Development of the Unified National Power Network of Russia

E. P. Volkov

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Abstract—Problems of functioning of the unified national power network (UNPN) of Russia are considered. Based on the analysis of the state and operation of power networks, the general principles of the development of the UNPN of Russia are determined.

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The operation problem of the unified national power network (UNPN) of Russia composes the basis of the transmission system of the Unified Energy System (UES) of Russia and involves power networks with a voltage of 220–330–500–750–1150 kV and some part of electric power lines (EPLs) with a voltage of 110 kV (not included in distribution networks).

At the beginning of 2010, the total extension of the UNPN EPLs was 122000 km. In addition, the UNPN contains about 800 electrical substations (SSs) with the total transformer power of 306000 MVA and other electrotechnical equipment (devices for compensation of reactive power, switches, breakers, and the automatic and computerized systems, including emergency automation systems).

The primary electrotechnical equipment mounted in installations of the UNPN, which operates in the continuous production cycle and determines the reliability and economy of the network operation, was made for the most part in the 1950s–1970s of the past century, yields to current developments in technical characteristics, dimensions and weight parameters, and reliability factors, and requires the periodic repair maintenance increasing in size as the lifetime rises.

The primary electric connecting circuits of operating SSs are oriented for equipment requiring constant technical maintenance, wherefore, they are meant for numerical ratios of switching apparatuses and connections which are in excess by modern criteria. This is the cause for the significant amount of serious technological violations through the fault of operation personnel.

Automation of technological processes at the end of 2010 was carried out for 79 SSs; and another 49 SSs are in the realization stage. Therefore, the basic scheme of the operation organization is oriented first of all to the 24-h residence of the operating personnel in them who control the installation state and fulfills operation switchings, which leads to a rise in the specific number of the personnel.

The UNPN installations for the most part use the base of the morally and materially outmoded apparatus of telemechanics and teleinformatics.

Electrical circuits of the majority of Russian power systems accept a voltage scale of 110–220–500–1150 kV. The Unified Power System (UPS) of the Northwest and, partially, the UPS of the Center use a scale of 110–330–750 kV. It should be noted that 330 and 750 kV networks in the UPS of the Center and the 330 kV network in the UPS of the South received an estimated expansion; and their further development is laid down, as a rule, in boundaries of regions of their substantial use.

The position of 10 kV lines amounts now to about 70% of the total extension for high-voltage lines (HVLs) with a voltage of 110 kV and more; and these lines gained the most expansion as the distribution network.

The 220 kV electrical networks operate in all regions of the Russian Federation except for single power systems of the UPS of the Northwest and the South for the power delivery of electric power stations and the power supply of loading centers of 35–110 kV networks and the power supply of large-scale consumers. For the most part, they are distribution networks, but fulfill system-forming functions in some power systems (Komi, Arkhangelskaya, Sakhalinskaya, etc.).

The 330 kV lines operate in the West and South of the UES of Russia. They realize power delivery of electric power stations, power supply of loading centers of 110 kV networks, and external power supply of large-scale production plants and connect the UES of Russia with the power systems of the Baltic States, Belarus, Ukraine, and Azerbaijan. The 330 kV electric networks in a number of power systems are system-forming.

The basic system-forming and intersystem EPLs in the UES of Russia are power networks with a voltage of 500 kV, which operate practically in all regions of Russia, providing the power delivery of the most large-scale electric power stations and the power supply of large-scale loading centers of 220 and 110 kV networks. The same EPLs serve for the connection of the
UES of Russia with the power systems of Ukraine, Kazakhstan, and Georgia.

The 750 kV power networks are used in the UPS of the Center and the UPS of the Northwest both as system-forming ones and for the power delivery of the large-scale electric power stations, first of all, of the nuclear power plants (NPPs) located in these regions. These networks serve also for the supply of 500 and 330 kV high-power loading centers and for the connection of the UES of Russia with the power systems of Ukraine and Belarus.

The UPS of Ural and Siberia are provided with HVLs with a nominal voltage of 1150 kV. The total extension of three 1150 kV HVLs in Russia is 953 km. Two Chelyabinsk—Kustanai and Altaiskaya (Bar- naul)—Eibastuzskaya HVLs were put into operation in the 1980s, consisting of the Siberia—Kazakhstan—Ural intersystem EPL. The Itat—Altaiiskaya HVL with an extension of 448 km was put into operation in 1998. At the present time, all three HVLs operate with a voltage of 500 kV, i.e., in this case, there is a freeze in capital investments. Furthermore, the supposed gradual raising of the electric power production in Siberia (including electric power stations of the Kansk—Achinsk Fuel and Energy Complex (KATEK)) and risks connected with the nonfulfillment of the program of putting into operation huge amounts of power in NPPs (~55 GW until 2030) and with the power debalance in the European part of our country cause the necessity to consider problems of the use of the available 1150 kV HVLs at the nominal voltage and the development of the transnational power system where Russia may be the connecting and stabilizing link between countries of the European Community and countries of the Asian-Pacific region.

In this case, it is possible to generate the power of large-scale hydroelectric power stations and power complexes (KATEK, etc.) in Siberia, intensify the intersystem of Europe—Siberia links, strengthen the cementing role of the UNPN in the country’s economy, and provide electric power export into foreign countries (Europe, Central Asia, and Northeastern Asia), especially, in the aggregate with the EPLs for direct current with a voltage of ±400—500—750 kV. This teamwork enhances the controllability of the system, reliability, and survivorship of the UES of Russia.

The decision of the realization of similar projects should be thoroughly reconciled; and there is a need to carry out serious substantiating calculations, determine conditions of the decision advisability; and, after comprehensive discussion, come to a competent conclusion.

An additional basis to this formulation is the fact that when calculations connected with the development of the power grid of our country have been carried out, the electric power output level was taken as 1 trillion kW h. This was in 1956—57 when the USSR produced about 200 billion kWh and the UES was calculated with this historical prospect.

In the present-day conditions during the choice of strategic directions of the development of the UNPN, there is a need also to take into account the change of the economy's development paradigm in the world and in the country. The economy of the impetuous industrial development increasingly more, especially in economically developed countries, is transformed into the economy of the postindustrial and neindustrial development when the overwhelming role begins to be played by new innovative technologies with a high ecological and energy efficiency and the roughly developed information and high-intelligence control systems and technologies.

In this case, both the power industry and power systems are changed and do not require complete strong centralization and hierarchical construction and control of them. Power plants and information systems increasingly operate not separately from each other, but jointly and integrally, subjecting each to interferences by the others.

Also, the technological and economic possibility appears for the construction of power systems controlled not only by the vertical, but by the horizontal as well.

The development of power information and control systems give the possibility for a closer connection between producers and consumers of power energy, forming the power system with the participation of both producers and consumers in the use of the load graphs by the optimum way in the online mode. In this case, networks must be different allowing producers and consumers to respond adequately to variations in operation modes; i.e., networks must have controllable elements which may economically effect changes in the operation parameters of power networks.

Thus, there is the appearance of the necessity in the development of local power systems with the distributed generation connected with the well-defined consumers by power networks with the controllable elements in the form of various types of reactive power compensators, voltage regulators in network centers, phase shifters, energy storage systems, and automation devices, which allow one to control the electric power and heat demand, etc.

Local power systems allow one to realize the simultaneous complex control of both producers and consumers of electric power and of networks, which now are called smart grids, i.e., all elements of the power grids take part in power processes equally, which makes these processes systemic and the possibility appears to optimize all parameters at the level lower than the power system of the country and, thereby, to enhance abruptly the efficiency of electric supply as a whole in the power industry.

Thus, the possibility appears to develop such local power systems and the UES of the country as a whole,