Key Aspects and Trends of Distributed Generation and Energy Decentralization in Russia

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Abstract. Distributed Generation (DG) is a global trend and it is actively spreading in Russia. In contrast to Western countries, the main incentive for the spread of DG in Russia is the desire of industrial owners to reduce the final cost of electricity. DG in Russia can successfully meet the challenge of supplying electricity to isolated and inaccessible areas and replacing outdated and inefficient generation. The widespread use of DG, including those based on renewable energy sources (RES) makes it necessary to create promising models for the inclusion of DG in the Unified Energy System (UES) of Russia. The paper deals with the efficiency of DG, analyses the application of this technology in Russia formulates the prospects for the development of DG in Russia and gives recommendations for the integration of DG.

1. Introduction
Russian energy system is characterized by a model of centralized generation. It includes 846 power plants with installed capacity of more than 5 MW [1]. This scheme for the development of the Russian power industry is due to the long distances between power sources and consumers, as well as the heterogeneity in the distribution of primary energy resources (oil, gas, coal, large rivers) with energy consumption centers [2]. The global trend is the gradual abandonment of the centralized model and transition to a distributed energy model, as well as a reduction in the share of fossil primary energy resources and an increase in RES [3]. The main aim is to make a forecast of the DG development in Russia until 2035.

2. Materials and methods
Case studies of leading companies were analyzed to determine the initial conditions. A qualitative study was carried out by a questionnaire to make the DG forecast. The questionnaire contained 19 questions. It was required to estimate validity of a statement and estimate the degree of its influence on the DG in Russia. The questionnaire was sent to over 40 organizations. A matrix of criteria was compiled by analysis of the questionnaires. On the basis of this matrix the most probable and significant criteria were identified.
3. Results

3.1. Distributed Generation.

In this paper the DG unit is understood as the power plant, consisting of at least one generation unit. It is connected to the distribution networks or internal networks of power supply at the voltage up to 110 kV. Generating units are as close as possible to the node of power consumption that works in parallel with the utility system or in island (stand-alone) mode. It has total installed capacity to 25 MW. DG used for the production of all types of energy (electrical, heat, cold, etc.) of any primary sources of energy, including RES [4].

According to the report of consulting company Guidehouse Research (USA), the global installed capacity of the DG will be more than 200 GW until 2025. Half of the installed capacity coming from solar power plants (SPP) is using photovoltaic modules (figure 1) [3].

3.2. Relevance of Distributed Generation.

The global energy industry has clearly seen the 3D trend in recent decades: Decarbonization, Decentralization and Digitalization. Structural changes in the energy industry are due to a complex of different reasons. One of the incentives for the “energy transition” for Western countries is the government’s response to the request of the citizens, for a transition to a low-carbon economy in general and low-carbon energy in particular.

Using the example of the German energy sector, as the leading economy in the EU and the world, the influence of the 3D technological trend on the structure and volume of the electric power industry can be clearly traced. In 2019, the total amount of electricity produced in Germany was 518 TW-h, with about 40 % of the total volume being generated from RES. Most of renewable energy installations is DG. Significant aspect of the development of the German electric power industry is the final cost of electricity for industrial and domestic use. According to the estimates of NP “Community of Energy Consumers", the final price for industrial enterprises in Germany is one of the highest in the world, due to the high share of installed capacity of generating facilities based on RES (figure 2).

The impact of the 3D trend is weak because of relatively cheap natural gas for Russia. In 2019, most of the electricity was generated by centralized hydrocarbon-fueled power plants. The share of installed capacity of RES power plants is about 1 % of the total installed capacity. According to respondents, the share of DG on hydrocarbon fuel and operating on a cogeneration cycle is 7% of the total installed capacity of the Russian Federation.
3.3. Current Status of Distributed Generation in Russia.

There is an annual increase in the commissioning of DG facilities in Russia. According to INEI RAS, over the past 10 years, the total installed capacity of 25 MW power plants has increased about 30%. Renewable energy facilities are being introduced to a greater extent in most countries of the world. In Russia, the increase in their number is due to thermal power plants with gas turbine units, diesel generator sets and gas piston units. They are connected to the distribution electric networks or to the internal power supply networks of industrial enterprises. The main incentive for the introduction of DG in Russia is the desire of the industrial enterprises owners to reduce the cost of electricity to increase the operational efficiency of production [5]. The Ministry of economic development predicts the indexation of wholesale gas prices (the main fuel for DG in the Russian Federation) for all categories of consumers (excluding household consumers) by 2-3% per year until 2030 due to rising electricity prices, which means an increase in the attractiveness of DG in the near future.

It is difficult to accurately estimate the current volume of DG in the UES of Russia. The Rosstat and the Ministry of energy of the Russian Federation in their official statistical annual and operational reports do not distinguish this type of generation in the reporting data. The main sources of data are estimates of experts, scientific organizations, indicators of enterprises and analytical work of consulting companies. In addition, in the Russian Federation there is a “gray area” of DG. These units operate without connecting to the UES of Russia. According to an approximate estimate, 487 DG units operated in the UES of Russia with a total installed capacity of 6 GW at the beginning of 2020. The main volume of generating unit is accounted for by industrial enterprise power plants using hydrocarbon fuel or burning production waste: 260 generating units with a total capacity of 3360 MW. According to the calculations of one of the leading engineering companies in the Russian Federation, the ISS group of companies and the Moscow school of management SKOLKOVO, the use of its own generation of industrial enterprise allows you to save up to 5 cents per kWh of electricity, despite the high cost of operating the DG (figure 3).

The global trend of development of DG based on RES can also be traced in the Russian Federation. Summary values for DG unit in the Russian Federation that operate as part of the UES are shown in table 1.

| Type        | Indust. PP | Sm. HPP | WPP | SPP | Tidal PP | Bio TPP | TPP |
|-------------|------------|---------|-----|-----|----------|---------|-----|
| Capacity, MW| 3360       | 480     | 98  | 634 | 1,1      | 2,4     | 1395|
| Number of objects | 260   | 76      | 11  | 46  | 1        | 1       | 94  |

Fifty nine DG facilities based on RES are in operation with a total installed capacity of 735 MW in the Russian Federation in 2020 (excluding small hydroelectric power plants). There are more than 2000 DG facilities located in isolated and inaccessible areas of the Russian Federation and operating on an island regime. Their total installed capacity is estimated at 840.3 MW. The main percentage of installed capacity (63 % – 525 MW) of these, generating facilities is located in four regions of the Russian Federation: The Republic of Sakha (Yakutia), the Kamchatka region, the Krasnoyarsk region...
and the Yamalo-Nenets Autonomous District. The other 19 regions account for 315 MW of installed capacity. The main type of fuel is diesel, but there are generating facilities that use renewable energy, whose total capacity at the end of 2018 is 16.6 MW (39 units).

The main feature of power generation in isolated and inaccessible areas is that the state subsidizes the cost of electricity to compensate for the difference between the economically justified tariff and the established tariffs for households and industrial enterprises. According to estimates of the Analytical Centre under the Government of the Russian Federation, the specific cost of electricity generation reaches 65 cents per kWh.

At present, Russia does not have a legal and regulatory framework for the harmonious development of distributed power generation within the UES of Russia. It is important to note that in recent years the legislative bodies, together with the relevant ministries and the energy community, have been actively engaged in law-making activities. Over the last two years, the Russian Government and the Ministry of Energy have already approved [6] a part of the fundamental documents containing the regulatory and terminological basis for DG, which will ensure stable, consistent development of the energy sector and application of new technologies within the legal framework.

3.4. Technological Trends in Distributed Generation.

The efficient operation of DG within the UES of Russia requires effective mechanisms for the integration, management and regulation of such power sources. The development of information, microprocessor and communication technologies in recent decades, together with modern economic models, has given an active impetus to the development of DG. Due to the large spread of distributed power generation and the need for its effective integration into the UES of Russia, the concept of Virtual Power Plant – an IT system to which distributed power sources are connected, mainly on the basis of RES - has emerged. The blockchain technology can be used in managing the electrical modes, exchange trading in electricity [7].

The digitalization of DG is correlated with the strategic directions of the program of the Ministry of energy "Digital Transformation of the Electric Power industry of the Russian Federation". At the moment, Russia is developing a digital pilot project to create a new system of consumer’s relationships on retail electricity market to optimize tariff — AEC [8] — the joint development of SO UPS, JSC, the group of companies STC UPS, JSC, the Ministry of energy and "Energynet". The AEC is a micro-energy system consisting of its own generation, electricity consumers, and network infrastructure. Power generation and consumption is carried out through a controlled smart connection. The economic feasibility of the AEC consists in the ability of each participant to pay the tariff for the maintenance of electric networks within the permitted amount, but not more than its actual consumption from the network, provided that its consumption can be limited to the established level.

An important factor and precondition for the development of DG, which is characteristic of all countries, is the gradual obsolescence of fixed production assets (figure 4), the need to replace obsolete and inefficient generation, and the construction of new generation to cover growing consumption [9].

According to the energy strategy of the Russian Federation, in the period up to 2035, the total installed capacity of power plants in the UES of Russia should achieve 251-264 GW [10], which, taking into account the projected withdrawal of generation unit [10], will require the input of up to 48 GW of new capacity. One of the options to partially cover this amount of capacity is the construction of DG facilities.
3.5. Trends and technological trends in distributed generation.

High cost of technological connection and electricity transmission and the need to replace worn-out and outdated capacities lead to an increase in tariff.

According to the Alteko, the average annual increase in electricity tariff for domestic consumers will be about 4% until 2035. At the same time, according to the NP "Community of energy consumers" [11] and the association “NP Market Council”, the price of electricity in the wholesale market for the 1st half of 2019 increased significantly – by 9% compared to December 2018. The price of natural gas for industrial enterprises is projected to increase significantly until 2024 (figure 5) and will average 3% per year [12]. This price ratio is an incentive to build your own generation.

In addition to economic incentives for the development of DG based on hydrocarbons until 2035, an important component of the "Energy Strategy of the Russian Federation for the Period Up to 2035" is to increase the share of DG in the total generation volume and load concentration in regional energy systems. The aim can be achieved by a large-scale upgrade of the Combined Heat and Power by installing heating 250-350 GTU with a capacity of up to 25 MW (total installed capacity of 3.6 GW). It also can be achieved by municipal boiler houses conversion to GTU/GPU. Mini-Combined Heat and Power will total up to 70 GW of newly introduced capacity by 2035. All this creates favorable conditions for the development of industrial enterprises and municipal enterprises generation as well as an increase in the total number of DG on hydrocarbon fuel.

4. Discussion

This study was presented at the Youth Forecast of the Global Energy Development 2020 by SO UPS, JSC team and was awarded the first place. Materials were presented at the conference Electricity Through the Eyes of Youth 2020 by the authors and were awarded the third place. The paper received a positive review from Ph.D., associate professor V.V.Zavalishin.

5. Conclusion

Summing up, it is worth noting that the unconditional advantages of DG will be assessed in the programs for supplying power to isolated and hard-to-reach territories and eliminate the consequences
of emergency situations [13]. And within the framework of integration into the UES of Russia, DG is considered not as a competitor to centralized generation, but as a harmonious complement to it.

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