Hybrid heat supply systems using alternative and renewable energy sources

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Abstract. The task of creating combined energy sources to cover diverse (thermal, electrical, etc.) loads is not entirely new. In the countries of the European Union (EU), hybrid energy systems for buildings, which combine heating, domestic hot water, as well as air conditioning, have long been widely used. The programs and normative documents adopted in these countries on improving the energy efficiency of heat supply and the use of renewable energy sources (RES) for this have contributed to the widespread introduction of hybrid systems and installations. The study analyzes the potential of non-traditional and renewable sources for energy supply systems of facilities. The world experience of introducing alternative energy sources is considered and the state and implementation of hybrid schemes in Russia is assessed. Hybrid power supply options for facilities for various purposes are proposed. The key problems of active use are examined and ways to solve them are proposed.

1. Introduction

Hybrid energy supply systems are widely used in EU countries. The programs and normative documents adopted in these countries on improving the energy efficiency of heat supply and the use of renewable energy sources (RES) for this have contributed to the widespread introduction of hybrid systems and installations [1]. The share of renewable energy in the EU’s energy balance is growing rapidly and should reach 20% by 2020, such a share of renewable energy will be used in the world’s energy balance by 2030 (figure 1). Specifically, in the field of cold and heat supply, the share of RES is increasing annually in all countries, without exception.

Although these systems have not yet been in high demand in Russia thermal power plants of various types and capacities were created just to solve such problems, different types of turbines were developed, as well as a set of corresponding circuit solutions. Basically, this concerned large consumers (industrial enterprises, cities), but now the problem of ensuring reliable energy supply to remote and hard-to-reach settlements outside centralized energy supply systems has again become urgent.
Figure 1. Assessment of the EU energy balance structure by 2030.

For the period 2013-2018, there has been some progress in the development of renewable energy in Russia. The Government of the Russian Federation adopted a number of Resolutions and Orders on the organization of work in the field of renewable energy. However, despite the extensive list of documents designed to ensure the development of renewable energy in Russia, in fact, they are mostly declarative in nature and poorly applied in practice. At the same time, according to Russian experts, the potential for renewable energy in Russia is more than 270 million tons of equivalent fuel equivalent. - about 30% of the total primary energy supply. Unfortunately, the initially established share of renewable energy sources - 4.5% of total electricity production in 2020, was reduced to 2.5%. Today in Russia we are talking about achieving economic growth, the need to develop space with different climatic conditions, corresponding to the construction of large volumes of housing and efficient production capacity [2]. The rational use of combined, hybrid RES-based systems in these cases may well contribute to more efficient solutions leading to various systemic (multiplicative) effects.

The inconsistency of energy output and the mismatch between the places where renewable energy is manifested and the consumed loads (cities) cast doubt on the feasibility of using hybrid energy supply systems. However, at the same time, natural inexhaustibility and environmental friendliness present wide opportunities for the use of heat supply systems based on non-traditional and renewable energy sources.

2. Generation and structure of energy consumption based on non-traditional and renewable energies

China and the USA remain the world leaders in the use of renewable energy sources (table 1). It is worth noting that most countries use the power of non-traditional sources mainly for the generation of electric energy. The largest applications in the energy sector of these countries have been received by solar power plants:
- Tengger Desert (China) - 1,500 MW;
- Solar Star (USA) - 579 MW;
- Topaz (USA) - 550 MW;
- Desert Sunlight Solar Farm (USA) - 552 MW.
Solar energy, in the first place, is very popular both in the residential and in the commercial sector [3]. Such demand is explained by rather clear weather in some countries in Europe. For example, according to the Solar Trade Association (STA), the generation of all solar panels in April 2020 reached a peak of 9.68 GW, a record of 32.23 GW was set in Germany. Recent years have shown the high efficiency of solar systems: more often, cases of negative prices for electric energy began to be recorded. However, the high cost of plants and the dependence on weather and time of day are insurmountable barriers to the construction of solar power plants in several countries.

| Power                                                                 | 1       | 2       | 3       | 4       | 5       |
|----------------------------------------------------------------------|---------|---------|---------|---------|---------|
| Renewable power capacity (including hydropower)                      | China   | USA     | Brazil  | Germany | India   |
| Renewable power capacity (not including hydropower)                  | China   | USA     | Germany | India   | Japan   |
| Bio-power generation                                                 | China   | USA     | Brazil  | Germany | Japan   |
| Bio-power capacity                                                   | USA     | Brazil  | China   | India   | Germany |
| Hydropower capacity                                                  | China   | Brazil  | Canada  | USA     | Russia  |
| Hydropower generation                                                | China   | Brazil  | Canada  | USA     | Russia  |
| Solar PV capacity                                                    | China   | USA     | Japan   | Germany | Italy   |
| Solar PV capacity per capita                                         | Germany | Japan   | Belgium | Italy   | Australia|
| Concentrating solar thermal power (CSP)                              | Spain   | USA     | South Africa | India | Morocco |
| Wind power capacity                                                  | China   | USA     | Germany | India   | Spain   |
| Wind power capacity per capita                                       | Denmark | Ireland | Sweden  | Germany | Portugal |
| Heat                                                                 |         |         |         |         |         |
| Solar water heating collector capacity                                | China   | USA     | Turkey  | Germany | Brazil  |
| Solar water heating collector capacity per capita                     | Barbados| Austria | Cyprus  | Israel  | Greece  |
| Geothermal heat capacity                                             | China   | Turkey  | Iceland | Japan   | Hungary |

2.1. Types of renewable energy in Russia
The vast territory and the diversity of climatic zones in Russia provide advantages and favor the use of a wide variety of alternative energy sources. Hydroelectric power plants are the most popular alternative energy source in Russia. Energy production from the existing 200 river hydropower plants reaches 20% of all energy produced in the country.

Solar energy in Russia is used both among the population as the main or alternative source of energy and on an industrial scale [4]. The largest solar plants are SES - "Vladislavovka" (Crym, figure 2), as well as installations in the Samara, Astrakhan, Orenburg regions. The total capacity of all installations is about 400 MW.

Geothermal energy is widespread in Kamchatka, which is facilitated by the abundance of volcanoes. The power of geothermal sources makes it possible to cover about 40% of the consumed power. According to studies, the potential of geothermal sources in Kamchatka is estimated at 5000 MW, but the annual use does not exceed 80 MW.
Other types of alternative energy, such as wind energy, etc., although used in special cases, have not received wide distribution due to lack of investments and gaps in the law.

3. Use of energy supply systems based on res in Russia

Currently, electricity generation in Russia through hybrid systems based on renewable energy sources is less than 1% of the total generation. Despite the low indicators of using the RES power in Russia in comparison with other countries, hybrid energy supply systems are widely used at the following facilities:

• private houses and cottages;
• cottage settlements;
• country estates;
• infrastructure facilities (treatment facilities);
• public institutions (kindergartens, schools);
• public buildings;
• small industrial facilities (workshops);
• small neighborhoods.

For the heat supply of private houses, heat pumps were widely used regardless of the climatic zone. Using a heat pump allows you to heat a house in the cold season, and to cool in the warm season. On the example of an individual residential building (Republic of Buryatia), one can evaluate the effectiveness of using hybrid heat and cold supply systems.

The energy supply scheme of a residential building using a reversible soil heat pump and solar collectors. The source of heat and cold are three wells with a depth of 100 m. Two groups of vacuum solar collectors (figure 3–4): 120 pipes on the roof of the house and 100 pipes in the greenhouse (total 18 m²). Solar collector has several modes (options) of operation:

1. In the winter (heating period) all 220 pipes work to heat the low circuit of the VT and cover 15-17% of the annual heat energy consumption for heating;

2. From the middle of March (end of the heating season) of the month, 100 tubes installed in the greenhouse switch to heating the soil in the greenhouse and a month later, in mid-April, the garden is planted. At the end of May, all the collectors work to heat the water in the outdoor pool and to heat the wells.
This combination of energy sources “heat pump and solar collector” is the most common in the Russian Federation. Almost the entire territory of Russia is subject to insolation in one way or another, therefore there are many such examples: a hybrid solar power plant with a capacity of 45 kW in the Krasnodar Territory, a cascade of geothermal pumps in the Omsk Region, a solar hybrid system that provides a high degree of uninterrupted power supply in Rostov-on Don, a geothermal heat pump in the Leningrad region, etc.

4. Main features and problems of active renewable resources implementation

The successful use of renewable energy sources, heat pumps in Russia still remains a lot of enthusiastic groups, outside of state policy and support, as a result, the country does not realize additional opportunities for the development of the economy and industry.

According to the creators of the above-mentioned projects, the key measures of system support for the development and implementation of renewable energy sources are:
- increase the market by providing subsidies for the purchase of renewable energy technology;
- provision of soft loans for the acquisition and installation of equipment through authorized banks;
- stimulation of the construction of energy-efficient housing with the installation of systems based on renewable energy sources and heat supply units as sources of heat and energy supply;
- applying reduction factors to the local electricity tariff for pilot RES installations (as is done for homes equipped with electric stoves);
- the creation (updating) of domestic regulations, standards, codes of practice, GOSTs, regulating the application of appropriate installations for renewable energy sources in Russian conditions;
- broad information support for successful projects in various fields and areas.

The key problems that hinder the massive implementation of renewable energy projects are presented in table 2.

Conclusion

Despite the existing obstacles to the active implementation of renewable energy sources, global trends show growth and the possibility of using renewable sources in most countries. Hybrid systems have not yet been appreciated, although their application provides some advantages over traditional systems: a significant reduction in environmental pollution, additional production of electricity in the required volumes in centralized energy supply zones, as well as ample opportunities for foreign investment.
Table 2. Key problems of the active introduction of renewable energy sources and their coordination.

| Economic                                                                                                                                  | Technical                                                                                                             | Organizational                                                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| The high cost of equipment (mainly imported), the absence of any subsidies or benefits for owners who have installed renewable energy systems | The variety of regional climatic, tariff, infrastructural and geological conditions, available sources of renewable energy sources and technical solutions based on different types of renewable energy makes it impossible to create standard projects for the use of renewable energy sources. It is necessary to prepare a thorough and costly feasibility study for each renewable energy project | Insufficient regulatory framework, technical regulations, standards, lack of empirical data on Russian projects, albums of best practices |
| The relatively low cost of fuel (especially main gas) with relatively high electricity tariffs negatively affects the economics of projects          | Restrictions on the use of renewable energy by climatic conditions in the regions of the middle zone and the north of Russia (lower working temperature requires additional calculations and justifications, especially when reconstructing existing heating systems) | Limited domestic production and the lack of Russian components (high-quality compressors, wind turbines, batteries) |
| High interest rates on loans for expensive equipment                                                                                  | The heterogeneity of the renewable energy potential in the regional context, both in terms of natural (water bodies, soil, geothermal heat), and technogenic sources (drains, ventilation emissions, etc.) | Lack of service support for many manufacturers                                                                 |
| Low profitability of renewable energy projects as is, the need for non-standard technical solutions (for heat storage, use of low-grade heat) | The need to ensure high reliability of heat supply from renewable energy sources in case of possible interruptions in the power supply may require both an independent second input of electricity and the installation of redundant backup equipment on fuel, possible restrictions on the capacity of the supply centers and power lines, especially in rural areas | The complexity and opacity of obtaining electric power for the operation of renewable energy in energy retail organizations |

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