Effects Of The Adoption Of Renewable Energy Sources Within The "Baikal-Khövsgöl" Cross-Border Recreation Area

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***Abstract* — The study provides an analysis of the current state of the power supply system within the "Baikal-Khövsgöl" cross-border recreation area, which stands for the area spanning from the southern part of Lake Baikal to Lake Khövsgöl through the Republic of Buryatia (Tunkinsky and Okinsky districts). There are a fairly large number of consumers connected to the end sections of transmission lines, as well as decentralized consumers in the area in question. The operating parameters of the power grid were evaluated in terms of a prospective increase in electrical loads. To ensure reliable power supply to consumers and compliance with the requirements of GOST R 32144-2013 with regard to voltage deviations, the feasibility of using renewable energy sources was investigated. Given the geographical location and the presence of special areas of conservation, the use of renewable energy is a strategic area of Russian-Mongolian cooperation. The wind energy and solar energy potential in the "Baikal-Khövsgöl" cross-border recreation area was assessed using the NASA POWER project datasets. A comparative analysis of the financial viability of solar power plants, wind power plants, and small HPPs was made for the conditions of this geographical area. Calculations of the power grid operating parameters were carried out to determine the sites for installation and installed capacity of renewable energy sources, taking into account the prospects for the growth of electrical loads.**

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***Index Terms* — recreation area, renewable energy sources, solar and wind energy potential, remote consumers, electric power quality, voltage deviation, reactive power compensation units.**

I. Introduction

The Baikal-Khövsgöl basin is one of the geographical areas whose sustainable development is not only of national but also of great international importance. Mechanisms for the conservation of the natural and historical biosphere and the rational use of natural resources in the basin of the unique ecosystems of Lake Baikal (Russia) and Lake Khövsgöl (Mongolia) warrant priority attention. The basin of Lake Khövsgöl, which is one of the stable main sources that feed the Selenga River and, consequently, Lake Baikal, remain almost untouched by human activities. There are some threats to the security of the unique ecological system of lakes, and a network of special areas of conservation has been created to overcome them [1].

The Russian-Mongolian border section at the Mondy-Khankh border crossing is the interface zone between two large national parks: the Lake Khövsgöl National Park (Mongolia) and the Tunkinsky National Park (Russia). The Khardyl-Sardyk nature reserve, adjacent to the Lake Khövsgöl National Park borders in the south-west, forms a single large tract of land with the latter. On the Russian side of the border, there is the Pribaikalsky National Park and the Irkutny sanctuary [2, 3].

Currently, special conservation areas are actively involved in ecotourism: new economic mechanisms of their operation are being introduced; they are being integrated into the sphere of social and economic development; government funding is being increased; participation in environmental projects financed by international nonprofit organizations is being expanded; and they are being reorganized and consolidated [2, 4].

In general, the Baikal-Khövsgöl natural area is very promising for the development of international tourism. It is home to four national parks: Pribaikalsky, Zabaikalsky, Tunkinsky, and Khövsgöl; Baikalo-Lensky, Baikalsky, Barguzinsky, Ulan-Taiga, and Khardyl-Sardyk nature reserves [2, 3]; a lot of sanatoriums; recreation facilities; and sites of the tourist and recreational kind. Lakes Baikal and Khövsgöl are connected by a highway passing through the Tunka valley. The region is dominated by middle mountainous terrain, and close to it, on the Russian-Mongolian border, there is Mönkh Saridag, the highest mountain in the Sayan Mountains, which is a popular destination for sports tourism [5].

The development of ecotourism should be carried out with great care as it is required to ensure that all conditions are in place to minimize environmental impacts. This applies mostly to the electric power supply system, which should be developed at a faster pace to back the growth of tourism infrastructure in the region.

Renewable energy sources (RES) have a lower impact on the environment than conventional sources of energy. Their adoption may prove feasible in the districts remote from the centralized power supply or those districts where extended outages take place due to long power lines, as well as the districts that are home to special conservation areas and tourist and recreational zones [6-10].

In Mongolia, support for renewable energy development at the national level is enabled by the National Renewable Energy Program. The program claims to promote and extend renewable energy development in Mongolia, to create conditions for ecological balance, to reduce unemployment and poverty, and to promote social and economic sustainable development. In Russia, mechanisms to stimulate the development of the renewable generation were introduced by Resolution of the Government of Russia No. 449 "On the mechanism of incentives to use renewable energy sources in the wholesale electricity and capacity market" dated May 28, 2013, and Resolution of the Government of the Russian Federation No. 47 "On amending certain acts of the Government of the Russian Federation on the incentives to use renewable energy sources in retail electricity markets" dated January 23, 2015.

In connection with the above mentioned, the use of RES in the cross-border recreation area "Baikal-Khövsgöl" is one of the strategic directions of expansion of the Russian-Mongolian cooperation and the relevance of the assessment of economic and technical effects of the implementation of these activities needs no further justification.

II. Analysis of the current state of the electric power supply system in the "Baikal-Khövsgöl" cross-border recreation area

In Mongolia, the centralized power supply covers all 4 sums bordering Lake Khövsgöl. The Renchinlkhümbe sum located on the western shore of Lake Khövsgöl is connected to the Tsagaannuur sum by a power line. The Khatgal and Chandmani-Öndör sums, located in the south and south-east of the lake, respectively, are connected to Mongolia's central power grid. On the northern shore of the lake, there is the Khankh sum, which is supplied with electricity from the territory of the Republic of Buryatia via the 10 kV interstate power line "Mondy-Zavod" that is 35 km long.

In the Russian part of this recreation area, the key elements of the electric power supply system in the Baikal-Khövsgöl zone are the 110/35/10 kV "Kyren" and 110/35/10 "Zun-Murino" substations located in the Tunkinsky district. These substations are connected by a 110 kV line, as well as a 35 kV line passing through the following localities of the Tunkinsky district: Akhalik, Khuray-Khobok, Arshan, Zhemchug, Nilovka, and Badary.

Electric power supply to consumers of the Okinsky district is provided by a single-circuit 110 kV power line "Kyren — Mondy — Samarta", a single-circuit 35 kV power line "Mondy — Sorok — Samarta", and a single-circuit 35 kV power line "Sorok — Orlik" (Figure 1).

Transmission lines are characterized by significant wear and frequent prolonged shutdowns [11]. In case of a failure in one of the power lines, about 4,360 people, 1 hospital, 6 schools, 6 kindergartens, 7 boiler house, and 5 localities are affected by power outage [11]. There are no redundant power lines available. Work to restore the power is complicated by the mountainous terrain and the large distance covered by power lines. These districts are among the underdeveloped and hard-to-reach places in the Republic of Buryatia. In case of long-term outages, diesel power plants at the 35 kV Orlik substation and the 35 kV Sorok substation with the capacity of 0.5 MW and 0.25 MW, respectively, are used for power supply to consumers. The Orlik substation is capable of handling the 1.4 MW while the Sorok substation is limited to the load of 0.3 MW. Thus, when one of the 35 kV lines cuts off electricity, diesel power plants are unable to carry the full load, and

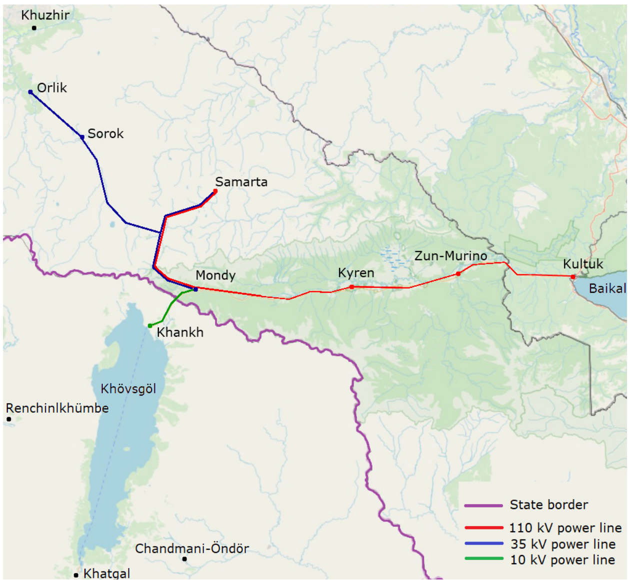

Fig. 1. General layout plan of the "Baikal-Khövsgöl" cross-border recreation area.

hence there is a cap for power consumption imposed on consumers [11].

Thus, the district under consideration is that of a large number of consumers connected to the end segments of transmission lines, as well as decentralized consumers supplied with electricity from low-efficiency diesel power plants.

When dealing with the system of electric power supply to consumers within the “Baikal-Khövsgöl” cross-border recreation area, one should highlight the low level of voltage at the consumer's end due to the extended length of single-circuit power lines. The dotted lines of the schematic diagram of the electric power supply in this geographic area (see Figure 2) indicate the planned construction of the Khuzhir power transmission line and the 35/10 substation for the power supply of the Konevinsky gold deposit. According to the Strategy of social and economic development of the Republic of Buryatia to 2035, the development of this field and the start of its operation is planned for the period from 2019 to 2021. [12]. The expected installed capacity of consumers at the Khuzhir substation is 4.1 MW [13].

Power grid operating parameters for the diagram in Figure 2 were calculated in two stages. At the first stage, all voltages at the nodes were assumed to be equal to nominal voltages, and the flows and power losses in the network sections in the direction from the loads to the power source were determined. The data on the level of electrical loads are assumed as per [13]. At the second stage, based on the specified voltage at the Kyren power substation and power flows at the sites, we calculated voltage losses at the sites and the substation busbar voltage.

Figure 3 presents the calculated electrical schematic diagram with the results of estimating the power grid operating parameters that has the Khuzhir 35/10 substation factored out. Busbar voltage levels of the 6, 10, 35 kV substations were obtained given the regulating capabilities of transformers. The voltage of the low voltage buses of Mondy, Sorok, Orlik, and Khankh substations ranges from 9.5 to 10 kV. The voltage deviation from 10.5 kV ranges from 5.1 to 9.9 % at the limit settings of voltage regulators. As per GOST R 32144-2013, the European standard EN 50160-2010 [14] such deviations are permissible. However, the expected increase in electrical loads due to the development of the geographic area under consideration will lead to a voltage deviation of more than 10% for the substation busbars.

Table 1 presents the results of estimating voltage levels for substation busbars under several power grid operating parameters: at rated transformation ratios and at available limit settings of regulators of devices of voltage regulation of transformers; with the

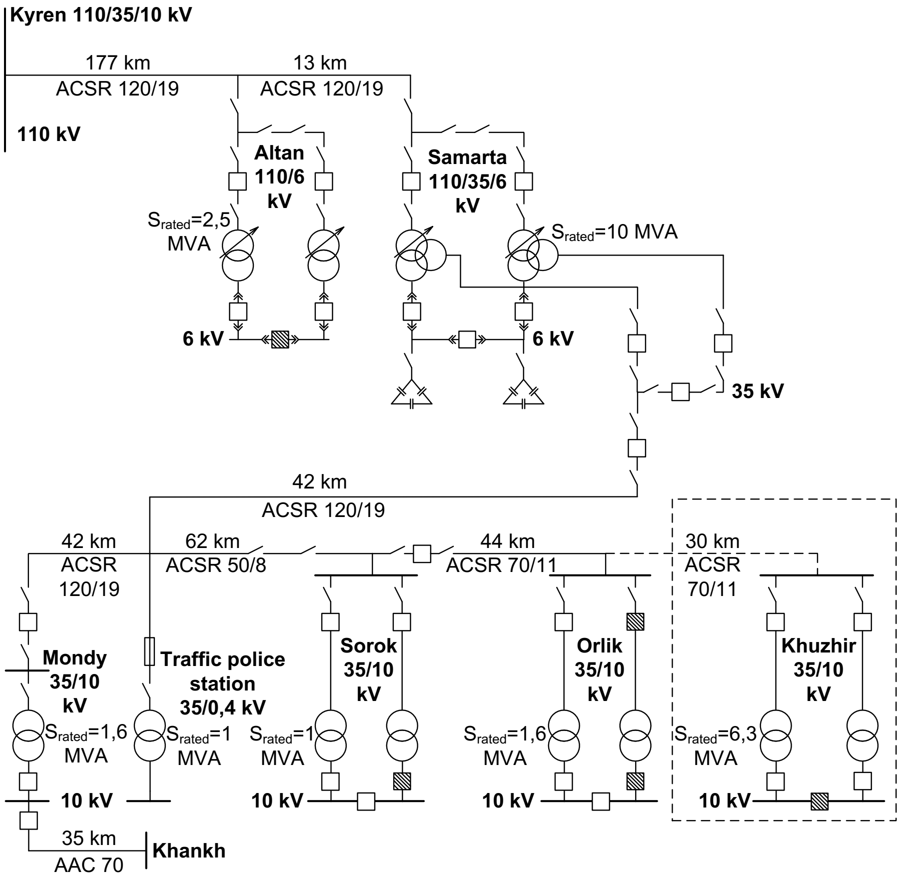

Fig. 2. Electrical schematic diagram of the power grid.

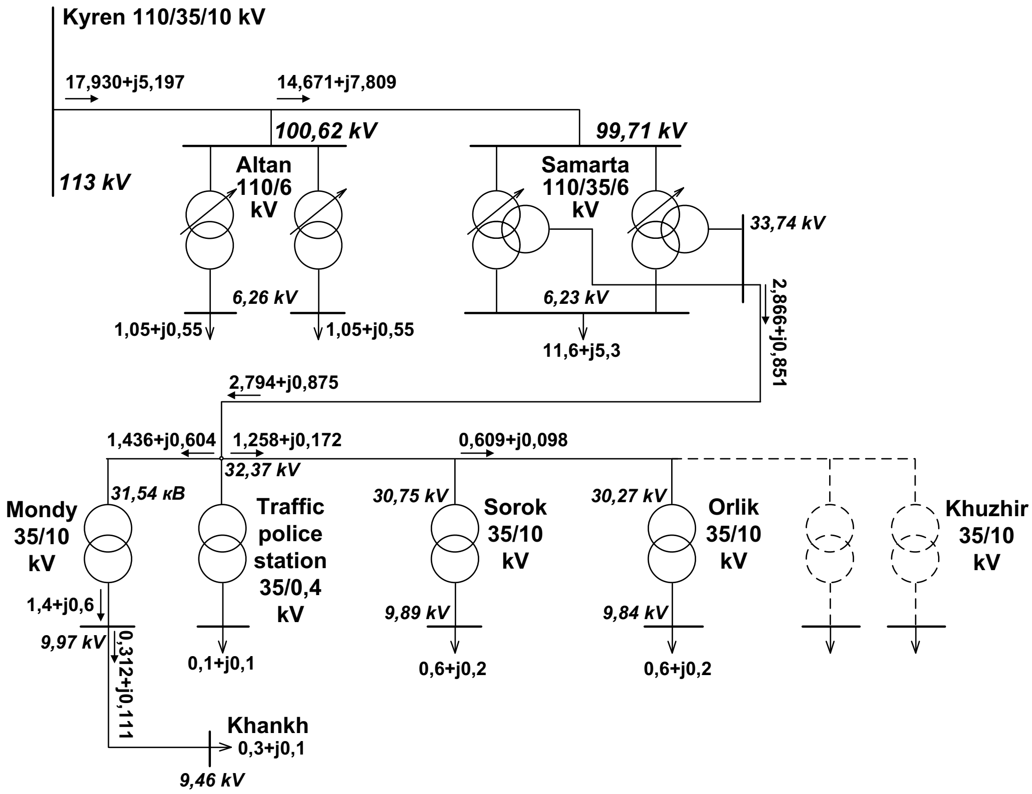

Fig. 3. Calculated power grid operating parameters.

Khuzhir substation factored in and out.

To assess the efficiency of measures aimed at increasing the voltage for the busbars of substations, Table 1 presents the relative voltage deviations from rated values δU, as well as estimates of the losses of active power ΔP in the power grid (Figure 2).

The estimation of the operating conditions considering the Khuzhir substation assumed its design load was assumed to be 50% of the installed capacity, and the power factor was assumed to be 0.8. The voltage for the low voltage buses of Mondy, Sorok, Orlik, Khankh, and Khuzhir substations ranges from 3.8 to 8.3 kV. The voltage deviation from 10.5 kV ranges from 21.1 to 64.3 % at available limit settings of voltage regulators. Thus, the growth of electrical loads will lead to significant deviations from the requirements stipulated by GOST R 32144-2013 and EN 50160-2010 with respect to the electric power quality when supplying power to consumers within the "Baikal-Khövsgöl" cross-border recreation area.

The following measures can be considered to increase the voltage level at the substation busbars: overhauling of the 35/10 kV Mondy substation with its conversion to 110/35/10 kV voltage, installation of compensating units and adoption of renewable energy sources located near consumers.

The estimation of the electric power operation performed in [12] has shown that overhauling the Mondy substation, including the adoption of compensating units at the Khuzhir substation, will not solve the problem of voltage deviation at the consumer's end.

In what follows we present an analysis of the RES potential within the "Baikal-Khövsgöl" cross-border recreation area carried out to assess the possibility and economic feasibility of construction of small power plants

Table 1. Results of estimating voltage levels for substation busbars and losses of active power in the power grid.

Localities / Parameters / Operating parameters	Mondy U, kV	Mondy δU, %	Khankh U, kV	Khankh δU, %	Sorok U, kV	Sorok δU, %	Orlik U, kV	Orlik δU, %	Khuzhir U, kV	Khuzhir δU, %	ΔP, %
With the Khuzhir substation factored in											
1. At rated transformation ratios	8.9	15.5	8.3	20.9	8.8	16.3	8.8	16.7	-	-	8.5
2. At limit settings of the regulators of transformer voltage regulation devices	10.0	5.1	9.5	9.9	10.0	5.9	9.8	6.3	-	-	
With the Khuzhir substation factored out											
3. At rated transformation ratios	7.3	30.9	6.6	37.6	5.1	51.1	3.6	65.8	2.3	78.2	14.6
4. At limit settings of the regulators of transformer voltage regulation devices	8.3	21.1	7.7	26.9	6.2	40.7	4.8	54.2	3.8	64.3	

III. Assessment of the wind energy potential of the "Baikal-Khövsgöl" cross-border recreation area

To assess the wind energy potential of the "Baikal-Khövsgöl" cross-border recreation area we used the NASA POWER project resources [18] that allow obtaining the data on the average annual wind speed for the period 1983 to 2013 at a height of 10 and 50 m. Figure 4 presents a map of the average annual wind speed at the 10 m height, based on these data.

The analysis of the distribution of wind speeds during the year for all the localities under consideration shows the same two-peak pattern. Wind speeds are highest in the spring (April) and the fall (November, December) and lowest during the summer (July, August). The patterns of wind activity coincide with the average load schedule of the localities, which will allow for the efficient use of wind energy in the power supply of the population and tourism facilities.

Based on the NASA POWER dataset on the average daily wind speed at the 10 m height for the period from 1983 to 2013, with the help of the Wind-MCA software, we estimated possible electric power generation by the horizontal-axis wind turbine (WT) Aeolos-H 20 (Table 2) in selected localities of the "Baikal-Khövsgöl" cross-border recreation area (Table 3). Wind speed as based on the NASA POWER data is recalculated to match the height

Table 2. Specifications of the wind turbine Aeolos-H 20kW

Parameter	Value
Rated power, kW	20
Cut-in wind speed, m/s	3
Rated speed, m/s	10
Maximum operating speed, m/s	25
Hub height, m	12

of the wind turbine rotor.

The capacity utilization factor (CUF) of WT in the areas under consideration is quite low, being below 10.4. To put this in perspective, as per the capacity supply contract, which is a mechanism of state support for renewable energy projects in Russia, the minimum value of the CUF is set at 27% for the operated WT. When 75-100% of this target value is achieved this will not attract a penalty, when the value is 50-75% of the target the penalty is imposed, while in the case of meeting less than 50% of the target the payment for capacity is declined.

Assessment of the solar energy potential of the "Baikal-Khövsgöl" cross-border recreation area

To assess the solar energy potential of the "Baikal-Khövsgöl" cross-border recreation area the NASA POWER project dataset [15] was used, which allows us to obtain data on the average annual total solar radiation inflow reaching the horizontal surface, given the cloudiness data for the period 1981-2018. Figure 5 shows the map with estimates of the solar radiation inflow based

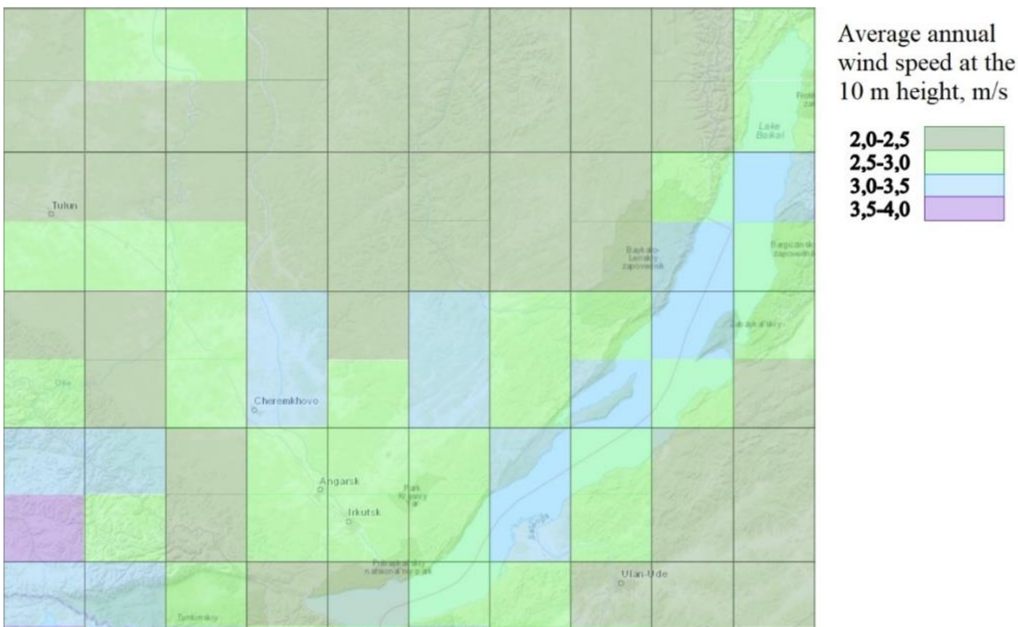

Fig. 4. Map of the average annual wind speed at the 10 m height within the "Baikal-Khövsgöl" cross-border recreation area.

Table 3. Estimates of electricity generation by wind turbines

Locality	Average annual wind speed, m/s	Average annual electricity generation by wind turbines, thousand kWh	Installed capacity utilization factor, %
Russia (the Republic of Buryatia)			
Mondy	3.3	13.1	7.5
Sorok	3.6	17.9	10.2
Orlik	3.6	18.2	10.4
Khuzhir	3.5	15.8	9.0
Mongolia (Khövsgöl aimag)			
Khankh	3.4	14.5	8.3
Renchinlkhümbe	3.5	15.9	9.1

on these data.

Relying on the NASA POWER dataset of the average monthly inflow of total radiation to a horizontal surface that takes into account the cloudiness levels for the period from 1981 to 2015, we used the approach outlined in [19, 20] to estimate possible generation of electricity by photovoltaic (PV) invertors tilted at an angle equal to the local geographic latitude. The AST-240 Multi PV inverter is used for the above assessment (see Table 4). The results of the assessment for individual localities of the "Baikal-Khövsgöl" cross-border recreation area are presented in Table 5.

Table 4. - Specification of AST-240 Multi PV inverter.

Parameter	Value
Maximum power, W	240
Efficiency, %	14.8
Dimensions (LxWxH), mm	1640x992x40

Table 5. Estimates of electricity generation by PV inverters.

Locality	Average annual total radiation incident on a horizontal surface, kWh/m^2	Average annual total radiation incident on a tilted surface, kWh/m$_2$	Average annual electricity generation 1 PVI, kWh	Installed capacity utilization factor, %
Russia (the Republic of Buryatia)				
Mondy	1295	1720	414	19.7
Sorok	1224	1624	391	18.6
Orlik	1229	1625	391	18.6
Khuzhir	1229	1602	386	18.3
Mongolia (Khövsgöl aimag)				
Khankh	1295	1711	412	19.6
Renchinlkhümbe	1287	1698	409	19.4

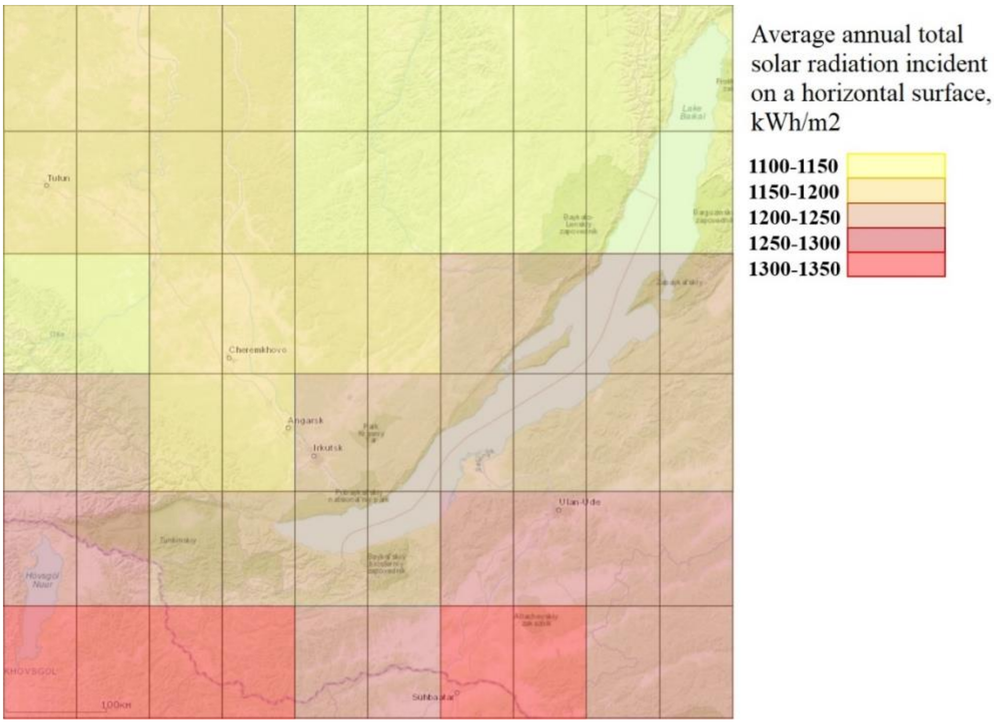

Figure 5. Map of the "Baikal-Khövsgöl" cross-border recreation area with estimates of the average annual total solar radiation incident to a horizontal surface within the area.

The capacity utilization factor in the districts under consideration is relatively high, ranging from 18.3 to 19.7%.

IV. Comparative analysis of the cost efficiency of individual types of RES under the conditions of their adoption in the "Baikal-Khövsgöl" recreation area

Wind power plants (WPPs), solar power plants (SPSs), and small hydropower plants (HPPs) were treated as alternatives for comparing RES-based electric power generation technologies. Table 6 presents interval estimates of specific capital expenditures for these types of power plants with energy accumulation factored out [15-17]. Interval estimates of the CUF for small HPPs are taken from the analysis of similar facilities, while for WPPs and SPPs it is the results of the calculations presented in Tables 3 and 5, respectively. Annual operating costs, including depreciation, are assumed to be 10% of the CapEx for WPPs and small HPPs, and 8% of the CapEx for SPPs. The electricity tariff that assumes a possible growth prospect is fixed in the range of 0.07-0.08 USD/kWh, based on the current (as of September 2019) maximum level of actual unregulated electricity prices in the Republic of Buryatia for the first price category of consumers with a voltage level of 0.4 kV. For Mongolia, the electricity tariff under the Renewable Energy Law is fixed at the level of 0.1-0.15 USD/kWh for wind power, 0.2-0.3 USD/kWh for solar power generation, and 0.08-0.1 USD/kWh for hydropower plants with a capacity of up to 500 kWh [21, 22].

Due to similar conditions with respect to possible changes in maintenance prices and electricity tariffs for the compared options, the cash flow assessment was performed with possible price dynamics and discounting factored out.

It follows from the results of the calculations presented in Table 6 that solar power plants have the greatest economic feasibility for use within the "Baikal-Khövsgöl" recreation area. Solar power generation in Mongolia is particularly promising due to the high legally-backed tariff for electricity produced by this type of plant.

To adopt small HPPs, one should carry out further detailed analysis at specific sites to clarify the CUF and capital expenditures due to a wide interval of estimates of their possible economic effect.

The use of wind energy can only have a limited scope of application, for example, at sites with higher than average wind energy potential due to local terrain features [23].

Thus, one of the most promising areas for improving the reliability of power supply and reducing voltage deviations on the consumer side to the permissible limits under increasing electrical loads is the construction of SPPs.

V. Deciding on the capacity and location of SPPs under conditions of their adoption in the "Baikal-Khövsgöl" recreation area

To determine the rational locations of the SPP sites and the amount of the minimum required installed capacity, calculations of the power grid operating conditions were carried out (Fig. 3). The cost-efficiency of reactive power compensation units (RPCU) was also assessed. The calculations took into account the regulatory capabilities of the transformer voltage regulators and the commissioning of the Khuzhir substation.

Considered were the options of installing RPCUs and SPPs at Mondy, Khankh, Sorok, Orlik, and Khuzhir substations. When working out the options for the installation location of SPPs, one should take into account the difference in solar energy potential of such installation locations However, the decisive influence on the process of solving the problem of voltage deviation at the consumer's end is due to the power supply distance of the installation location from the Samarta power substation. The greatest positive effect on the voltage deviation indicator is achieved by installing SPPs or RPCUs at the most remote substations. Thus, the total voltage deviation of the 5 substations is $\sum \delta U=207.2\%$ (Table 1, Operating parameters 4). Table 7 presents estimates of the total voltage deviation when installing 100 kW SPPs at various substations. Another factor of significant influence is the load at a substation as generated by its consumers.

Choosing the capacity and location of SPPs and RPCUs is an optimization problem. For the preliminary study, the calculation of the operating parameters was carried out for four options of RPCUs and SPPs installation (Table 8).

Option 1. Only the RPCUs installed at Mondy, Khankh, Sorok, Orlik, and Khuzhir substations are used. The capacity of the units was chosen to be 600, 100, 200, 200, 200, 100, 769 kVar, respectively, to fully compensate the reactive power of consumers.

Option 2. SPPs are installed in all localities, the capacity of SPPs is assumed to be equal to 50% of the load power of each of the substations.

Option 3. SPPs are installed only in the most remote

Table 6. Results of evaluating cost-efficiency of adopting RES in the Republic of Buryatia (Russia).

Renewables	CUF, %	Specific CapEx, USD/kW	Specific annual return, USD/kWh		Cost of electricity generation averaged over 25 years, USD/kWh
			Republic of Buryatia	Khövsgöl aimag	
WPP	7,5 to 10.4	1250 to 1560	-83.2 to -79.3	-59.7 to -19.6	0.24 to 0.27
SPP	18.4 to 19.7	1030 to 1200	30.1 to 42.0	238.9 to 421.5	0.08
Small HPPs	30 to 45	2185 to 4215	-34.5 to -106.1	-27.3 to -8.3	0.12 to 0.15

Table 7. Effect of the installation of 100 kW SPPs in individual localities on total voltage deviation at the consumer's end.

Locality	Distance to the Samarta power substation, km	$\sum\delta U$, %	Change, %
Mondy	84	203.85	3.35
Khankh	119	202.30	4.9
Sorok	104	201.31	5.89
Orlik	148	199.89	7.31
Khuzhir	178	181.90	25.3

locations, the capacity of SPPs is chosen as being proportional to the power load of the substation.

Option 4. SPPs are installed in all localities, the capacity of SPPs is distributed to take into account the remoteness and power load of the substations.

Table 9 presents the results of the evaluation of voltage levels of substation busbars under four calculation cases.

When RPCUs are installed the acceptable level of voltage is provided only at the Mondy and Khankh substations, while at the Orlik, Sorok, and Khuzhir substations deviations from the rated voltage range from 17,7% to 27%. It should also be noted that the installation of RPCUs offers little in the way of mitigating prolonged outages at the consumer's end as a result of accidents long power lines are prone to.

- Installation of SPP as per option 2 does not ensure permissible voltage deviations high installed capacity notwithstanding.
- Installation of the SPPs under option 3 proves the most cost-effective and ensures acceptable voltage levels at all substations. However, the problem of power supply redundancy on the consumer part is yet to be solved at the Mondy, Sorok, and Orlik substations.
- Installation of SPPs under option 4 ensures the necessary redundancy and acceptable level of deviation at the consumer's end but requires large capital expenditures.
- The considered options of SPP capacity additions in individual localities assume only minimal prospective growth of electric loads.

For the integrated development of the investigated geographical area, the adoption of RES is the main way of improving reliability, reducing voltage deviations at the consumer's end to acceptable limits, and reducing losses of active power in the power grid. These effects will be achieved with less environmental impact than when relying on conventional energy sources such as diesel power plants.

VI. Conclusion

Currently, special conservation areas are actively involved in ecotourism: The Baikal-Khövsgöl natural territory is very promising in this regard. There are a fairly large number of consumers connected to the end segments of transmission lines, as well as decentralized consumers supplied with electricity from low-efficiency diesel power plants in the investigated area. Further growth of electric loads will affect the quality of electricity: the deviation of voltage levels at the consumers' side will exceed 10%.

An assessment of wind and solar energy potential was made for the studied area. WPPs, SPPs, and small HPPs were considered as alternatives for comparing RES-based electric power generation technologies. The SPPs that have the lowest electricity production cost equal to about USD

Table 8. Installation site and capacity of PFCUs and SPPs for four calculation cases.

Substation	Option 1	Option 2	Option 3	Option 4
	Q_{PFCU}, kVar	P_{SPP}, KW		
Mondy	600	700	-	500
Khankh	100	150	100	100
Sorok	200	300	-	100
Orlik	200	300	-	100
Khuzhir	769	500	900	800
Total capacity	1869	1950	1000	1600

Table 9. Results of the evaluation of voltage levels on the substation busbars and active power losses in the power grid with the use of RES factored in.

Localities	Mondy		Khankh		Sorok		Orlik		Khuzhir		ΔP,%
Options / Parameters	U, kV	δU, %	U, kV	δU, %	U, kV	δU, %	U, kV	δU, %	U, kV	δU, %	
1. Using reactive power compensation units	10.0	4.5	9.6	8.2	8.7	17.7	8.0	23.8	7.7	27.0	12.1
2. Installation of SPPs in all localities with the capacity equal to 50% of the load	10.0	5.1	9.7	8.0	9.3	11.9	8.8	16.1	8.6	18.4	9.3
3. Installation of SPPs in the most remote localities	9.9	6.0	9.5	9.6	9.6	8.6	9.5	10.0	9.5	9.2	8.9
4. Installation of the SPPs in all localities, the power is proportional to the remoteness of the substation and its load	10.1	3.8	9.7	7.3	9.7	7.9	9.5	9.9	9.5	9.8	8.6

0.08/kWh prove the most economically viable for use.

The procedure of choosing the capacity and installation location of SPPs under conditions of their adoption in the Baikal-Khövsgöl recreation area was performed. The estimation of the operating parameters performed under 4 cases of PFCUs and SPPs placement has shown the feasibility of SPP installation at the most remote substations with a higher power load.

Commissioning of small RES-based power plants in the localities of the Baikal-Baikal-Khövsgöl cross-border zone will ensure that the voltage level at the consumer's end meets GOST R 32144-2013 and EN 50160-2010, as well as reduce the loss of active power in the power grid. In the event of prolonged accidents on extended power lines, it will be possible then to supply power to individual consumers responsible for power supply to their respective localities.

Aknowledgements

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References:

[1] Martynova N.A. The soil cover of national parks of the Baikal-Khövsgöl natural area and its monitoring as a required element of sustainable development. Izvestija Irkutskoj gosudarstvennoj ekonomicheskoj akademii (Baikal State University of Economics and Law). 2010. No. 4. P. 360-367. (in Russian)

[2] Evstropieva O.V. Cross-border tourism in neighboring regions of Russia and Mongolia. - Irkutsk: Publishing House of the V.B.Sochava Institute of Geography, Siberian Branch of the Russian Academy of Sciences, 2009. — 143 p. (in Russian)

[3] Kalikhman T.P., Bogdanov V.N., Ogorodnikova L.Yu. Special areas of conservation of the Siberian Federal District. Atlas. - Irkutsk: "Ottisk" Publishing House, 2012. – 384 p. (in Russian)

[4] Evstropieva O.V., Korytny L.M. How to foster the development of cross-border ecological tourism in the Lake Baikal basin. EKO. 2014., No. 12, P. 76-85 (in Russian)

[5] Enkhtaivan D., Evstropieva O.V. Cross-border tourism in Mongolia. Sovremennye problemy servisa i turizma No. 4, 2015, Volume 9, P. 37-43. (in Russian)

[6] Calderón-Vargas, F., Asmat-Campos, D., Carretero-Gómez, A. "Sustainable Tourism and Renewable Energy: Binomial for Local Development in Cocachimba, Amazonas, Peru," Sustainability, Vol. 11(18), p. 4891 (2019).

[7] Katircioglu, S.T. "International tourism, energy consumption, and environmental pollution: The case of Turkey,". Renew. Sustain. Energy Rev. Vol. 36, pp. 180–187 (2014).

[8] Zhang, L., Gao, J. "Exploring the effects of international tourism on China's economic growth, energy consumption and environmental pollution: Evidence from a regional panel analysis," Renew. Sustain. Energy Rev. Vol. 53, pp. 225–234 (2016).

[9] Beer M., Rybár R., Kaľavský M. "Renewable energy sources as an attractive element of industrial tourism," Current Issues in Tourism, Vol. 21 (18), pp. 2139-2151 (2018)

[10] Khaboot, N., Chatthaworn, R., Siritaratiwat, A., Surawanitkun, C., & Khunkitti, P. "Increasing PV penetration level in low voltage distribution system using optimal installation and operation of battery energy storage," Cogent Engineering, 6(1), 1641911 (2019).

[11] The master plan and program of development of the electric power industry of the Republic of Buryatia for years 2019 to 2023, approved by the order of the Government of the Republic of Buryatia dated April 30, 2019, No. 229-r. (in Russian)

[12] The strategy of social and economic development of the Republic of Buryatia to 2035, adopted by the People's Khural of the Republic of Buryatia on February 28, 2019. (in Russian)

[13] The master plan and program of development of the electric power industry of the Republic of Buryatia for years 2016 to 2020, approved by the order of the Ministry of Transport, Energy and Road Facilities of the Republic of Buryatia dated April 30, 2015 No. 65. (in Russian)

[14] Vagin G.Ya. Comments on GOST R 54149-2010, the new standard for electric power quality, and its accompanying standards. Promyshlennaja energetika. 2013 - No. 01, pp.39-43. (in Russian)

[15] HEVEL Group of Companies. Available at: http://www.hevelsolar.com/https://www.hevelsolar.com/catalog/network/ (Accessed on November 14, 2019). (in Russian)

[16] Alternative energy. Available at: http://alen-e.ru/products/22489724 (Accessed on November 14, 2019). (in Russian)

[17] Blyashko, Ya.I. The current state and problems of the small hydropower industry in Russia. Trends in the development of mini HPPs / CJSC "MNTO INSET". International Congress REENCON-XXI, June 06, 2018, Moscow. Available at: https://www.hse.ru/data/2018/06/10/1149857960/%D0%91%D0%BB%D1%8F%D1%88%D0%BA%D0%BE%20%D0%AF.%D0%98.pdf (Accessed on November 14, 2019). (in Russian)

[18] NASA power. Available at: https://power.larc.nasa.gov/ (Accessed on November 31, 2019)

[19] Ivanova I.Yu., Tuguzova T.F., Khalgaeva N.A. Opportunities and issues involved in using solar

radiation for small-scale power generation. Proceedings of the All-Russian conference with international participation "Energy: Management, quality, and efficiency of energy resources use", Blagoveshchensk, May 2011. – P. 360-365 (in Russian)

[20] Ivanova I.Yu., Tuguzova T.F., Khalgaeva N.A. Determination of the optimal renewable energy source capacity for the consumer isolated from the power system. Izvestia RAN. Energetika. 2014. No.3. P.22-28.

[21] Mongolia: Upscaling Renewable Energy Sector Project. Available at: https://www.adb.org/sites/default/files/project-documents/50088/50088-002-pam-en.pdf (Accessed on November 14, 2019). (in Russian)

[22] Law of Mongolia on renewable energy. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/1464%20English.pdf (Accessed on November 14, 2019)

[23] Shakirov V.A., Artemyev A.Yu. Selection of a wind farm site location using terrain and wind flow computer simulation. Proceedings of Irkutsk State Technical University. 2017. Vol. 21. No. 11 (130). P. 133-143. (in Russian)

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