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ACRONYMS

CBA	Cost Benefit Analysis
EIA	Environmental Impact Assessment
EnCT	Energy Community Treaty
EU	European Union
GoG	Government of Georgia
GSE	Georgian State Electrosystem
HPP	Hydro Power Plant
km	Kilometer
kV	Kilovolt
MEPA	Ministry of Environmental Protection and Agriculture of Georgia
MoESD	Ministry of Economy and Sustainable Development of Georgia
MW	Megawatt
OHL	Overhead Line
S/S	Substation
TSO	Transmission System Operator
TYNDP	Ten Year Network Development Plan
USAID	United States Agency for International Development
VRE	Variable Renewable Energy
WPP	Wind Power Plant

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INTRODUCTION

In October 2016, Georgia signed the Energy Community Treaty (EnCT) signaling the country's commitment to direct future energy planning and market development towards approximation with the European Union (EU). This step commits Georgia to enhancing the security of energy supply by promoting the development of relevant infrastructure, increasing market integration and gradual regulatory approximation towards key elements of the EnCT, and promoting the use of renewable energy sources. In order for Georgia to meeting its strategic commitments in the energy sector, the United States Agency for International Development (USAID) is providing technical assistance and policy advice on legal, regulatory and institutional reform issues, including facilitating investment and deal structuring, engineering and environmental analyses, financial planning, and outreach, and other consulting. This technical assistance, ("USAID Energy Program") is being rendered by Deloitte Consulting LLP, under a USAID contract, AID-OAA-I-13-00018.

The objective of USAID Energy Program is to support Georgia's efforts to facilitate increased investment in power generation capacity as a means to increase national energy security, facilitate economic growth, and enhance national security. The project will have a significant impact on energy market reform efforts of the Government of Georgia (GoG) to comply with the country's obligations under the EnCT. The investment objective will be achieved through the provision of technical assistance to a variety of stakeholders in the energy sector.

The purpose of USAID Energy Program is to: (1) support Georgia in energy market development per Georgia's obligations under the EnCT, (2) build the capacity of the GoG and relevant institution(s) to evaluate the fiscal and long-term impacts of regulatory changes, (3) promote energy investments, primarily in variable renewable energy development, (4) to support integration of non-hydro renewable energy into the power system, and (5) provide strategic advisory services to the GoG to increase Georgia's energy security.

The ultimate goal of this Program is to enhance Georgia's energy security through improved legal and regulatory framework and increased investments in the energy sector. The ultimate expected outcome of this Program is an energy market legal and regulatory framework that complies with European requirements and encourages competitive energy trade and private sector investments.

USAID Energy Program is tasked under its contract, AID-OAA-I-13-00018, to assist the Ministry of Economy and Sustainable Development of Georgia (MoESD) in developing a support scheme for encouraging investment in electricity generation infrastructure to promote the development of energy generation from a diversified source of native resources.

To facilitate making energy projects eligible for financing, USAID Energy Program is providing technical assistance to the Variable Renewable Energy (VRE) developers to construct and operate renewable energy generation projects, primarily variable renewable energy generation projects. The program assists in the preparing application for interconnection to country's grid. For these reasons, USAID Energy Program prepared recommendations for Infinite Energy on the connection of Imereti 1 wind power plant to Georgian Transmission System.

SUMMARY

Infinite Energy requested USAID Energy Program to provide recommendations on the connection of Imereti Wind Power Plant (WPP) to Georgian Transmission System. The MoESD (former Ministry of Energy) granted a concession to Infinite Energy for the construction of a WPP in the region of Imereti. Over the last years, there has been a strong penetration of renewable energy resources into power systems all over the world. Wind energy generation will play a vital role in the electric energy sector in Georgia for the coming years. The connection of wind generation to electrical power systems influences the system operation point, the load flow of real and reactive power, nodal voltages and power losses. The rising impact of wind power generation in power systems forces system operators to extend grid connection requirements to ensure its accurate operation.

Three options were considered for interconnection. The main recommendation is to connect at the highest voltage level, 500 kV, for technical, cost, and environmental reasons.

DESCRIPTION OF THE PROJECT

Imereti 1 WPP will be developed within two areas (boundaries) which are given to Investor in concession by the MoESD. Once the wind measurements are carried out, the WPP will be built. According to a preliminary wind resource assessment, the location of Imereti WPP is suitable for the installation of up to 100 wind turbine generator units with the total installed power of 400 MW. The implementation of the Imereti WPP project is planned to be accomplished in several phases. The initial phase of the project envisages the construction of only 36 wind turbines (approx. 150 MW). Future integration of other wind turbines is planned for the later phases. Two alternative options are reviewed for the connection of the WPP to the transmission grid to nearest 500 kV grid and 220 kV grid. The first option considers the construction of the 500 kV type substation. 500 kV Overhead Line (OHL) Kartli-2 with a total length of 164 km runs near Imereti WPP area. The line is part of the 500 kV Georgian Transmission Network and connects important 500 kV nodes: Substation (S/S) Zestaponi 500/220 kV and S/S Ksani 500/220/110 kV. The Option 1 takes advantage of the existing line proximity in a way that new S/S Imereti substation will be built no further than 500 m from the existing OHL. The connection of the existing 500 kV OHL to the substation will be carried out in such a way that both ends of the cut-out line will be connected to S/S Imereti. The second option considers the connection to the 220 kV transmission network. There is no 220 kV network in the vicinity of the Imereti WPP area, therefore the closest possible point of connection is located at the S/S Khashuri substation. So, to accomplish this connection, it is necessary to build a 220 kV Double Circuit OHL in length of approximately 36 km.

Based on these considerations IVICOM Consulting outlined three options for the connection of the WPP substation to the transmission grid:

- **Option 1** – construction of S/S Imereti 500/35 kV and connection to the existing 500 kV OHL Kartli-2 via double circuit 500 kV OHL with a length of 0.5 km;
- **Option 2** – construction of s/s Imereti 220/35 kV connection to S/S Khashuri 220/110 kV via single circuit 220 kV OHL with a length of 36 km;
- **Option 3** – construction of two S/S Imereti-I 220/35 kV and Imereti-II 220/35 kV connection to S/S Khashuri 220/110 kV via a double circuit 220 kV OHL with a length of 36 km.

Option 3 has the same characteristics as option 2, but doesn't propose any added value to the project, apart from costs increase due to additional 220 kV substation and is therefore is rejected as a possible option.

COST BENEFIT ANALYSIS

The cost analysis for the project was made on the basis of the Cost Benefit Analysis (CBA) prepared by IVICOM Consulting. The range of estimated costs for three initial options for the completion of the connection to the transmission grid are outlined below:

- **Option 1** – S/S Imereti 500/35 kV connected to 500 kV OHL Kartli-2, cost - EUR 11,279,000
- **Option 2** – S/S Imereti 220/35 kV connected to s/s Khashuri 220/110 kV, cost -EUR 5,074,000
- **Option 3** – S/S Imereti-I 220/35 kV and s/s Imereti-II 220/35 kV, cost - EUR 20,428,000

The initial three options were reduced to two viable options for further cost benefit analysis and the construction costs for these two selected options are listed below.

Table 1: Cost Estimation for Interconnection

N	Description	Option 1: Connection to 500 kV OHL Kartli-2 Costs, EUR	Option 2: Connection to 220 kV s/s Khashuri Costs, EUR
1	Power transformer	2,100,000	1,400,000
2	Outdoor utilities	7,387,000	2,589,000
3	Switchgear and electrical indoor equipment	870,000	895,000
4	SCADA and Communications	160,000	160,000
5	Substation control building and relay building	230,000	180,000
6	Bop engineering	70,000	70,000
7	OHL connection to the transmission grid	372,000	9,720,000
8	**Total**	**11,279,000**	**15,074,000**

SCADA – Supervisory Control and Data Acquisition

The difference between the two selected options is EUR 3,795,000 and shows that the Option 1 has a higher net benefit and is preferable for the connection of the substation to the transmission grid.

LEGAL ASPECTS

There are no specific legal requirements in the existing Georgian legislation for the connection of wind generators to the transmission grid. There is in the legislation a general reference to benefits that are expected from generated energy from renewable energy sources, notably in wind and solar projects. In this case, the existing legal and regulatory framework and the technical and environmental standards and regulations should be considered as a basis for connection requirements.

Security of supply is important for the Georgian power system, which is small size and radial layout. The Transmission System Operator (TSO), Georgian State Electrosystem (GSE) notes that the acceptable total capacity to absorb from all windfarms into the Georgian power system is 100 MW until 2021. And the perspectives of increasing to 400 MW (with the consideration of commissioning of all planned regulating HPPs and cross-border lines) in 2025-2030[1], but not more than 45 MW for each wind geographic region[2]. The plan by Imereti to connect 150 MW would need storage to comply with this 45 MW limit. Or the Network Development Plan would have to be revised.

TECHNICAL ANALYSIS

Option 1 – S/S Imereti 500/35 kV is a solution that will ensure the safe evacuation of generated power, due to connection to a strong 500 kV network. This option will ensure that, in case of future Imereti WPP extension (up to 400 MW), no additional works will be needed to strengthen the existing local network or substation/s.

Option 2 – S/S Imereti 220/35 kV provides the possibility of evacuating only the first phase of the Imereti WPP generated power, due to a limited capacity of the current 220 kV local network. Future expansion of Imereti WPP with the addition of new wind turbines won't be possible without the major reinforcement of the existing 220 kV network. Also, the need to build a 36 km additional OHL to connect future S/S Imereti.

The existing S/S Khashuri makes this option less appealing due to the estimated investment costs and environmental (and social) impacts.

Option 3 – two S/S Imereti I and Imereti II 220/35 kV entails problems typical to the Option 2 and does not offer any added value, except cost increases due to additional 220 kV substation, and is therefore rejected as a viable option.

The transmission network of Georgia is divided into 12 electrical districts. In the Option 1 S/S Imereti 500/35 falls under the district Tbilisi-Ksani-Kvemo Kartli and district Imereti. Results from the analysis, conducted by GSE, regarding the opportunities of connecting new generation power to 500 kV transmission network (for 500 kV OHL Kartli-2 connecting substations) is sufficient to evacuate the produced power during the summer and winter period until 2027. Data reveals that the transmission capacity of 500 kV OHL Kartli-2 is sufficient to evacuate the energy of the WPP Imereti, not just in case of the first phase of project development (150 MW), but also in potential future phases of additional wind turbines integration (400 MW). It should be noted that additional and thorough power flow analysis (and other type of analysis) should be conducted to make a definitive conclusion regarding capacities.

For both Options 1 and Option 2, the single contingency (N-1) criterion is met. This issue, however, requires additional and thorough Power Flow Analysis. Although the connection in the Option 2, between future S/S Imereti 220/35 kV and the existing s/s Khashuri is proposed with a branch network connection of 220 kV D/C OHL link, it is less reliable compared to two-way 500 kV ring connection of s/s Imereti in the Option 1. In addition, the Option 1 provides readiness for the future integration of additional wind turbines as a part of further developments (should such developments prove economic to implement).

Option 2 takes into account the construction of the 220 kV type substation. There is no 220 kV network in the vicinity of the wind power plant in Imereti area, therefore the closest possible point of connection is located at the s/s Khashuri substation. To accomplish this connection, it is necessary to build a 220 kV double circuit OHL in length of approximately 36 km. Currently, there are 3 unequipped spare 220 kV bays in s/s Khashuri, which offer the possibility for connection of the incoming 220 kV double circuit OHL to two spare 220 kV bays of s/s Khashuri.

For integration of generation to the transmission grid, if the Option 2 is preferred, WPP Imereti falls under the district of Shida-Kartli district. The results of the analysis, conducted by GSE, regarding the opportunities for

[1] GSE Ten-Year Network Development Plan 2018 – 2028
[2] GSE Ten Year Network Development Plan 2018 – 2028 determined 9 geographical regions for wind energy development

connecting the new generation power to 220 kV transmission network (to s/s Khashuri) show that 17 MW new capacity can be connected to s/s Khasuri.

The presented material contains no data regarding the calculations of network losses and voltage drops of electricity lines. In order to avoid the overestimation or underestimation of the electricity lines size, power losses and voltage drop in the network have to be taken in the sizing consideration.

GSE stated in Ten - Year Network Development Plan (TYNDP) 2018 – 2028, that starting from 2021 up to 2030, sum installed capacity of wind farms in Georgian power system must not exceed 400 MW but only with the consideration of below presented conditions:

1. Commissioning of 500 kV highway “Jvari-Tskaltubo-Akhaltsikhe” parallel of 500 kV OHL “Imereti”;
2. Commissioning of second 500 kV OHL connecting Georgia to Russia;
3. Commissioning of seasonal regulating large hydro power plants (such as “Khudoni”, “Namakhvani”, “Nenskra”, “Tskhenistskali”);
4. Diversification of 400 MW power coming from the wind power plants on the existing wind zones in such way that maximum amount of power in each zone must not exceed 45 MW;
5. Assimilation of the special program complex in order to implement wind forecast with very high precision as well as to conduct analysis of connection wind power, which is already integrated to SCADA.

In TYNDP 2018 – 2028 GSE proposed for the wind developers that in order to integrate wind station having capacity higher than the acceptable capacity given in the TYNDP, relevant company shall build a storage plant or battery, which will, for at least 8 hrs, provide accumulation (consumption) of such power and the already utilized capacity.

Figure 1: Single Line Diagram of Georgian Transmission Network

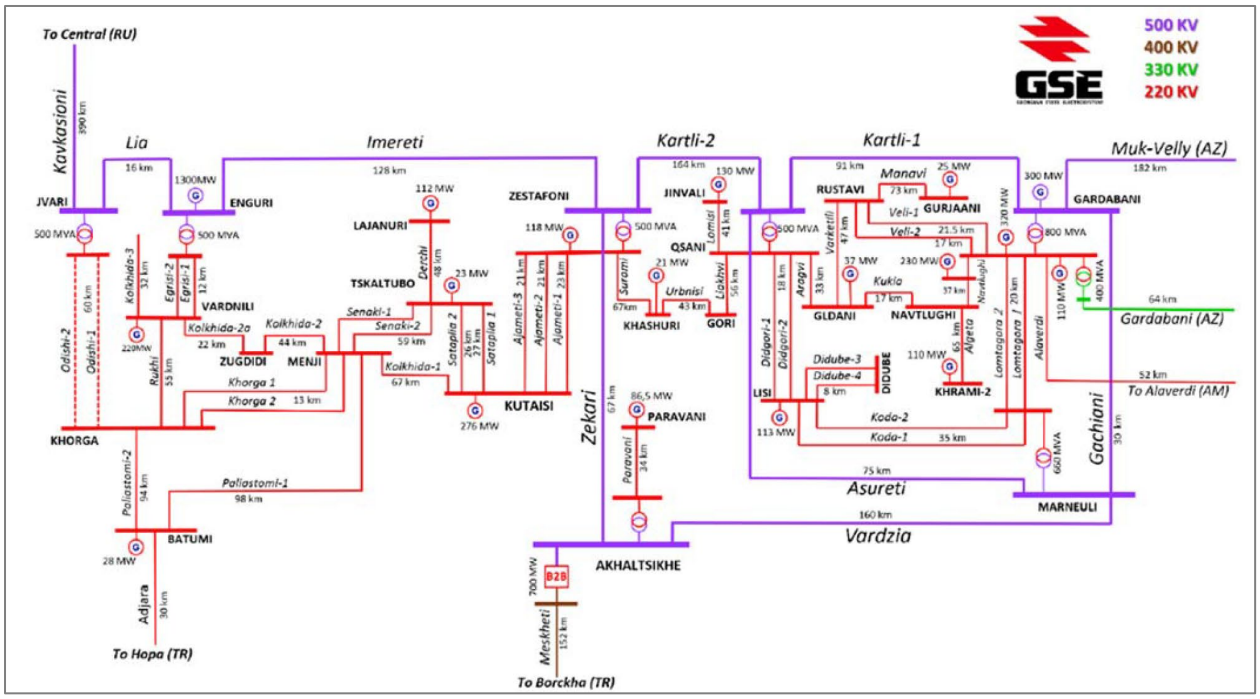
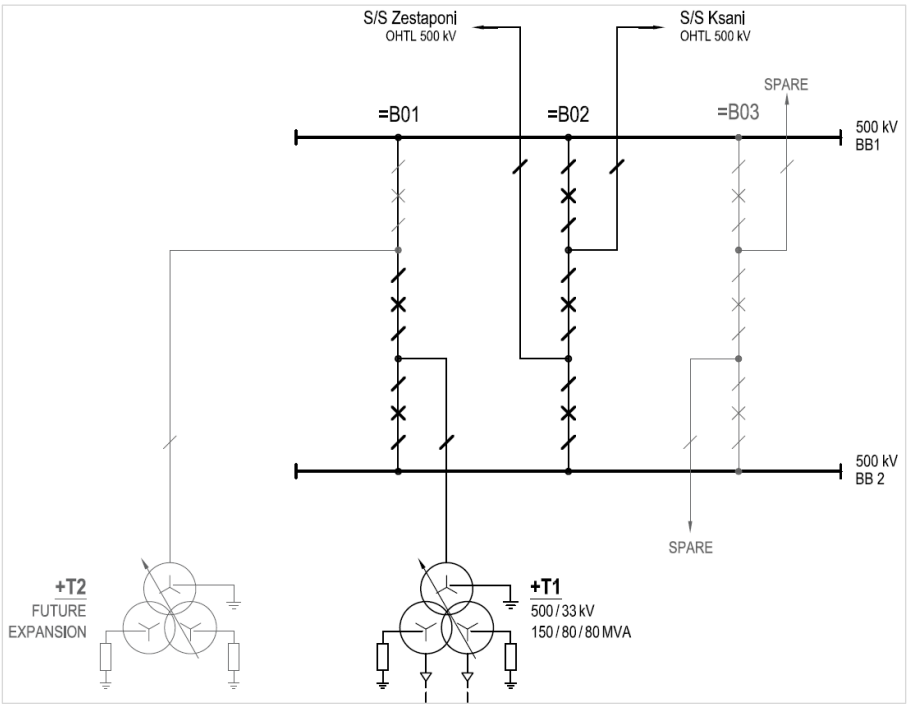


Figure 2: S/S Imereti 500 kV Busbar System



ENVIRONMENTAL IMPACT

Construction of 220 kV D/C OHL will have a significant environmental impact. Some negative impacts can be expected, such as soil erosion after vegetation clearance for corridor (60 m in wide), due to land and soil formation for the new 220 kV OHL, air pollution due to dust and fumes during construction and increased noise and vibration. The proposed route envisages the avoidance of urban and inhabited parts, therefore the social impact is not expected.

With its length of 36 km, 220 kV OHL will have a significant environmental impact compared to the 0.5 km 500 kV line and option 1 is the preferred option due to being more environmentally friendly. Construction of 36 kV OHL falls under the Annex I projects of the Law of Georgia- Code on Environmental Assessment that implies mandatory Environmental Impact Assessment (EIA) Procedure. Accordingly, the Option 2 may not be considered unless the positive Environmental Decision issued by the Ministry of Environmental Protection and Agriculture of Georgia (MEPA).

In overall, the Imereti wind farm project needs to undergo Environmental Screening procedure in accordance to the Law of Georgia- Code on Environmental Assessment in its early development stage. The latter procedure will inform whether the planned project is subject to EIA. If required for the project, the EIA report is to be prepared and submitted to the MEPA for the Environmental Decision. The issuance of the Environmental Decision or the decision on the refusal to implement the project takes no less than 51 (fifty-one) and no more than 55 (fifty-five) days after the registration of an application. Though, the preparation of EIA report may take from several months up to 2 years.

The Environmental Decision is the precondition for starting construction stage and hence for the implementation phase of the project development.

CONCLUSIONS AND RECOMMENDATIONS

1. Based on the CBA of the two shortlisted options, connection to the transmission grid through 36 km 220 kV OHL from S/S Imereti to S/S Khashuri will increase the costs of the project by EUR 3,795,000. Therefore, the Option 1 for connection of S/S Imereti to 500 kV OHL Kartli-2 is more economically efficient compared to the Option 2;
2. According to the analysis, conducted by GSE, the transmission capacity of 500 kV OHL Kartli-2 is sufficient to evacuate the energy of the wind power plant Imereti, not only in case of the first phase of project development (150 MW), but also in potential future phases of additional wind turbines integration (400 MW). According to the analysis conducted by GSE, S/S Khashuri, without the reinforcement of the 220 kV network and s/s Khashuri, has a capacity limit for the connection of new generation capacity of 17 MW, which is not enough to integrate 150 MW capacity of the Imereti wind power plant for the analyzed period until 2027;
3. For both Option 1 and Option 2, the single contingency (N-1) criterion is met;
4. For the selected options, additional and thorough Power Flow Analysis need to be carried out for meeting the single contingency criterion (N-1);
5. In order to avoid the overestimation or underestimation of the power lines, power losses and voltage drop in the network have to be taken in the sizing consideration;
6. The connection in the Option 2 between S/S Imereti 220/35 kV and the existing S/S Khashuri is proposed with a branch network connection of 220 kV double circuit OHL link, which is less reliable than two-way 500 kV ring connection of S/S Imereti to 500 kV Kartli-2 in the Option 1;
7. Option 1 provides readiness for future integration of additional wind turbines as a part of further developments of the wind farm (should such developments prove economic to implement);
8. The connection of S/S Imereti to the 500 kV transmission network will have a less environmental impact compared to connection to the S/S Khashuri with 36 km 220 kV OHL which will have a significant environmental impact, therefore the Option 1 is preferred option.
9. Additional CBA need to be prepared for the costs of Imereti WPP in respective stages of development, taking into account the requirement of GSE for construction by the wind power plant of a storage plant or battery if the plant exceed the capacity determined in TYNDP.
10. Utilization of centralized wind forecasting system by GSE will facilitate the process for integration of the energy produced by large scale wind power plants.

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