THERMAL POWER PLANTS

THE EFFECTIVE UTILIZATION OF RENEWABLE ENERGY SOURCES IN A LOCAL POWER SUPPLY SYSTEM

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The problems involved in increasing the utilization efficiency of power plants based on renewable energy sources when designing local power supply systems are considered. A method of estimating the operational risk of the electric power supply to consumers is proposed, based on portfolio analysis theory, which enables the economic factors of projects with a consumer power supply risk to be compared.

**Keywords:** low distributed power, renewable energy sources, operational risk to consumer power supply, portfolio analysis.

Many power problems in Russia (the limited nature of the unified power system, the ageing of the main power plant equipment and networks, the considerable losses of electric power etc.) can be solved by constructing small electric power plants and power equipment, and extending the use of local and renewable energy sources, i.e., by the development of a small distributed power system.

The technical units of a small distributed power supply are the local power systems, represented by different combinations of generating and network units. A small distributed power system may consist of isolated “islands” or have electrical connections with the Unified Power System and interact using “microgrid” technologies [1]. The unit power of equipment in a small distributed power system does not exceed 25 MW. Several installations may form part of a single unit and the total power may be considerable [2]. To develop a Russian scientific-technological and production-engineering base, capable of maintaining a large-scale power distribution system based on advanced technologies, the “Small Distributed Power System” technological platform was introduced in November 2010 [1].

The small distributed power system of Russia consists of up to 50,000 different power plants (more than 98% of them diesel power plants) with a mean unit power of 340 kW and a total power of 17 million kW (8% of the total installed power in Russia), generating up to 50 billion kWh of electric power and consuming about 17 million tons of conventional fuel per annum [3]. The use of power equipment in small distributed power systems based on renewable energy sources is promising. The wide use of such power sources is one of the main priorities of the “Power Strategy of Russia” [4].

We can distinguish three groups of consumers for which a power supply from small distributed power systems based on renewable energy sources is important:

1) consumers who require uninterrupted power supply;
2) consumers far from a centralized power supply;
3) consumers aiming to be power independent.

One of the main indicators of the susceptibility of regions to threats of power accidents is the extent to which regions can ensure their own fuel-power resources [4]. The effective use of renewable energy resources in local systems for supplying electricity to consumers is therefore an urgent problem.

Practically the whole spectrum of renewable energy sources (solar, wind, hydro for small hydroelectric systems etc.) have been developed in Russia at a high technical level. Such large organizations as the “Élektroprivbor” Central Scientific Research Institute (St. Petersburg), the Tushino Machine Building Factory, the Kovrov Mechanical Factory etc. have produced designs in the area of renewable energy sources. Companies such as “RusGidro,” “Rostekhnologii,” “Rosatom,” “Rosnano,” and “Renova” possess sufficient re-

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Fig. 1. Portfolio analysis of an electrical supply system based on renewable energy sources (RES).

sources to set up a market in renewable energy sources. Modern technologies and production capabilities enable commercially viable and competitive designs based on renewable energy sources to be developed. Many of the Russian power plants are ahead of similar foreign versions in a number of features.

According to estimates of Russian scientists and leading specialists [5], the fraction of sources of distributed energy production in the electric power industry will reach approximately 16% by 2030.

But, despite the availability of resources, the possibility of producing power equipment, the development of rules and providing a technical and economic base for supporting renewable power engineering, and the wide practical use of renewable energy sources is limited by two features of renewable energy. The low density of the supply and the irregularity of the energy supplied lead to variations in the output power and irregularity in the production of electric power. These problems result in high costs in developing renewable energy and a considerable probability of a breakdown in the supply of electricity to consumers.

Also, as a rule, in the majority of regions the availability of solar radiation and the presence of winds are in antiphase (when there is bright sunshine there is no wind, and when there are strong winds solar radiation is at a minimum). Hence, it is not advisable to construct large individual power plants, but rather to set up complex local power systems based on renewable energy sources.

The development of complex power systems based on mixed energy sources requires the development of recommendations on choosing the optimum parameters for power stations using renewable energy sources. To do this it is necessary to develop a calculation procedure, which takes into account a wide assortment of equipment based on renewable energy sources and the different factors which influence power production.

The problems involved in increasing the utilization efficiency of renewable energy sources in complex local power systems were solved by Sher’yazov [6], Tashimbetov [7] and others. The methodology for choosing a rational combination of consumable energy resources is based on indicators of the fraction of the energy, replaceable by renewable energy sources, and on the characteristics of the economic advantages of using renewable energy sources in a power supply system. However, these parameters do not estimate the degree of instability of renewable energy sources.

For a quantitative estimate of the degree of instability of renewable energy sources it is proposed to introduce the idea of the operational risk of the electricity supply to consumers (ORESC), which enables the probability that consumers will not obtain the required power in systems using renewable energy sources due to the risk of variations in the energy supplies to be determined.

We propose to use the apparatus of portfolio analysis to calculate the ORESC.

The foundations of portfolio theory were laid by the American mathematician-economist Harry Markowitz [8]. A portfolio is a collection of shares (stocks) which a participant in the market possesses. The main feature of a portfolio is its return $R$. In portfolio theory the return of each share is a random quantity [9]. The statistical properties of the return are determined by the mathematical expectation $\mu(R)$ and the standard deviation $\sigma(R)$. The mathematical expectation represents the predicted value of the return from the investment of capital. The standard deviation is a measure of the risk. The less the spread in the values of the return the less the investment risk. When determining the investment risk of a portfolio it is necessary to take into account the relation between the return of the shares considered by introducing an additional parameter — the correlation coefficient $\rho(R_{ij})$. A portfolio formed from the actions of companies in different branches of industry ensures the reliability of obtaining positive results.

Consider the apparatus of portfolio analysis as it applies to determining the operational risk of the electrical supply to consumers when using renewable energy sources (RES). In Fig. 1 we show a portfolio consisting of renewable energy sources.

In view of the dependence on the annual conditions, the power of a renewable energy source $P$ can be assumed to be a random quantity. For probability modeling of the electrical supply to consumers, we will postulate the hypothesis that the power distribution of each energy source obeys a normal law. One of the properties of a normal distribution is the fact that the sum of the independent normally distributed random quantities also corresponds to a normal distribution law. The energy sources in the portfolio considered are not independent. Hence, to ensure a normal distribution of the sum of the normally distributed powers of the energy sources we will introduce an interconnection coefficient between the sources $\rho(P_{ij})$.

The mathematical model for determining the risk of an electrical supply is based on the statistical characteristics of the power of the portfolio of renewable energy sources. The mathematical expectation of the total power of the portfolio $\mu(P_{\text{port}})$ defines the predicted value of the generated power.