Possibility of using renewable energy sources in the Republic of Ingushetia

M I Malsagov, A R Elbazurov and G R Titova

National Research University Moscow Power Engineering Institute, 14, Krasnokazarmennaya ave., Moscow, 111250, Russia

E-mail: islamaga@mail.ru

Abstract. The article is devoted to an acute problem of the humanity - the scarce of energy sources, in particular in the Northern Caucasus. Therefore it is necessary to use renewable energy as a pure and undeveloped source. In this paper the authors explore the situation in Ingushetia. Nowadays the Republic has got a serious problem of electricity liabilities non-transparency of accounting system, quality and reliability of electricity supply. In the article it is possible to find general features of the region, the analysis of the current situation in the electric industry of the Republic, the power system characteristics, the electric industry development program and profitability of wind, water and geothermal energy analysis. The issue of switching to renewable energy is also considered.

1. Introduction

The civilization today can not be imagined without energy. Improving living conditions, growing life expectancy, needs satisfaction – all these require access to energy. Humanity is in constant search for new methods of obtaining energy, while increasing its consumption. Progress depends on industrial development, which depends on energy [1]. At the same time, we must not forget that energy is one of the serious factors that have an adverse impact on the environment.

The Republic of Ingushetia is an energy-deficient region [2]. The energy system of the republic is characterized by moral and physical deterioration of substations and power lines and, as a result, significant losses in the power grids with increase in electricity consumption by the population.

This growth is predicted in the future. All these factors affect the development of the Republic of Ingushetia and do not allow developing confidently in the industrial sector. One of the ways of energy development, as well as preserving the integrity of the natural heritage is using renewable energy sources.

2. General features of the region

The Republic of Ingushetia is located on the northern slopes of the foothills of the Greater Caucasus Mountain Range (in its central part) and on the small ridges adjacent to it – the Tersky, Sunzhensky and Skalist [3]. Length: from north to south – 144 km, from west to east – 72 km.

The climate of the Republic is continental, alpine, depending on the height above the sea level. The average temperature of January is −5 °C, July + 21 °C. The main river is Sunzha. There are also smaller rivers such as Assa, Fartanga, Armkhi, Guloykhi, Phatonka and Chemulga [4]. The total area of the river basin is 3073 km². There are significant reserves of water power; There is also a network of irrigation canals.
Ingushetia is an agrarian-industrial republic, 60% of the territory is occupied by agricultural land, half of which is arable. The industry of the Republic is underdeveloped.

3. Electric energy development program for the Republic of Ingushetia

In 2016 according to the Russian Government the decree subprogram under the title “Social-economic development of the Republic of Ingushetia for the period from 2017 to 2025” was issued. It is a part of state program “Northern Caucasus Federal District development for the period until 2025”. The main goal of the program is stabilization of social and economic situation in the Republic of Ingushetia providing long-term basis for economic growth and living standards improvement.

To achieve this goal it is necessary to solve the following problems: development of housing and public utilities as well as engineering infrastructure, overcoming technical underdevelopment, maintenance of industrial and agricultural development, development of electricity supply system.

Power self-sufficiency in particular the development of electricity and gas supply systems of the region is of key significance for sustainability of Ingush economy. The launch of important investment projects on creation of industrial and innovation clusters in the Republic make the solution of this problem especially acute. The priority direction is the development of electricity supply system which includes development of the integrated electric grid and generation in the Republic.

The development of generation is important because of the absence of generation facilities in the Republic. Construction of generation facilities will provide regional development according to the Republican focused program including the development of the advanced investment sites.

4. Solar energy development

Solar energy is ecologically pure as it has been coming to the Earth for billions of years and all the processes on the planet are accustomed to it. People must control and use it, preserving by that means the unique climate of the Earth.

The Republic of Ingushetia possesses huge resources of solar energy due to the large number of sunny hours and the level of solar radiation. As an example for our research we took a private house for a big family (more than 4 persons). At the first stage of designing of an autonomous solar power plant (ASPP) we make a list of all using equipment and calculate its energy input and voltage [5]. The recounted voltage of an electric user is also calculated so that to calculate the efficiency factor of an autonomous voltage inverter according to the formula (1):

$$P_{r,i} = \frac{P_{r,i}}{\eta}$$

where $P_{r,i}$ – nominal capacity of receiver $i$; $P_{r,i}$ – capacity of receiver recounted on the main distribution bus of ASPP; $\eta$ – voltage inverter efficiency.

Then we evaluate how long the electric devises are used per day and calculate the daily demand on electric power making a load variance profile. Total capacities of loads in certain periods of time are calculated according to the formula (2):

$$P_{r,j} = \sum_{i=1}^{N} P_{r,i}$$

where $N$ – number of receivers put into the network in j-m period of time

The output capacity of ASPP is determined as the maximum capacity of electric load for a summer daytime interval.

It is possible to get more accurate calculation of the demanded power level if we consider ASPPs of different capacities and state their generation level for each month, and the consumer will choose the capacity available to him on the basis of his requirements. To this purpose we have the data of METEONORM database about monthly insolation in the Republic present in Table 1.
Table 1. Data on insolation in the Republic from METEONORM database

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Insolation, KWh/m² | 39 | 60 | 95 | 127 | 160 | 162 | 170 | 146 | 112 | 75 | 41 | 30 |

After that we calculate the produced energy be means of solar modules, and write to the table 2.

\[ W = kE \]

(3)

where \( E \) – magnitude of insolation for the chosen month, \( P_w \) – capacity of the chosen module, \( k \) – ratio which equates 0.6 and 0.85 during summer and winter periods consequently. For the winter period the months with an average temperature below zero centigrade (November, December, January and February) were chosen.

Table 2. Energy generated by solar modules, kWh

| Month | P_w, kW | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 5.5   | 180.9  | 278.2| 312.5| 417.5| 528.3| 534.3| 560.0| 480.5| 368.0| 247.8| 190.7| 139.3|
| 6     | 197.4  | 303.5| 340.9| 455.4| 576.4| 582.8| 610.9| 524.2| 401.4| 270.4| 208.1| 152.0|
| 6.5   | 213.8  | 328.7| 369.3| 493.4| 624.4| 631.4| 661.8| 567.8| 434.9| 292.9| 225.4| 164.6|
| 7     | 230.3  | 354.0| 397.7| 531.3| 672.4| 680.0| 712.7| 611.5| 468.3| 310.4| 242.8| 177.3|
| 7.5   | 246.7  | 379.3| 426.2| 569.3| 720.5| 728.6| 763.7| 655.2| 501.8| 338.0| 260.1| 190.0|
| 8     | 263.2  | 404.6| 454.6| 607.2| 768.5| 771.1| 814.6| 698.9| 535.2| 360.5| 277.4| 202.6|
| 8.5   | 279.6  | 429.9| 483.0| 645.2| 816.5| 825.7| 865.5| 742.6| 568.7| 383.0| 294.8| 215.3|
| 9     | 296.1  | 455.2| 511.4| 683.1| 864.5| 874.3| 916.4| 786.2| 602.1| 405.5| 312.1| 228.0|

Also the best possible banking angle of solar array was calculated for each month as shown in figure 1:

![Optimal panel inclination angle](image)

Figure 1. Optimum tilt angle of solar modules.

The best possible banking angle during the year was 33 degrees.

5. Water energy development
The own production of energy is one of the key tasks of the region. The Republic of Ingushetia possesses significant water power recourses which is about 1.5 bln kWh that is proportionate to the energy...
demands of the Republic and also wind and solar energy production capabilities. The main part of water power production capabilities of the rivers of Ingushetia (55%) is located on the Assa River. According to the data of predesigning research of the previous years the construction of a hydroelectric power chain on the Assa River is highly recommended: Pervomayskaya WPP, Alkunskaya WPP, Targimskaya WPP, with total capacity of 40 MW each.

For this region one of the most efficient directions of developing non-traditional energy production is using the power of small water flows through micro and small WPP working within the range from 3 to 100 KW and to 5000 KW consequently. On the one hand it is explained by the significant capability of such flows and simplicity of their use, on the other hand the coming exhaustion of the big rivers’ capability in this region.

6. Geothermal energy development
There is a good possibility of using geothermal energy in the Republic of Ingushetia as there are powerful sources of geothermal industrial waters with the temperature up to 160 above zero.

Though nowadays geothermal sources in the Republic mostly serve for thermal energy production, it possible to get electric energy from this source as well because the temperature of the geothermal waters is in the high-potential group [6].

Geothermal energy has a range of advantages: such as low cost which does not depend on climate and weather and has a high ecological compatibility. It is especially important because there are a lot of wildlife areas in Ingushetia and we can not undermine its natural identity.

7. Wind energy development
For the efficient utilization of wind energy we must have full information about the wind as a natural phenomenon and a source of energy [7]. Today we know a long-term average annual wind velocity in the region which serves as the initial feature of the wind intensity general level in the certain place. Based on it we can assess the possibility of using wind energy sources. The data on the long-term wind velocity are given in the Table 3.

| Month     | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Velocity, ms⁻¹ | 5.01 | 4.82 | 4.41 | 4.29 | 4.13 | 3.83 | 4.04 | 4.25 | 4.26 | 4.36 | 4.66 | 4.99 | 4.42 |

According to the evidence we come to the conclusion that the region possesses sufficient wind velocity to consider the point of a wind driven generator construction. It should be mentioned that we do not consider the construction of a wind driven generator higher than 10 m.

Considering a wind driven generator with the following characteristics in the table 4 as an example
The capacity of a wind driven generator is determined by the following expression:

\[
N_{wg} = 0.125 \rho \pi D_{vd}^2 \nu_{hv} (t) \eta_w \eta_h \eta_g = 0.125 \cdot 1.226 \cdot 3.14 \cdot 4^2 \cdot 4.42 \cdot 0.45 \cdot 0.9 \cdot 0.95 = 255.8 \text{ W}
\]  

\[(4)\]

where \(\rho\) – atmospheric density; \(D_{vd}\) – vane diameter; \(\nu_{hv}\) – air flow velocity at the height of the WDG tower at the moment of time \(t\); \(\eta_w\) – windwheel efficiency factor; \(\eta_h\) – herringbone gear efficiency factor; \(\eta_g\) – generator efficiency factor.

Energy output by a WDG is calculated according to the formula:

\[
E_r(T) = \sum_{j=1}^{N} \left( N_{wg}, t(DV_{jr}) \right) T = 0.2558 \cdot 0.98 \cdot 8760 = 2196 \text{ kWh}
\]

\[(5)\]

where \(N_r\) – number of wind velocity repeatability radiuses; \(T\) – monitoring period; \(t(DV_{jr})\) – wind velocity repeatability factor.
Table 4. Data on the long-term wind velocity

| Parameter                                             | Value                      |
|-------------------------------------------------------|----------------------------|
| Capacity at 12 ms⁻¹                                   | 3500 W                     |
| Capacity at 9 ms⁻¹                                    | 2300 W                     |
| Capacity at 5 ms⁻¹                                    | 500 W                      |
| Generator starting torque                            | from 2.5 ms⁻¹              |
| Range of generation altitude                         | 3 to 25 ms⁻¹, more than 20 ms⁻¹ defensive inhabitation is switched on |
| Number of vanes                                       | 3 items                    |
| Material of vanes                                     | reinforced glass fiber with protective covering 3M, USA |
| Rotor diameter                                        | 4 m                        |
| Weight of the wind driven generator with vanes and tail unit: | 130 kg                    |
| Vertical shaft                                        | Bearing current collector  |
| Working lifespan                                      | Minimum 10 years           |

8. Results and Discussion

The research on this point showed that using renewable energy sources has a lot of advantages:

- Sustainable electricity supply which is absent in the most towns and villages of the Republic.
- Electric power of good quality (without voltage and frequency surges)
- Transparent accounting system of electric power
- Possibility of supplying power to the electric grid of the Republic.
- Releasing energy sources due to energetic self-sufficiency of consumers
- Decrease in equipment deterioration as a result of low-quality and unstable energy
- Industrial production growth.

The only disadvantage is the necessity of huge investment at the first stage.

9. Conclusion

Taking into account the fact that Russia is making its first steps towards renewable energy development by legal acts as well as big power plants projects and the Republic of Ingushetia is also interested in this sphere, these energy sources must be developed that will improve living standards and the investment climate in the whole region guaranteeing economic growth.

Introduction of small generation would meet electric power demand in the Republic of Ingushetia and decrease the final cost of electric energy that is important for its development.

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