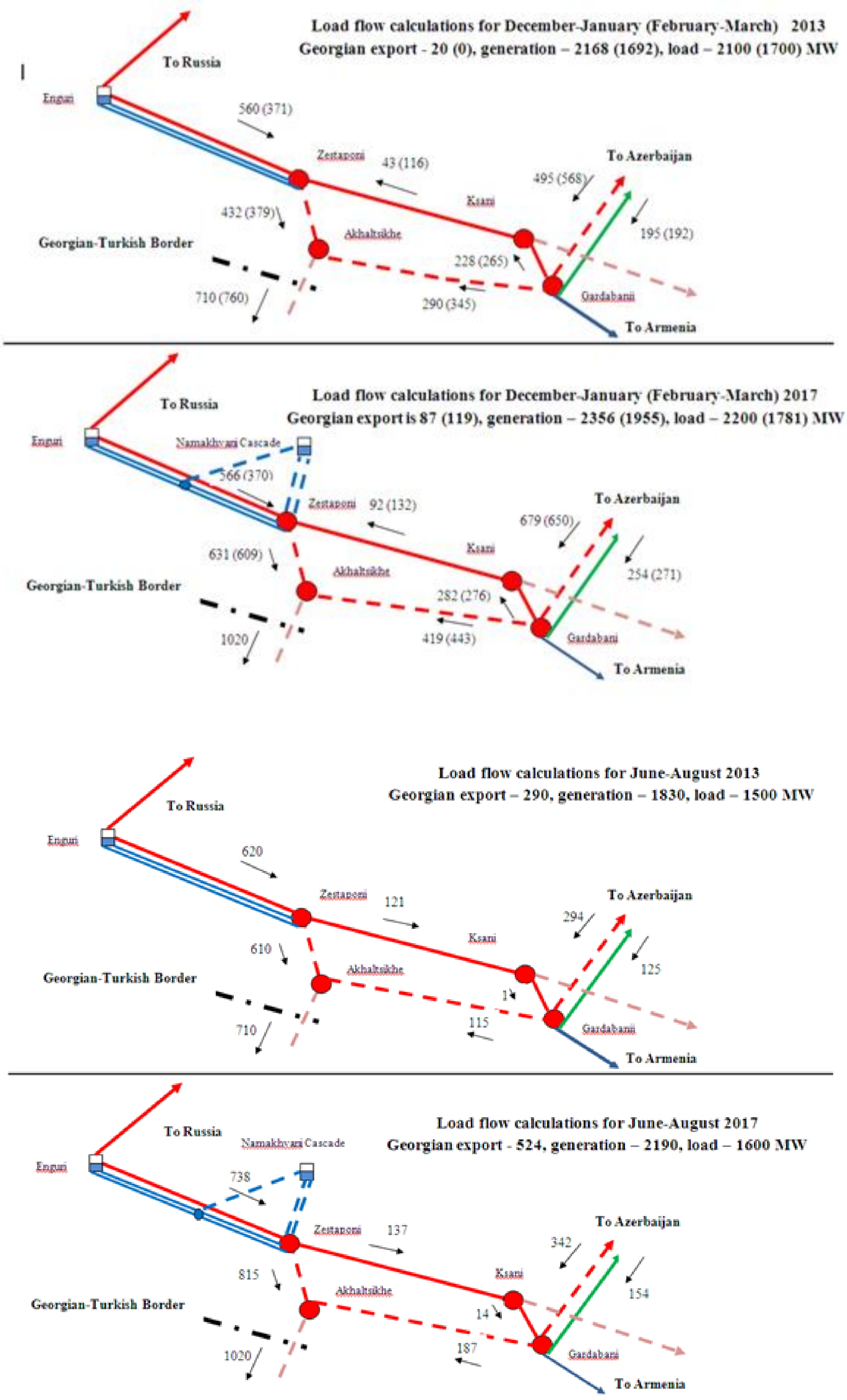
   Under this approach the HPPs of daily regulation may gain, but their construction is more expensive. For “run-of-river” HPPs it will be problematic to sell the night-time electricity. They may sell this night-time electricity to the daily regulated HPPs, which will accumulate water at night and will receive the opportunity to use it with profit at peak hours.

   Currently, the capacities of the Georgian reservoirs in summer for additional regulating are limited (no more than 80-100 MW), whereas in winter such a regulation may reach 300 MW. If new regulated HPPs are constructed, these capacities will increase.

2. Reduction of the transmission tariff for exporters of Georgia.

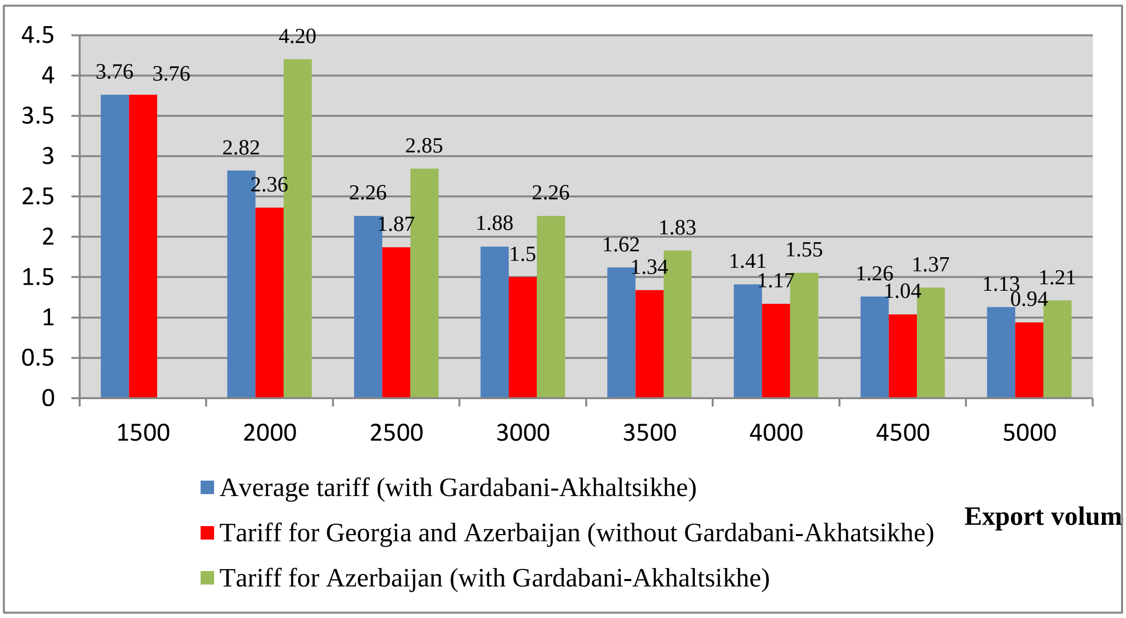
   This has quite a reasonable justification. In the delivery scheme of electricity to Turkey a new line of 500 kV Gardabani-Akhaltsikhe is figuring, which, undoubtedly, increases the reliability of the Georgian power system; however, from the viewpoint of power flows to Turkey, this line serves solely for transit of the Azerbaijan electricity. This is assured by calculations [3] for summer and winter periods of 2013 and 2017 (Fig. 3.13.).

Fig. 3.13. Load flow calculations results [3]



In this regard we may take into account the possibility of attributing the costs of this line purely to the costs of transit from Azerbaijan. Even if the cost of line is estimated to be $60M (data from [2] are used), under the above-mentioned calculation conditions it is possible to reduce the tariff for the Georgian exporters by $3-4/MWh(Fig. 3.14).

Fig. 3.14. Transmission tariff decreasing path for Georgian exporters



It is obvious that to attract private investors into construction of new HPPs in Georgia, it would be necessary to suggest alternative directions for delivery of electricity, other than Turkey due to possible technical and economic restrictions mentioned above.
The possibilities for delivery of electricity to Russia, Azerbaijan, Armenia and Iran will be analyzed in the next paragraphs.

5.15 Export from new HPPs to Russia and Azerbaijan

Trading of electricity between Georgia and Russia (Georgia delivers electricity in summer and Russia delivers in winter) is carried out on the border through mediation of the Russian company “InterRAO”, i.e. Georgia is not a direct participant of the Russian market.

In principle, influence of this circumstance on trading is insignificant considering that the wholesale prices on the Northern Caucasus market do not exceed $40/MWh and at the same time the average price of trading with “InterRAO” is roughly the same.

Trading is implemented by three daily price zones (night-time minimum, semi-peak, peak), which considerably differ by prices. It is obvious that, similar to the case with Turkey, delivery of peak electricity to Russia is profitable for Georgia.

The transfer capability of 500 kV line “Kavkasioni” (Fig. 3.1), even though it is rather long (about 460 km) allows transferring 500 MW with reserve.

It should be noted that with availability of the Turkish direction the existing scheme of trading may change in the case, when Russia also begins exporting to Turkey. In such a case trading from new Georgian HPPs in the direction of Russia will hardly be feasible.

In principle, trading is possible also via 110 kV lines; however, the volumes in this case will be small. In addition, to the fact that wholesale prices are by themselves relatively low, currently they are also being subsidized by the State (there is a decision at least up to 2015), which limits the possibility of sales from new HPPs of Georgia, the required price of which is several times higher than the prices of the existing HPPs.

For exporting to Azerbaijan, the actual deliveries in this direction will be practically absent, given the fact that Azerbaijan has got, as of today, 1000 MW of generation surplus and increasing generating surplus up to 2000 MW within the foreseeable future.

Deliveries to Turkey are the first-priority of Azerbaijan (an agreement is signed on establishment of the power bridge Azerbaijan-Georgia-Turkey), if the due price is ensured. Currently Azerbaijan delivers even gas to Georgia for thermal plants at a reduced price of 143/tcm (in volumes required for the TPPs of Georgia to generate for domestic needs only). It is obvious that the purchase of electricity from Georgia, which is more expensive than that generated at such price of gas or even at a low price, considering transportation to the center of loading via the planned 500 kV line will not be of Azerbaijan's interest.

Vice versa, to return the investments made into new generating capacities and new network construction, Azerbaijan should export electricity to the maximum extent. Directions of that export will be defined by the level of prices on the neighboring electricity markets, and if due export is not ensured, then their own generation will be maximally used inside the country, considering availability of flexible pricing for gas (domestic resource).

5.16 Export from new HPPs of Georgia to Armenia (synchronous operation while the Armenian power system is disconnected from Iran)

Synchronous operation of the Georgian and Armenia power systems is possible only in case of Armenia being disconnected from Iran. Although this option is not the first priority for Armenia, as well as probably for Georgia, too, consideration of this option will allow evaluating possibilities of export from new HPPs of Georgia to cover the domestic consumption needs of Armenia within the period 2013-2022.

Let's analyze the factors inside Armenia having influence on the Georgian export.

5.17 Domestic consumption and its covering by power plants of Armenia

Currently the company Tetra Tech in Armenia is implementing a project "Assistance to energy sector to strengthen energy security and regional integration" (funded by USAID). Within the framework of this project the possible options of integration with countries of the region, except for Iran, are being considered. The years 2015 and 2020 are taken as base years. Results of this work are published on the project's official web-site: www.armesri.am[11].

Based on their data, the domestic consumption growth rate in Armenia is 2.7%, which means that for the review period the levels of consumption with losses (without own needs) will be 5850, 6500 and 7400 GWh for 2013, 2017 and 2022, respectively.

In [11] the operation regimes of the Armenian power system in isolation are analyzed; the net generation price for domestic consumers is calculated, which should be a criteria for efficiency of regional integration. The isolated regime of the Armenian power system is first of all characterized by the necessity to unload the Armenian NPP (the maximum net generation is 350 MW) within the period from March to its date of annual refueling and preventive maintenance (end of September).

This is conditioned by the requirement that capacity of a single unit should not exceed 75% of the power system's load (currently during the night-time valley in summer the aggregate load decreases to 400MW and sometimes even more).In the majority of power systems, this requirement is limited to 60%, whereas in Armenia increase of this limit is conditioned by installation of automatic unloading by frequency deviation rate.

Considering that the load curve in Armenia is quite irregular (the daily maximum is often twice higher than the daily minimum) to cover the maximum load in summer, it is necessary to use the combined-cycle unit at the Yerevan TPP (the maximal generation in summer is 190 MW). However, it is, of course, not allowable to start up-shut down that generator during one day, requiring that it should operate at night as well, at least on its technical minimum. This fact brings to even greater necessity to unload the NPP.

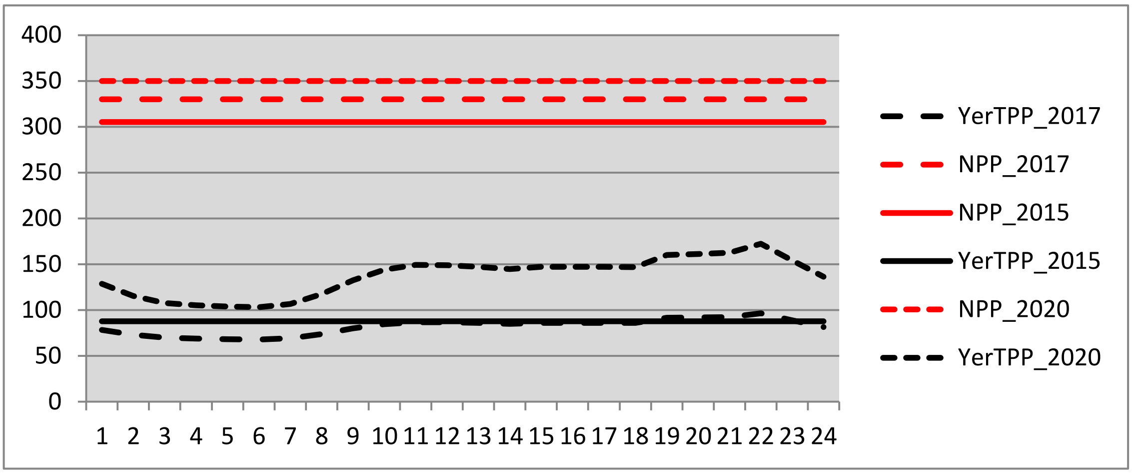
It is clear that the net generation price increases, meaning that the fuel component of the Yerevan TPP is about $44.5/MWh (the current price of the Russian gas for TPPs of Armenia is $200/tcm) and the variable costs of the NPP amount to $11.5/MWh (all values are provided without VAT).

5.18 Possibilities of export from new HPPs of Georgia to cover the domestic consumption of Armenia

Option 1. The existing generation structure in Armenia

As shown in [11] from March to the end of September under the isolated operation regime of the Armenian power system in 2015 (hourly calculations), only the Yerevan TPP out of other TPPs participates in covering the load, and over certain weeks of May and June the power system is dispensed even without it (only the NPP and HPPs operate). Whereas, for the majority of days before the year 2015, the Yerevan TPP participates in the daily schedule at capacity approximately equal to its technical minimum (small deviations in the daily profile) and with net generation of 85 MW (Fig.3.15). This is explained by sufficiency of the regulation range of the Sevan-Hrazdan and Vorotan cascades of HPPs.

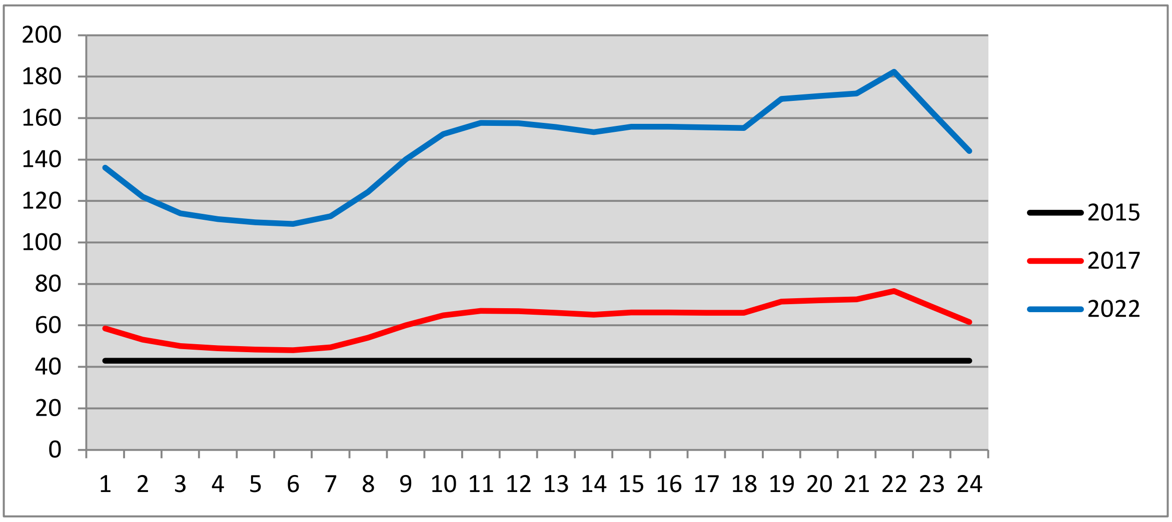
Fig. 3.15. Hourly net generation of NPP and YerTPP in summer day (August) in MW



If the Armenian power system is connected with the Georgian power system, the limitation of the NPP by capacity could be taken off and the plant can participate with its full capacity (net generation of 350MW).

Fig. 3.15 provides data on level of contribution of the NPP and the Yerevan TPP in covering the daily load in summer (August) in case of isolated operation for the period 2015-2020. Based on these data, the required volumes of import from Georgia have been calculated for the situation, when the Yerevan TPP is shut down and the NPP is fully loaded for the period 2015-2020 (Fig.3.16).

Fig. 3.16. Required hourly import from Georgia to replace YerTPP (August) in MW



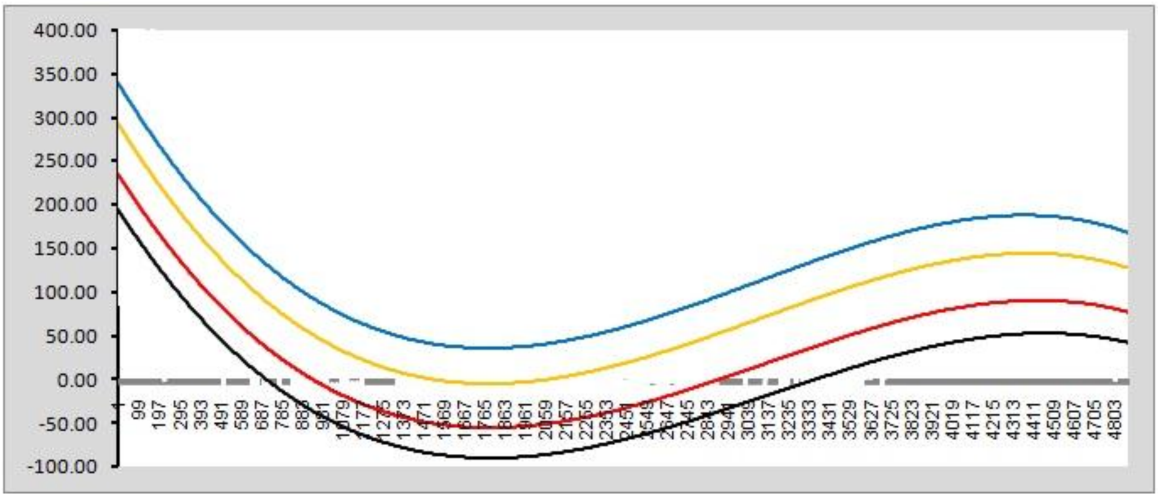
Analysis of the results shows that the required import for this period changes within the range from 40 MW (smooth delivery schedule) to 180 MW by the year 2022. Such volumes of delivery are quite possible to be realized via the existing connection 220 kV Gardabani-Alaverdi (see Chapter 2).

It should be noted that although for analysis of the required import, the scenario with isolated operation of the Armenian power system has been selected as a base regime, it becomes obvious that if the interconnection line is switched on and maximization of the NPP loading is allowable, this does not mean that the NPP will be covering the total load (if maximization of the NPP's load will not allow to meet the daily peak of the system without a thermal power plant, then it would be necessary to do a compulsory unloading of the nuclear plant). Thus, the below given results do not depend on the base scenario.

In an isolated system the regimes, when the NPP is unloaded and only the Yerevan TPP participates in load schedule, are observed in the period from the second part of March to the end of September (NPP shut-down). In respect of these regimes the required volumes of import for this specific period have been analyzed.

Fig. 3.17 provides the trend lines of power flows between Georgia and Armenia with the thermal plant in Armenia being stopped. It appears from this figure that only by the year 2022 in March there is a little excess of the marginal flow to Armenia (220 MW) mentioned in Chapter 2.

Fig. 3.17. Armenian required import(+)/export(-) hourly curves from March to September in MW



Considering that the margin by thermal stability, 220 MW, is defined for summer time (in March it could reach up to 250 MW) it may appear to be quite allowable (otherwise, Georgia may start exporting a little bit later). Besides, by the year 2022 significant changes may occur in terms of generation structure and, probably, in terms of transmission. These factors will be considered in details later.

Very important is the period May-June, when up to 2020 Armenia can do without import, moreover the system has got small surplus of electricity up to 120 MW (currently) that could be exported.

This situation cannot be considered favorable for the HPPs of Georgia, since the Georgian HPPs have a big potential of generation in that period and realization of that electricity is limited in Turkey (paragraph 3.2) and practically reduced to zero in Armenia. However, taking into account that a surplus could be considered the electricity of the NPP in Armenia (electricity from large HPPs is even cheaper), the variable costs of which amount to $11.5/MWh, and this electricity is available at a smooth schedule, the new HPPs of Georgia may use this opportunity to buy it and by that to provide for reduction of price of their own electricity offered on the Turkish market (the price of total electricity will be less than the price of their own electricity). Moreover, a new HPP may sell the night-time electricity to an HPP of daily regulation in Georgia at quite a cheap cost and the later will accumulate the water and will sell more electricity at peak hours to Turkey.

While analyzing the state of things in Armenia, we take into consideration the prices reflecting only the variable component of generation price. This is due to the fact that a two-part tariff for electricity and capacity is applied in Armenia for generators and fixed costs of plants are fully covered by the company “Armenian Electric Networks” CJSC (a single buyer) regardless of generation volumes.

Let’s evaluate the efficiency of import from Georgia for Armenia and potential prices of export from new HPPs of Georgia.

The price limit for replacing the thermal energy on the account of additional loading of the NPP and of import will be as follows:

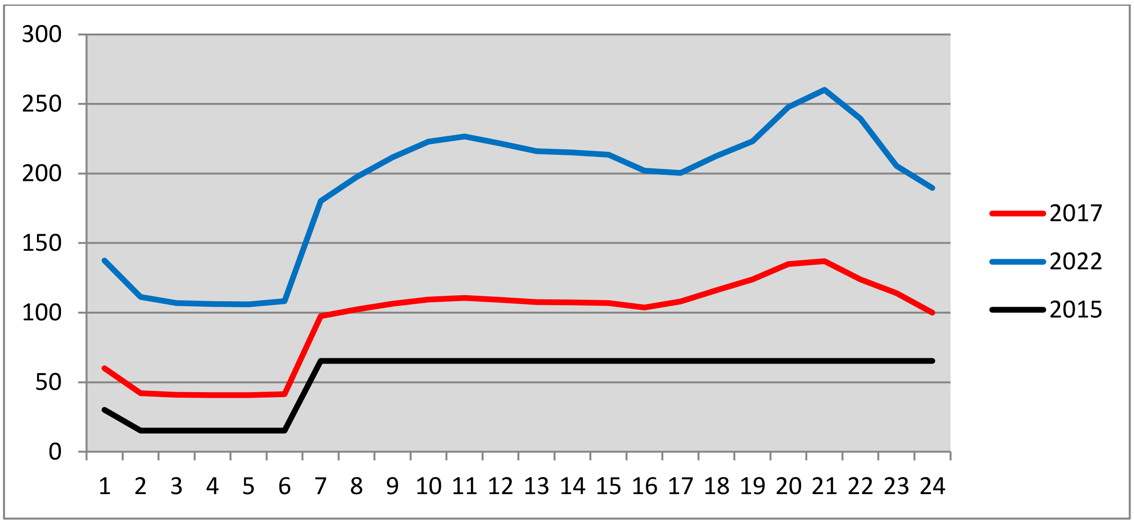
$$T_{imp.lim} = \frac{\Delta E_{NPP} * (T_{TPP} - T_{NPP})}{E_{TPP} - \Delta E_{NPP}} + T_{TPP} \qquad (1)$$

where,
$T_{imp.lim}$ – the marginal price for import for Armenia,
T_{TPP} – fuel component of the Yerevan TPP ($/MWh)
T_{NPP} – price of variable costs of the Armenian NPP ($/MWh)
E_{TPP} – daily net generation of the Yerevan TPP (MWh)
ΔE_{NPP} – difference between the maximal and the actual daily net generation of the NPP (MWh).

For a summer day (Fig. 3.15 and 3.16) the daily required volumes of import would be 1030, 1970, 3480 MWh and prices limits of replacing amounted to $79/MWh, $52.5/MWh and $54/MWh (if in 2022 HrazdanTPP No.5 participates in the system balance instead of the Yerevan TPP) for 2015, 2017 and 2022, respectively, which shows that with the increase of the required import the price limit decreased, however, even at that level prices in summer for new Georgian HPPs seem to be attractive, given that they are considerably lower on the domestic market.

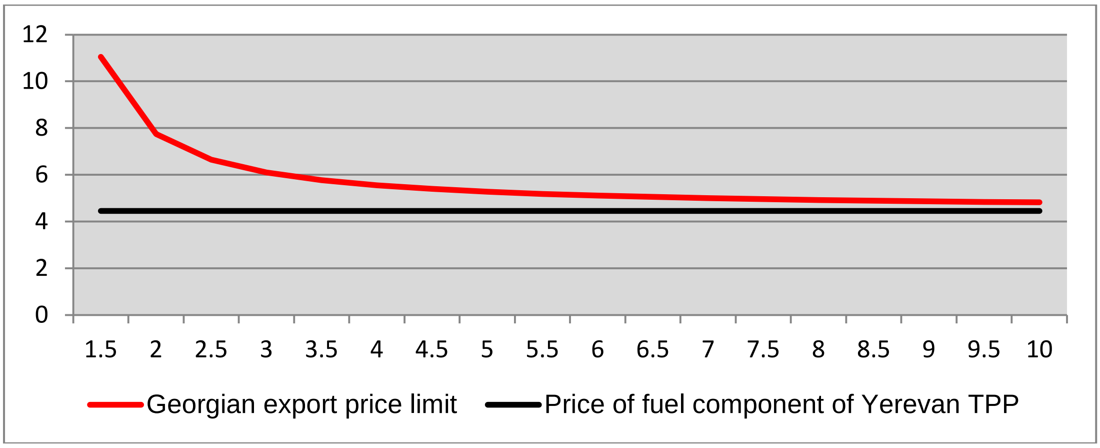
The most important thing here is that these plants get an opportunity to sell in summer the night-time electricity at a favorable price, which is rather problematic in the Turkish direction. In March (Fig. 3.18) the corresponding prices and daily volumes will be as follows: 1285 MWh and $59/MWh (2015), 2285 MWh and $55/MWh (2017) and 4560 MWh and $54/MWh (2022 with operation of Hrazdan 5).

Fig. 3.18. Required hourly import from Georgia to replace TPP (August) in MW



The following conclusion may be done: the less the relation $E_{TPP}/\Delta E_{NPP}$ in Armenia, the more expensive is electricity from the new Georgian HPPs (Fig. 3.19).

Fig. 3.19. Georgian limit export price in USc/kWh in dependence regarding EYerTPP/ΔENPP



It is obvious that for efficiency of import-export relations, it is necessary that both parties receive profit from trading, therefore the potential price of delivery to the Armenian market will be lower than the calculated price limits.

For example, let's calculate the export price for HPPs of Georgia for the analyzed summer day of 2015 (Fig. 3.15 and 3.16), at which both parties have equal profits.

Assume that the price of electricity of an HPP of $50/MWh is the price covering costs with consideration of return on investments. The received price of export to ensure equal profit will be $64.5/MWh. If we take into account the current price of transmission and dispatch in Georgia, then the price, at which this HPP may sell that energy for export, will be about $59/MWh, which significantly exceeds the price needed for the minimum return on investment.

It should be noted that the aforementioned calculations suppose that the Russian gas price for thermal power plants of Armenia is $200/tcm ($180 on border). Despite the fact that many European countries reduce the purchase price for the Russian gas (it was significantly higher from the beginning), we should not exclude the probability that for Armenia this price may grow a little; this will allow Georgia to sell electricity at a higher price.

For example, at the price of gas $236/tcm (20% growth rate on the border) the calculation of price for HPP with opportunity of equal profit will give the price $68/MWh instead of the earlier received $59/MWh.

Growth of load in the course of time may bring to the situation that even the maximal net generation of the Yerevan TPP (180-200 MW depending on a season) may not be sufficient to cover the maximum (for example, March 2022, Fig.3.18) and to substitute it the Hrazdan 5 will be activated, which efficiency is lower than the efficiency of the Yerevan TPP (40-42 % versus 49 %). This will also increase the possible price of export of the Georgian HPPs due to increase of the fuel component T_{TPP} (1).

It is clear that with growth of consumption in Armenia and with increase of import potential from Georgia, the possible price will be decreasing getting closer to the price of fuel component of the thermal plant to be substituted.

Within the review period of the year (March-September) exchange of electricity on a daily profile basis is possible (Fig. 3 .20) – Armenia supplies at night.

Considering that usually the night-time energy is considerably cheaper than the peak energy, the Georgian HPPs may receive a profit in this case (daily exchange), too, given that to substitute a thermal plant small volumes of electricity are needed to be delivered rather than big volumes at a 24-hour import by Armenia. This will allow to have higher level of prices.

Fig.3.21 provides volumes of the potential export from the Georgian HPPs to meet the domestic demand requirements in case of shut-down of TPPs in Armenia for the period March-September by Option 1.

Fig. 3.20. Power exchange between Georgia (+)& Armenia (summer week) in MW

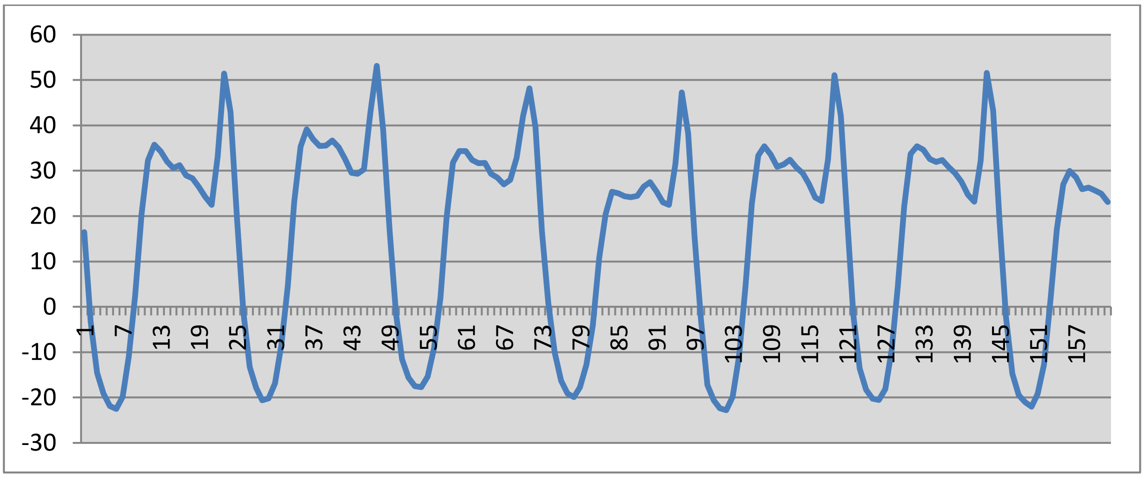
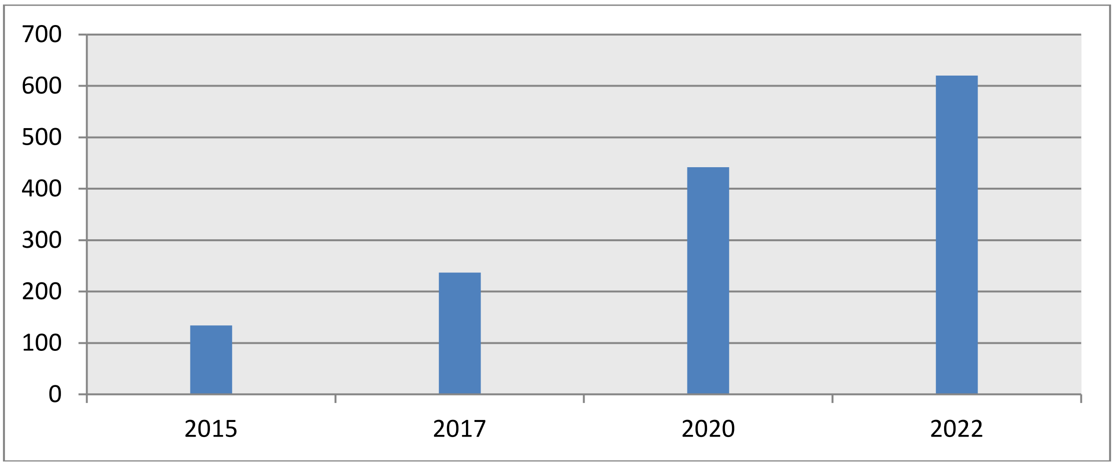


Fig. 3.21.Potential Georgian export volumes for March-September by Option 1 in GWh



The period reviewed until the year 2022 brings to the necessity to evaluate the effects of certain processes in Armenia, namely, the probable shut-down of the Armenian NPP and substitution of its capacity by a new generator.

Option 2. Changes in the generation structure of Armenia

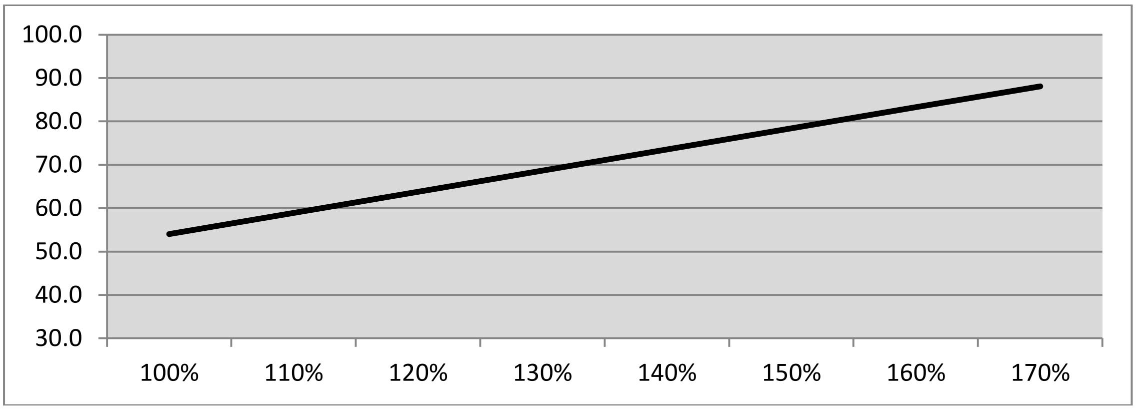
In 2017 the useful operating time of the Armenian NPP expires and it should be either shut-down or special life expansion measures should be implemented. The second case corresponds to the Option 1, while in case of the NPP shut-down, the following may happen:

1. Construction of a new NPP of 1000 MW. This is actually the intention of the Ministry of Energy and Natural Resources of Armenia, although realization of this plan is hardly possible, since the project implementation budget (about $5 billion) is 15-17 times higher than the annual turnover of the power sector and the issue of attracting investments, discussion of which have started long ago, is a hard-to-solve issue (until now only Russian Government-owned entities announced intentions to provide $1 billion). Moreover, considering the way the Russian NPPs are constructed, it would hardly be possible to accomplish and to commission the plant within the period under review. In terms of our task, commissioning of such a plant will practically mean impossibility of export from Georgia to Armenia, since the requirement to operate even with a capacity of 750-800 MW will suppose a round-year export from Armenia.
2. The most probable option is that as a substitution to the NPPa gas-firednew combined-cycle unit will be constructed at the Yerevan TPP with a net generation of 200 MW similar to the existing one or with a higher capacity - 410 MW.

It is obvious that in case of shut-down of the NPP the price limits of import from Georgia will be based on the price of the fuel component of the low-priority generator (this will be the Hrazdan 5, because if a new combined-cycle unit is constructed, the efficiency of the latter will be higher).

As it was already mentioned, the fuel component price for the Hrazdan 5 at the existing gas price $200/tcm makes not less than $54/MWh.
Relation between the price limit of the Georgian export and the price of gas for the Armenian TPPs is presented on Fig. 3.22.

Fig. 3.22. Georgian export price limit regarding gas price increasing for Armenian TPPs in $/MWh



5.19 Possibilities of export from new HPPs of Georgia to Armenia and Iran

5.20 Export to Armenia and Iran in summer

As it was already mentioned, for Armenia the synchronous operation with Iran is the first priority in terms of technological aspects (frequency control, support in emergency situations, etc.) and in terms of economy.

In such conditions only asynchronous operation of Armenia and Georgia through B2B converter is possible, whichis discussed below.

The “electricity for Iranian gas” swap contract effective between Armenia and Iran until 2027 allows for efficient use of TPPs of Armenia regardless of the market gas prices.

The matter is that according to the terms of contract Armenia should delivery to Iran 3 MWh of electricity against 1000cm of gas. The Yerevan TPP can generate 4.5 MWh/tcm and the Hrazdan 5 up to 4 MWh/tcm. Thus, even considering transmission losses there is an obvious opportunity to have a portion of generation (for domestic consumption) using free gas.

Considering that the TPPs of Armenia participate also in covering of the domestic consumption, it becomes necessary to receive (purchase) additional gas from Russia. Refusal of Armenia to purchase the Russian gas for its TPPs could be considered the criteria for import from Georgia.

Table 3.2 provides calculations of the required volumes of import by years under the generation structure of Armenia

Table 3.2 Calculation results of imported energy into Armenia (2013, 2017, 2022)

Structure component	Measurement unit	2013	2017	2022
Consumption	TWh	**5.9**	**6.5**	**7.4**
Net generation, Total, including	TWh	**8.9**	**9.0**	**9.1**
NPP	TWh	**2.5**	**2.5**	**2.5**
TPPs	TWh	**4.2**	**4.2**	**4.2**
HPPs	TWh	**2.2**	**2.3**	**2.4**
Surplus	TWh	**3.0**	**2.5**	**1.7**
Gas requirement	billion cm	**1.050**	**1.050**	**1.050**
Gas received by swap, including losses (3%)	billion cm	**0.970**	**0.808**	**0.550**
Required export to Iran, including losses (3%)	TWh	**3.25**	**3.25**	**3.25**
Required import from Georgia	TWh	**0.25**	**0.75**	**1.55**

Assessment of the Georgian export price on the border depending on the Russian gas price on the border with Armenia for this option is provided in Table 3.3.

Table 3.3. Forecasted Price of Natural Gas and Limits on Electricity Imports – Armenia

Price of the Russian gas for TPPs of Armenia, $/tcm	***200***	***250***	***300***
Price limit for import of electricity from Georgia, $/MWh	***64***	***80***	***96***

Thus, even the existing price for the Russian gas supposes the probable price for the Georgian HPPs to be about $57/MWh, including transmission tariff in Georgia and 3% of losses.

With growth of gas prices, the conditions for the Georgian export will be quite favorable. The most important factor here is the one that the schedule of deliveries from Georgia is not limited at all. The matter is that the swap contract with Iran stipulates only for the maximum capacity and for annual delivery volumes, which by the year 2022 should reach the level of 6.9TWh.

Thus, Georgia can supply the required volumes of electricity (Table 3.2) by a smooth daily delivery schedule. The only requirement is that the power flow capacity not to exceed the limit of the interconnection link Georgia-Armenia. For example, delivery on a smooth schedule within the period from April to October is assumed to be about 150 MW, which is absolutely allowable given the transfer capability of the existing interconnection tie. In 2022, the similar power flow will be over 300 MW and upgrading of the transmission interface will be necessary.

Increase of the transfer capacity of the interconnection line Georgia-Armenia should strongly depend on development of generation in both power systems and on power flows actually possible in terms of sizes and in terms of timing, since minimization of costs of new interconnection line will allow for maximization of prices of export from the Georgian HPPs. This issue will be discussed in paragraph 3.5.5.

Let's analyze the option, when the Armenian NPP is shut down after the year 2017 with and without substitution of its capacity.

Results of Table 3.2 show that in case of substitution of capacity,Armenia will have self-balance in 2017and energy deficit for the next years, which will reach the level of

800 GWh in 2022, unless considering the potential of two old units each of 200 MW at the Hrazdan TPP (they are not efficient and can generate no more than 3 MWh/tcm). In this case Armenia will have to cancel exports to Iran and to operate on Russian gas at a price that will be formed by that time.

However, this option is hardly possible; therefore, let's analyze the case with commissioning of one more thermal units of 210 or 410 MW.

Results of the analysis of the required import in case of operation of the Armenian TPPs only on the Iranian gas are provided in Table 3.4

Table 3.4 Impacts on Armenian imports by replacing NPP with new CC Units

Generation structure	Unit	2017	2022
Consumption	*TWh*	6.5	7.4
Net generation, in total, including:	*TWh*	7.9 / 9.3	8.0 / 9.4
New TPP	*TWh*	1.4 / 2.8	1.4 / 2.8
Existing TPPs (without units of 200MW each of the Hrazdan plant)	*TWh*	4.2	4.2
HPPs	*TWh*	2.3	2.4
Surplus	*TWh*	1.4 / 2.8	0.6 / 2.0
Gas requirement	*billion cm*	1.35 / 1.65	1.35/ 1.65
Gas received by swap, including losses (3%)	*billion cm*	0.45/ 0.90	0.20 / 0.65
Required export to Iran, including losses (3%)	*TWh*	4.18 / 5.10	4.18 / 5.10
Required import from Georgia	*TWh*	2.78 / 2.30	3.58 / 2.70

Here we see a drastic growth of demand for import. With availability of such capacities in Georgia there is a principle opportunity of using the existing contract between Armenia and Iran as it provides for delivery of electricity up to 6.9TWh per year by 2022.

Direct delivery of electricity from Georgia to Iran are practically possible, however, conditions of such contract should ensure an appropriate price for the Georgian HPPs. As of today, Iran pays for electricity by gas and many things will depend on the price of gas on the Georgian market, the price of transit of electricity through Armenia and of gas through Armenia or Azerbaijan, as well as on aggregate volume of electricity (from Armenia and Georgia), which Iran will be willing to buy.

5.21 Possibilities of export from new HPPs of Georgia to Armenia and Iranin winter

Until now it was talked about a favorable for the Georgian HPPs "summer" period. This paragraph will address the possibilities of export within the periods from the end of September to the beginning of November and in November-February.

The first reviewed period is characterized by shut-down of the Armenian NPP for refueling and maintenance works (6 weeks). At that period to cover the domestic demand of Armenia both the Yerevan TPP and the Hrazdan Unit No.5 are used. Obviously, if Georgia is able to export electricity at that period, then the price on the border should be not less than the price of the Unit No.5 ($54/MWh). It means that for the new HPPs of Georgia delivery from bus-bars will be at a price not exceeding $47/MWh.

Using data published on the ESCO's official site, we can see that for the given period purchase of electricity from non-regulated HPPs (including new HPPs) by the ESCO for the last years is deviating in the range of $52-55/MWh.

It is clear that sale of electricity inside Georgia is more profitable for these plants, and given the fact that actual pace of commissioning of new generating capacities in Georgia are behind schedule, it can be supposed that the situation will still remain the same for a long time.

Absolutely the same conclusions could be done for the period from November to February.

We should not forget that the generators in Georgia are obliged to sell all the electricity inside Georgia during three winter months.

Thus, sale of winter electricity from HPPs of Georgia is rather problematic.

5.22 Impact of the interconnection link Georgia-Armenia on export fromnew HPPs of Georgia

As was demonstrated above, the high transmission tariff stipulated by a wide-scale network construction has an impact on export prices and therefore the possibilities of export to Turkey. The size of the tariff directly depends on volumes of power flows.

Construction of the 400 kV Georgia-Armenia line was suggested in [1] and the scheduled power flow was estimated to beup to 350 MW. Currently, official bodies of both countries discuss the following option, considering the necessity of asynchronous operation of Georgia with Armenia and Iran:

- Double-circuit line (to increase the reliability) Marneuli-Hrazdan TPP of 400 kV or 500 kV (depending on the place the transformer 500/400 kV is installed) at the length over 100 km;
- Transformer 500/400 km;
- B2B converter (capacity is not specified).

Even if capacity of the converter will be 350 MW in total (at that the line will be under loaded), the cost of such a project will exceed €100M (only the converter will cost €60M).

At the same time, power flows will hardly exceed 1000-1200GWh by the year 2020. Similarly to calculation of the transmission tariff from Georgia to Turkey, we could estimate that the transmission tariff only for this connection Georgia-Armenia will be about $18-20/MWh, what will serve as a serious barrier for export of the Georgian electricity to Armenia (Iran).

This estimation is done based on the fact that both in Georgia and in Armenia the transmission costs will be most probably vested entirely upon the exporters, applying the “cross-border facility using” methodology aimed to minimize the rates of tariff growth for the domestic consumers.

Let’s consider the options of ensuring power flows with minimization of transmission costs.

As the aforementioned results demonstrate, until 2017 the power flow from Georgia to Armenia will hardly exceed 150-170 MW both for the internal consumption and for power flows to Iran. In that case it is possible for the mentioned period to install a B2B converter of 175 MW (similarly to the one planned by EnergoPro for transfers to Turkey) on the existing interconnection Gardabani-Alaverdi. Cost of such a converter will hardly be over €20-25M. It means that the transmission tariff will be 4-5 times lower than the one suggested in case of 500/400 kV line.

Later on, in case of increase of power flows (it will be defined by availability of surplus of useful capacities in Georgia and demand in Armenia and Iran), as well as to increase the reliability of the connection, the following could be done:

- To construct one more 220 kV converter of 175 MW;
- To construct 220 kV line Gardabani-Vanadzor.

In this case the transmission tariff will twice lower (preliminary estimate) than 400kV option.

Decision on construction of a new connection planned by the officials should be supported by considerable increase of power flows, for example, by values presented in Table 3.4.

It is also important that the new construction be implemented not in advance, but as the need arises.

It is quite important for the potential investors of new HPPs of Georgia that decisions concerning the network construction be optimal from the point of view of the future transmission tariff.

6.0 REFERENCES

1. Regional Power Transmission Extension Plan for Caucasus Countries. Final Report, FICHTNER, November 2007
2. Financing of energy infrastructure projects. GSE, 2011
3. Black Sea Regional Transmission Project.Project Appraisal Document., Joe Corbett, June 2008
4. Electricity export opportunities from the Caucasus to Turkey , Econ Pöyry, 2008
5. Turkish 10 year generation Capacity projection. TEYAS, 2011
6. Turkish Electric Power Sector. Tubitak, July, 2011
7. Coruh river development plan. UbeydSezer, 2009
8. Turkish Energy Industry Report. DELOITTE, August 2010
9. Turkish Monthly Power Market Report (August-November 2011). HIPP, Special Study Group, 2011
10. Turkish Transmission Tariff. HIPP Special Studies Analyses, 2010
11. Assistance to energy sector to strengthen energy security and regional integration (website – www.armesri.am). Tetra Tech, Armenia, 2011

USAID Hydropower Investment Promotion Project (USAID-HIPP)

Deloitte Consulting Overseas Projects - HIPP

Tiflis Business Centre, 13th Floor

11 Apakidze Street

Tbilisi, 0171, Georgia