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Development Prospects for Renewable Energy Sources in the Chechen Republic

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***Abstract*—The article presents a review of the current status of world power engineering, which is focused on the development of alternative and renewable energy sources (RES). The power resources' production and consumption tendency, as well as the evaluation of renewable energy sources usage in Russia, is analyzed. The stimuli of renewable energy sources development with existing characteristics in the world are determined. The authors conclude about the importance of development of the given branch in the Chechen Republic. The technical potential of wind energy and solar radiation of Russia is estimated. The use of wind and solar energy resources, as well as small hydropower of the Chechen Republic, is examined. Wind potentials, solar radiation and the hydropower potential of small hydropower of the researched region in different periods of the year are assessed. Options of development and effective application of renewable energy sources are considered, given that energy use on the basis of modern innovative technologies, new prospective alternate sources implementation, search for the ways of encouraging the use of RES, where organization and introduction of tariff policy is supposed, are the main challenges of development in electric power. They provide a complete systematic understanding of the scope of the problem of power system transfer to innovative tracks.**

Keywords—renewable energy sources; wind energy; solar energy; small hydropower; rated power

I. Introduction

Present-day scientific and technological progress, which started at the beginning of the 21st century, is a combination of fundamental qualitative changes in the technology, means, organizations and production management on the basis of modern scientific principles. Apart from development of science and productive forces, this progress also provides social changes taking place in the society as a result of a universal innovative process. First of all, sustainable development of any region in the age of scientific and technical progress is based on its energy security. Against the background of rising power consumption and power resources prices, there is a growth of limited hydrocarbon raw materials, population and necessity of socio-economic conditions' improvement, worsening of environmental problems, interest in renewable energy sources. The growth of coal and oil use could rise by 2020 through an increase in the share of renewable energy sources and natural gas [1, 2].

II. Development methods of renewable energy sources in the world

Energy and environmental problems started arising side by side. Particular attention was drawn to RES as a result of several major political and ecological crises, after which active research for revealing of environmentally safe energy sources and technologies for their transformation began around the world.

Every year RES are gaining popularity worldwide. There are laws that promote the development of renewable energy sources in the United States of America, the European Union, Japan and some other countries, including developing ones. As a result, a series of energy generation countries based on renewable energy sources was organized (Fig. 1).

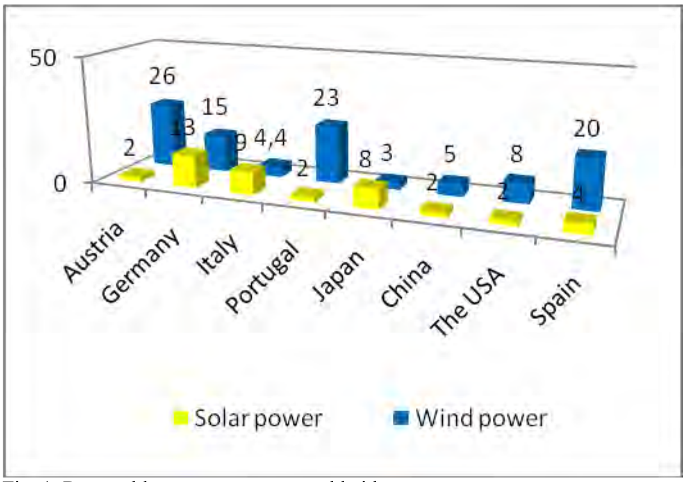

Fig. 1. Renewable energy sources worldwide.

European states properly and successfully demonstrate the development of renewable energy. In Latvia, for example, the company "Eko Osta" built a power plant on its territory dealing with solar energy which partially supplies the company with electricity and also allows a significant reduction in CO2 emissions. This project was considered to be successful. The power plant "Eko Osta" consists of panels of

700 square meters and power up to 120 kWh, which is used for production.

Alternative energy is developing rapidly in Estonia as well. For five years the number of those who produce electricity on their own has increased almost 8 times. If in 2013, in "Elering" there were 107 renewable energy sources, now this number is close to a thousand. At least the number of renewable energy sources is growing at an annual rate of a hundred units. In 2017 there was a great interest in renewable energy sources in Estonia, resulted in an increase in the volume of more than 300 units per year.

It is time to intensify the process of electricity development based on renewable energy sources in Russia. The steady innovative promotion of renewable energy sources will improve the management principles and the very model of the electric power industry organization. In the face of these significant changes in electricity, important decisions will be made to develop powerful centralized and low-power distributed generating sources of electricity, which will entail a balanced activity between consumers and the centralized power system [3].

Contemporary Russian energy accounts for about 600 power plants with a specific capacity of more than 5 MW. The total installed capacity of existing power plants in Russia is 250 GW and has the following structure by type of generation (Fig. 2).

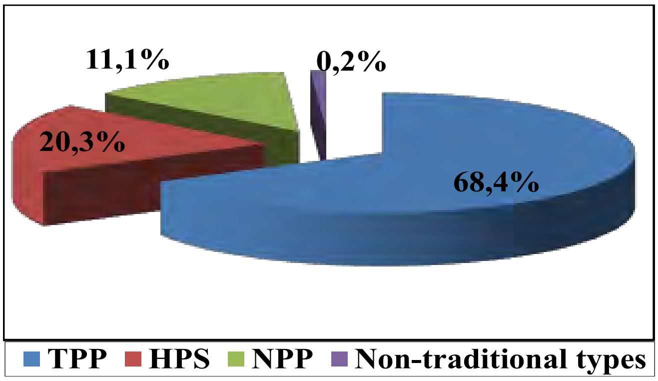

Fig. 2. Operating power plants structure of the Russian Federation by type of generation

III. RESULTS AND DISCUSSION

3.1. Wind energy

The use of each source of natural resources has its advantages and disadvantages, but wind energy is considered as the most accessible and effective [4].

In accordance with preliminary statistics published on April 12 of this year by the World Wind Energy Association (WWEA), the total capacity of all wind turbines in the world at the end of 2017 was 539 GW. 52 GW are wind turbines commissioned in 2017, which is slightly more than in 2016, when 51 GW was introduced.

Wind installations are most profitable to use in places where it is impossible to conduct a common power grid, or the connection is very expensive, and also in places with frequent power cuts. Wind energy plants should be installed at an average annual wind speed of 3 m/s.

Many producers of wind units manufacture wind turbines with a unit capacity of 250-750 kW, and as a result, 4 wind turbines with a capacity of 250 kW are needed for a wind farm of 1 MW. However, two 500 kW turbines can also be installed for 1 MW. Wind energy stations (WES), externally known as wind farms, are the most economical use of wind turbines when they are combined into groups. The total capacity of one wind farm ranges from hundreds of kilowatts to hundreds of megawatts. With increasing capacity requirement, the number of wind installations can be expanded. Nowadays, a wind farm with a capacity of 50 MW can be built within 18 months.

For example, the German Federal Agency for Network Management (Bundesnetzagentur) published the results of the next competitive selection in the mainland wind energy industry. There was high competition and almost three times more bids were submitted to the tender than the capacity was played out. The winners of the competition were 67 projects with a total capacity of 1013 MW, while the number of received applications was 281, and their total volume was 2,927 MW. Such intense competition could not but affect the prices of wind power. The average amount that wind energy station operators will receive for each produced kilowatt-hour was 4.28 euro-cent (which is equivalent to about 3 rubles at the current exchange rate). This is almost one and a half cents lower than at the last auction. A similar trend in the wind energy development is observed in several other European countries [5].

According to expert estimates, the economic potential of wind energy in Russia is about 31 billion kWh/year, and the technical potential is more than 6 billion kWh/year. In this regard Russia belongs to one of the richest countries, where there is the longest coastline, an abundance of flat treeless areas, large areas of inland rivers, lakes and seas, which are the most favorable places to host wind power plants [6, 7].

The total capacity of all operating Russian wind farms is about 130 MW, or it is 0.06% of the total generating capacity of the Russian Federation (~ 250 GW).

Typically, wind farms consist of several separate wind turbines interconnected with a transmission network. Previously, the use of modern wind turbines was considered economically feasible with an average wind speed of 5 m/s, but now, in view of design technologies improvements, it is also advisable at an average wind speed of 3 m/s.

The Chechen Republic belongs to a region with an average level of wind energy, where there is an uneven distribution of wind speed and direction both throughout the territory and with intensity at different times of the year [8]. The most enhanced types of local winds are the winds of the mountain valley, which arise as a result of air temperature contrasts of certain parts of the valleys or slopes and pools. Wind in a mountain valley is characterized by a daily change in speed and direction. In summer the wind circulation in mountain valleys is much stronger, where it reaches peak power.

Nowadays wind turbines are manufactured from a few tenths of a kilowatt to 10-20 kW. They have a wind generator at a distance of 30-40 m from residential buildings (so that the noise from the blades does not interfere with the residents). For efficient operation, it is advisable to build a wind turbine mast of such a height where the wind wheel axis will be at least 3-4 meters higher than obstacles located within a radius of less than 200 m. The ideal location of a wind generator is a clean field or steppe.

A wide variety of reliefs also affects the distribution of repetition of calm. The greatest frequency of calm – 44-58% is observed in closed pools and under the slopes of the mountains. It reaches 30% in the foothill and mountainous regions of the republic.

In this region the wind speed of the year varies in fairly wide ranges – from 0.8 to 6.0 m/s. The most intense winds are observed in open relief forms at high altitudes. Orographic factors of this zone are accompanied by an increase in pressure gradients and contribute to the convergence of air currents. The average annual wind speed of this zone reaches about 5-6 m/s. The average annual wind speed reaches lower values on open plains and in wide valleys – 3-4 m/s. The wind speed in the foothills is about 3 m/s, and in the southern lowland areas, as well as in the closed pools, no more than 1-2 m/s.

3.2. Solar energy

Despite the long-standing history of existence, there have been no changes in the work and principle of operation of modern solar panels. In the production process, the designs of some parts and materials were improved thanks to which manufacturers had the opportunity to increase the photoelectric conversion coefficient or efficiency of the panels. It should be noted that in the mid-90s, the efficiency of solar cells was about 15%, and at the beginning of the 21st century it was possible to increase it to 22%.

Every year, and especially in recent years, the number of generating capacities based on solar panels has been constantly increasing, resulting in a reduction in the cost of electricity from solar energy. Such a rapid fall in the price of solar energy can lead to cheaper electricity produced from traditional fossil fuels [9, 10]. Moreover, annually there is a drop in the cost of the solar panels themselves. If in 2008 they cost 3.49 US dollars per watt, then in 2018 the cost per watt was 0.42 US dollars.

Today, solar energy is being implemented at the level of local small projects in Russia. The use of solar panels in Russia is still practiced only by some objects. So, at present, the base stations are in the Southern region, OJSC “VimpelCom” (OJSC “Beeline”) and OJSC “MTS”.

At the same time, solar collectors are used for heat supply in the North Caucasus, in Southern Siberia and in the Middle East. At this stage, the production of solar collectors in Russia is 1-2 thousand m^2 per year. In order to achieve the target figures for the production and consumption of electricity using renewable energy sources, established by the Decree of the Government of the Russian Federation, No. 1-p, of January 8, 2009, it was necessary in the coming years to put into operation more gigawatts of electrical power based on renewable energy, including solar energy with a further increase in electricity generation by 60% more. Commissioning of these objects was not made.

Due to the long territories of Russia, in its different regions the levels of solar radiation vary quite in large ranges. If solar radiation in remote northern regions per year is up to 810 kWh/m^2, then in southern regions its value is more than 1,400 kWh/m^2. The values of solar radiation also vary with seasonal variations. For example, in January solar radiation at latitude of 55 ° is 1.69 kWh/m^2 per day, and in July it reaches 11.41 kWh/m^2 per day. Solar energy continues to improve its economic efficiency and has the greatest potential in the field of renewable technologies [8].

The situation in the Chechen Republic between 42 ° and 46 ° north latitude causes a significant effort of solar radiation. In the lowland and foothill areas, the value of the radiation balance is 50-55 kcal/cm^2 per year, and with an increase in the height of the area decreases, as a result of which at an altitude of 2500 m its value exceeds 30-35 kcal/cm^2. The radiation balance in the high mountain zone of the republic decreases to negative values and at an altitude of more than 3000 m is 3-4 kcal/cm^2. The radiation balance in the flat area remains positive almost throughout the year. As the height of the terrain increases, the expenditure part of the balance in the winter months begins to exceed income. The physiographic conditions of the Chechen Republic are due to the vast diversity, resulting in the formation of conditions for a wide range in the distribution of the duration of sunshine. The sunshine during the year is about 330 days, and the solar radiation reaches 0.33 kW/m^2. At the same time, in mountainous areas, as well as in a flatter area, the solar radiation of the product is 0.46 kW/m^2. In the valley-foothill areas of the republic, there are few days without sunshine in the year, about 34-40 days, and in the highlands only 10-12 days. The largest number of days without the sun falls into flat territory and is 61 days. The number of days without the sun is more observed in winter – 6-12 days. From June until the end of September, only 1-5 days elapse without sunlight. Cloud cover over the years reduces the possibility of direct radiation by 20-25% of the potential.

The total radiation is determined by the total admission to the horizontal surface of the direct and scattered radiation. The greatest intensity of total radiation in the whole territory of the republic is in May-July. For foothill areas the intensity of total radiation ranges from 280 to 300 mJ/m^2. In the highlands it varies from 360 to 400 mJ/m^2.

About 10 million Russian citizens currently live without centralized power supply. One possible solution to the problem is the use of solar energy. Even if photovoltaics electricity is used for 1 million citizens (~ 2 kWh/day for each citizen), it will be necessary to install more than 500 MW of maximum power of photovoltaic systems.

The second largest Russian potential consumer of industrial products is the agricultural sector, which can consume most of the energy of photovoltaic systems per year. If we add to this the market of autonomous photovoltaic systems to support navigation, telecommunication systems, systems for the sanatorium-resort business, cottages, solar street lamps, etc., the total demand for solar batteries in Russia may be more than 1 GW/year.

3.3. Small hydropower

At this stage in Russia there are about 300 small hydropower plants (HPPs), the total capacity of which is more than 1 GW and the annual electricity generation is more than 2.3 billion kWh. In the process of developing small hydropower plants in Russia, one of the most significant ones is the opinion of the federal generating company “RusHydro”. In order to design and efficiently build modern technologies for small hydropower plants, the New Energy Fund was formed, which is the operator of the Small Hydropower Development Program of JSC “RusHydro”. This program allows one to create in the territory of Russia in the period up to 2020 about 275 small hydropower plants with a total capacity of 1.86 GW.

Small hydropower plants allow the power supply of individual consumers to be isolated from the common power system, but most of them are connected to the local power systems. Experts believe that for economic reasons hydroelectric power stations with a capacity over 50-100 kW should be classified as a micro-hydro and up to 4000-6000 kW - small hydroelectric station.

Since 2013, in the Chechen Republic, the Kokadoy hydroelectric station with a capacity of 1.2 MW (Itum-Kalinsky district) has been operating in isolation from the general power grid. According to experts, the development of only 10% of the hydropower potential of small rivers in the middle mountain and high mountain belt of the Chechen Republic will make it possible to electrify up to 70% of small settlements and agricultural facilities.

An analysis of 112 sections on 29 large, medium and small rivers with a catchment area of more than 500 to 13,600 km^2 for the possible construction of small hydropower plants was carried out [8].

The total technical potential of small watercourses in the mountainous part of the republic is estimated at an average capacity of 302.4 MW. According to the estimates, it was established that 67 small hydropower plants (including small hydropower plants on the Terek River and the Sunzha River) with an installed capacity of 1,127 MW can be built on the territory of the Chechen Republic.

Indicators of energy consumption of priority small hydropower plants were obtained. According to the calculations, it was established that the primary 14 small hydropower plants with a total installed capacity of 9.2 MW can generate electricity – 31.2 million kWh and with it saved 10.8 thousand tonnes of fuel equivalent. A preliminary calculation of the economic components of small hydropower plants will be too cumbersome due to the fact that the exact cost of the hydroelectric unit can be determined only after the selection of the construction site, since the design and composition of the equipment largely depend on the operating mode of the hydroelectric station and the characteristics of electricity consumers. Approximate cost of installed power of 1 kW is 3-5 thousand US dollars. Therefore, the estimated investment for the implementation of the first stage of construction of small hydropower plants in the Chechen Republic in 2010 prices amounts to 1.38 billion rubles.

TABLE I. HYDROPOWER POTENTIAL OF SMALL RIVERS IN THE MOUNTAINOUS PART OF THE CHECHEN REPUBLIC ON 01/01/2009

No	Rivers	Capacity, MW	Catchment area, km^2	Average catchment height, m	Flow module, l / s km	Water consumption, m^3/s	Distance from the mouth, km
[1]	Yaryksu	5.0	186.0	1076.0	7.8	1.46	33.0
[2]	Yamansu	0.8	142.4	685.0	3.5	0.5	26.0
[3]	Aksai	6.0	452.0	4190.0	117	5.23	93.0
[4]	Elistanzhi	3.0	224.0	1319.0	3.3	0.74	22.0
[5]	Benoy-Yassi	14.0	177.4	1069.0	15.5	2.75	28.0
[6]	Hulhulau	12.0	503.0	1276.0	3.26	1.62	54.0
[7]	Belka	12.0	119.0	790.0	5.0	1.07	92.0
[8]	Bass	14.0	510.0	690.0	6.0	2.64	87.0
[9]	Dzhalka	20.0	533.0	672.0	8.2	4.47	82.0
[10]	Keloyakhk	12.0	130.0	1820.0	15.6	1.98	16.0
[11]	Hulandoyahk	16.0	107.0	2606.0	22.8	2.44	16.0
[12]	Dzumserk	6.0	110.0	1575.0	7.7	0.85	19.0
[13]	Kerigo	30.0	252.0	2508.0	20.0	4.6	25.0
[14]	Geshichu	8.0	102.0	1992.0	14.5	1.47	25.0
[15]	Martan	10.0	544.0	747.0	6.7	3.38	62.0
[16]	Roshnya	6.0	35.8	1030.0	10.5	0.38	27.0
[17]	Osukhi	8.0	118.1	1890.0	18.6	0.23	13.0
[18]	Gekhi	40.0	332.0	1071.0	10.4	3.47	70.0
[19]	Shalazha	5.0	258.0	790.0	7.0	1.86	34.0
[20]	Nethoi	8.0	60.9	1132.0	11.1	0.72	39.0
[21]	Fortanga	40.0	69.0	1785.0	17.3	1.2	75.0
[22]	Guloykhi	16.0	902.0	1800.0	18.6	-	23.0
[23]	Meridzhi	10.0	109.0	1770.0	17.3	1.88	14.0
[24]	Michik	0.6	200.0	537.0	1.0	0.8	35.0
Total		302.4					

The hydropower potential of the energy of small and medium-sized water flows in many rivers of the Chechen Republic will also allow the installation of non-dammed hydropower plants. One of the most appropriate rivers for the construction of cascades of non-dammed hydropower plants is the river Terek, as the most abundant of those reviewed, river Sunzha like a river with abundant low-flow and others.

According to CJSC Joint Stock Company “INSET”, the utilization of dam-free hydroelectric power plants using water pressure is possible on the Terek and Sunzha rivers with a total capacity of up to 100 MW. The estimated project cost on the river Terek – 1.0 billion rubles in a cascade, which will save up to 510 thousand tons. It was planned to use the energy of 24 small rivers with an installed capacity of 1,227 MW and an annual output of 595 thousand kWh. The implementation dates were 2011-2020 [8]. The project would also provide:

1. Creation of a generating industry as part of the fuel and energy complex of the Chechen Republic.

2. Electric power generation: 2015-356.6 million kWh, 2020-1101.6 million kWh, 2025-1586.7 million kWh.

3. Creation of new jobs – 800 people, taking into account the development of infrastructure - 20 000 people.

IV. Conclusion

Progress in improving the structure of electricity generation in a state or region should be organically combined with the evolution of electric power networks and systems.

In order to make effective decisions in the development of the electric power industry and to ensure reliable and balanced energy supply of the country, as well as its regions, including the Chechen Republic, a gradual improvement of all links of the energy sector is required. An important component is the investment between the structures of the federal government and the regulation of the energy balance, as well as business entities of private capital, which are the link between generating companies, investors and regional electric power networks. It is necessary to look for ways to stimulate the use of renewable energy, where it is supposed to organize and implement a tariff policy. At the same time, it is necessary to mobilize finance for the modernization of the energy system through the use of efficient innovative technologies. This suggests that the electricity generated by renewable sources must be acquired by state power supply organizations of electricity into common electrical networks. However, payment for this electricity must be made with stimulating tariffs, as well as differentiation depending on the type and terrain (mountain or flat) of RES used. Built on such structure, the system will allow connecting to state electric networks without fail.

In some developed countries, there is a more common method of stimulating the development of renewable energy in the field of power generation facilities called FIT – tariffs (running tariffs) and RPS – standards (renewable portfolio standards) [11].

The meaning of these stimulating economic methods is that FIT tariffs are especially important for increasing electricity tariffs, purchasing energy for renewable energy sources and security. They work in dozens of countries around the world and are approved for a long period (from 10 to 20 years) in accordance with international standards of energy saving. In any case, depending on the form in which they can be used, manufacturers can use them in the following cases: either in terms of production volume or in terms of power consumption.

RPS – standards (renewable portfolio standards) prevalent and applied in 18 countries and in several states of the USA, Canada and India are an effective mechanism for regulating the development of renewable energy sources. These standards are approved at the government level, after which energy companies, as well as groups of companies or energy consumers, are obliged to provide a given share of renewable energy sources by installed capacity, or by production or consumption of electricity.

To date, 138 countries of the world have formulated goals for the development of renewable energy sources by 2020 and subsequent years. In most cases, in the near future, the contribution of renewable energy to the energy balance is expected to be from 10 to 30%. The most ambitious targets are observed in the European Union [12].

Efficient use of energy resources, the introduction of new promising alternative energy sources based on the experience of other subjects and countries, developing innovative technologies in this direction, are the most important tasks of the electric power industry development in the Chechen Republic.

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