OPTIMISATION OF RELIABILITY OF POWER SUPPLY TO CONSUMERS

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Abstract

An approach of solution of the problem of consumers’ power supply reliability is presented. The electric power systems is assumed operating in a market environment.

Introduction

Historically, the electric power industry of Russia was developed step-by-step interconnecting and parallel operating of regional electric power systems (EPS), creating interconnected power systems (IPSs) and forming the Unified power system (UPS). The UPS of the former Soviet Union guaranteed a high level of coordination of electric power production, transmission and consumption, an effective operation of the whole industry and a high reliability of consumer power supply. The efficiency of parallel operation of EPSs within the UPS prior to the electric power industry restructuring resulted in saving of 10-15 mln. kW of installed capacity. It was reached due to the coincidence of load curves and emergency assistance of EPSs and 12-14 mln. ton of standard fuel per year.

There existed a hierarchical system of reliability control which was typical for the so-called industrial model of the electric power industry structure. The relationships between electric power producers and consumers were based on the normative approach, i.e. on fulfillment of obligations, instructions and regulations regardless the expenses, since everything was paid the state. At the end of the last century the deficiency of such structure of electric power industry became obvious, especially due to transition to market environments.

Transition to the market economy changes dramatically relations between electric power producers and consumers. Electric power producers began to compete in electricity sale, contradictions arose between the market subjects that led to heavy operational regime of electric power systems and complicated their managing. The problems of mutual assistance of EPSs in critical situations has been arisen. Transition of the electric power industry to market relations in Russia led to the change of ownership relations with consumers and to restructuring the industry management system. Now relationship between producers and consumers of electric power is based on contractual obligations and mutual financial settlements.

In these conditions, the key objective is to eliminate decrease in reliability level that existed under the centralized management and adapt it to the requirements of each consumer. For this purpose, a new system of reliability control is to be implemented that combines normative approaches and economic mechanisms.

Initial concepts

The proposed technique of power supply reliability optimization is based on the combination of normative and market approaches and the following initial concepts.

Reliability is an object ability to perform its functions under certain operation conditions [1]. Object is this case is a network of electric power systems, and its function is consumer power supply.

S*ystem reliability* is a power system ability to successfully perform its functions keeping operating parameters in required limits the values of all parameters, characterizing the system ability to perform the set functions.

Consumer power supply reliability is an ability of a power system to deliver required electric power to consumers without limitations and in accordance to contractual obligations. Of course, all qualitative and quantitative requirements to EPS operation reliability and all requirements to power quality established by technical regulations have to be satisfied [2].

Consumer power supply reliability depends on the system reliability level and consists of reliability of power supply to feeding nodes that is maintained by the system means (system structure, capacity reserves, reserves of energy resources and transfer capability margins of tie lines, control devices, etc.) and reliability of power supply systems. In a market environment the power supply reliability is a commodity that has its price and is realized through the market services, is assured by all market subjects in the area of responsibility for reliability with their technological and economic interaction [3]. A system operator (SO) plays a leading role in management and coordination of reliability problems in a market environment. Its task is to assure system reliability, i.e. to create such conditions of EPS operation and control, in which electric power is produced, transmitted, distributed and consumed according to the contractual obligations between management subjects and market participants by means of technological interaction of generating units, electric networks and electric installations of consumers. The system operator is responsible for reliable power supply to nodes of the main grid, which supply feeding nodes with electric power. Power supply companies (PC), delivering electric power to consumers in the required volume in accordance with the consumption schedule foreseen in the project for a long-term operation, if consumers fulfil all technical and financial obligations, bear responsibility for reliability of power supply systems and power supply to consumers on the whole. Such sharing of responsibility makes it possible to solve the problem of power supply reliability stage-by-stage: at first at the system level for feeding nodes, then at the level of feeding nodes for individual consumers.

Problem statement and its mathematical model

Solution of the problem of power supply reliability of interconnected power system (IPS) with weak ties is suggested. The annual planning of EPS operation under the industry restructuring and transition to the market is taken in consideration. Due to large dimension and high complexity of the problem, IPS is represented as a numerical model. Each node of the network includes points of connection to an electric systems of generation companies (GC) and each supply nodes connected to consumers. The electric power companies and consumers are supposed to have advance contracts. The applications for connection to the network are submitted to SO. The system operator jointly with the network companies approves the points of electric power supply from the generation companies to feeding load nodes, which supply electric power to consumers. On the basis of known requests for the forthcoming year and the information from the electric generation companies about available capacities, knowledge of electric networks configuration and power transfer capabilities are laid in the basis of calculating scheme for solving the following problem.

Let the interconnection be represented by the model where nodes contain generation companies and feeding nodes connected to the market network. A year is the calculated period that is divided into discrete time intervals of equal duration. At each node of the calculated scheme, one knowns:

- *generating unit commitment and its changes in time because of commissioning of new capacities and removal of operating facilities from operation for reconstruction (updating) or some other reasons;*
- *characteristics of equipment (unit capacity, emergency rate);*
- *total available generation capacity of the node and its generation companies at each time interval;*
- *total consumers load in the feeding nodes at each time interval;*
- *annual volume of scheduled maintenances of generating facilities.*

Transfer capabilities are given for each tie line between the nodes of the calculated scheme.

Under these initial conditions, the maximum possible reliability level of power supply to consumers, connected to the network, for the whole interconnection should be ensured based on the normative requirements to the reliability level of power supply of the feeding nodes which supply electric power to consumers; power balance at the nodes of the calculated scheme and constraints on its components; transfer capabilities of tie lines between the scheme nodes.

At the annual planning of EPS operation, when available capacities of power plants and consumer loads are known and hence, the value of the total reserve capacity is determined, the reliability is achieved primarily by its rational use. It is known that some part of the reserve is intended to compensate power losses due to failures of power plant equipment and to cover random unforeseen load growth, i.e. **operating reserve**. Another part of the reserve is used to compensate power decrease because of scheduled maintenance of equipment, i.e. **maintenance reserve**. The stated above problem can be solved on the base of the optimal (by the reliability criterion) division of the total reserve capacity between these parts. The reliability level may be estimated by the index of consumer provision with electric power that takes into account failure frequency, duration and severity in the system in an integral way. Application of this index is justified by the long advance time (a year) and the scales of the studied object (interconnection), where large load nodes are consumers, whose power supply reliability can be validly estimated by the integrated index. The chosen index has a simple physical sense and is rather sensitive to different disturbances, leading to reliability decrease (emergency power fall, random load growth, equipment repair, etc.) and to measures improving reliability (commissioning of new facilities, increasing transfer capabilities of tie lines, redundancy, etc.). It belongs to normalized integrated reliability indices.

The formulated problem is reduced to solution of an optimization problem.

Determine the maximum of reliability function

$$\frac{1}{W}\sum_{\mu=1}^{M}\sum_{j=1}^{G}\pi_{\mu j}\cdot W_{\mu j}\to \max \tag{1}$$

subject to constraints on its parameters,

where: M – the number of nodes of the calculated scheme;
G – the number of discrete time intervals;
$W_{\mu j}$, W – the forecast power consumption volumes of the μ-the node of the calculated scheme at the j-th time interval and the interconnection as a whole for a year;
π_{μ_j} – the index of consumer provision with electric power of the μ-the node at the j-th time interval that is determined from the expression: $\pi_{\mu j}=\frac{W_{\mu j}-\Delta W_{\mu j}}{W_{\mu j}}$;
$\Delta W_{\mu j}$ – the mathematical expectation of power undersupply for consumers of the μ-the node at the j-th time interval.

The mathematical expectation of power undersupply is calculated based on the power shortage probabilities by the formula:

$$\Delta W=\sum_{\psi=r+1}^{\Psi} P^{g}_{(\psi-r)\varepsilon}(\psi-r)\varepsilon T\,, \tag{2}$$

where: T – the duration of the studied period;
ε – the calculated power stage;
r – the number of standby units of the capacity ε;
ψ – the number of units of the capacity ε that are needed to cover the maximum power shortage;
$P^{g}_{\psi\varepsilon}$ – the probability of power shortage $\psi\varepsilon$.

In the case of reserve unavailability, the power shortage is supposed to be the result of both emergency failure of power plant facilities and sudden load increase under the influence of random factors. All possible values of power shortage probabilities $P^{g}_{(\psi-r)\varepsilon}$ are determined by multiplying the series of probability distribution of emergency power fall and load deviation from its predicted level. The value of predicted electric power in view of the error in load forecast is

$$W=\sum_{m=-\nu}^{\chi} P^{h}_{m\varepsilon} m\varepsilon T+N^{0}\varepsilon T\,, \tag{3}$$

where: N^0 – the number of units of the capacity ε that are needed to meet load without reserve;
$P^{h}_{m\varepsilon}$ – the probability of load deviation from its predicted value by $m\varepsilon$.

The reliability level depends on numerous parameters and factors, in particular on the unit commitment and its emergency rate, load and error of its forecast, operating reserve and mutual assistance of nodes. If the reliability index $\pi_{\mu j}$ is represented as a function of load, operating reserve and power flows by tie lines that vary in time,

$$\pi_{\mu j} = F(N_{\mu j}, RO_{\mu j}, PL_{lj}), \qquad (4)$$

where: $N_{\mu j}$ – the load of the μ-th node at the j-th time interval;

$RO_{\mu j}$ – the operating reserve of the μ-th node at the j-th time interval;

PL_{lj} – the power flow by tie line 1 at the j-th time interval,

then in the process of optimization because of laborious calculations for a large-dimensional problem the use can be made of the approximation of this function by the polynomial

$$\pi_{\mu j} = \sum_{\alpha} \sum_{\beta} A_{\mu\alpha\beta} \left(N_{\mu j} \pm \sum_{l} PL_{lj} \right)^{\alpha} RO^{\beta}_{\mu j}, \ \alpha = \overline{0,s}; \ \beta = \overline{0,s}; \ \alpha + \beta \le s; \ l \in L_{\mu}, \qquad (5)$$

where: s – the polynomial power;

$A_{\mu\alpha\beta}$ – the polynomial coefficients;

L_{μ} – the set of tie lines in the calculated scheme that are adjacent to the μ-th node.

The results of studies performed to estimate an error introduced with the approximation of function (4) by polynomial (5) of different powers have shown the admissibility to apply in this case a quadratic polynomial [4]. The polynomial coefficients $A_{\mu\alpha\beta}$ are selected by the least-squares method based on the set of values for π at different loads of the nodes, considering their mutual assistance and operating capacity reserve.

Solution to the problem by criterion (1) assures the maximum reliability at the minimum annual losses caused by power shortage, if the losses are proportional to the volume of power undersupply. The normative requirements to reliability of power supply to the feeding nodes are taken into account by the constraint on the reliability index π

$$\underline{\pi_{\mu}} \le \pi_{\mu j} \le \overline{\pi_{\mu}}, \qquad (6)$$

где: $\pi_{\mu j}$, $\underline{\pi_{\mu}}$, $\overline{\pi_{\mu}}$ – the calculated value of reliability index of power supply to the feeding nodes of the μ-th node at the j-th time interval, its normative value and the maximum possible value, respectively.

The normative reliability level of power supply to the feeding nodes is achieved by the system means intended for all consumers to the same extent (the principle of equality and non-discrimination). The deficient nodes can experience difficulties with assurance of the normative reliability level and in this case reliability becomes a problem of SO and an object of its market relations with the market subjects. The system operator can solve this problem by using additional system services, purchasing the lacking electric power from surplus nodes and transmitting it to deficient nodes on the base of reserve capabilities of networks. This is done on account of the means of market subjects, guilty of the problem arisen. The means of the system fund of reliability or the insurance funds can be used, if necessary. Thus, at this stage the market mechanism of interaction between the market subjects to maintain power supply reliability comes into play in parallel with the normative approach.

Constraints (7)-(11) added to the model provide power balance at the nodes of the calculated scheme and take into consideration constraints on its components.

$$P_{\mu j} - N_{\mu j} \pm \sum_{l} PL_{lj} - RO_{\mu j} - RP_{\mu j} - RK_{\mu j} = 0, \quad l \in L_{\mu}, \tag{7}$$

where: $P_{\mu j}$ – the available generation capacity of the μ-th node at the j-th time interval ($P_{\mu j} = \sum_{k=1}^{K_\mu} P_{\mu kj}$, $P_{\mu kj}$ – the available generation capacity offered by the k-th generation company of the μ-th node at the j-th time interval to the market, Kμ – the number of GCs at the μ-th node of the studied scheme);

$N_{\mu j}$ – the total load of the μ-th node at the j-th time interval ($N_{\mu j} = \sum_{n=1}^{U_\mu} N_{\mu nj}$, $N_{\mu nj}$ – the load of the n-th feeding node at the μ-th node of the calculated scheme at the j-th time interval, Uμ – the number of feeding nodes at the μ-th node of the calculated scheme);

PL_{lj} – the power flow by tie line 1, neighboring to the μ-th node at the j-th time interval;

L_{μ} – the set of tie lines, neighboring to the μ-th node;

$RO_{\mu j}, RP_{\mu j}, RK_{\mu j}$ – the operating, maintenance and commercial capacity reserves, respectively, at the μ-th node at the j-th time interval, constraints on whose value is set by inequalities (8), (9), (10).

$$\underline{RO}_{\mu} \le RO_{\mu j} \le \overline{RO}_{\mu} \tag{8}$$

where: $RO_{\mu j}$, $\underline{RO}_{\mu}$, $\overline{RO}_{\mu}$ – the operating reserve at the μ-th node at the j-th time interval and its maximum possible values specified by the normative requirements to the operating reserve value. At negligible differences between the right and left limits of inequality (8) the calculated value of operating reserve is leveled in time, which involves leveling of the calculated reliability level during a year.

$$\sum_{j=1}^{G} RP_{\mu j} \cdot \Delta T_j = V_\mu , \qquad (9)$$

where: $RP_{\mu j}$ − the maintenance reserve required to replace equipment capacity of the μ-th node that can be removed for scheduled maintenance at the j-th time interval without loss for reliability;

ΔT_j − the length of the j-th discrete time interval;

V_μ − the annual volume of scheduled maintenances of generating facilities of the μ-th node, that is obtained based on the standard durations of maintenances.

$$RK_{\mu j} \geq 0 \qquad (10)$$

Commercial reserve capacity $RK_{\mu j}$ was entered into the balance equation for the nodes with redundant power which can be used at the discretion of generation companies.
The following equation is used to set the constraints on the value of power to be transmitted along the electric ties between the nodes.

$$\underline{PL}_l \leq PL_{lj} \leq \overline{PL}_l , \quad l = \overline{1, L}, \qquad (11)$$

where: L − the number of ties between the nodes of the calculated scheme;

$PL_{lj}, \underline{PL}_l, \overline{PL}_l$ – the power flow by tie line l at the j-th time interval and its transfer capabilities, respectively. Network company that owns or manages the network equipment of the tie line should coordinate with system operator and provide transfer capabilities of all elements and cutsets during normal operating conditions and during maintenance periods.

Problem (1)–(11) consists in the choice of optimal values for operating reserve capacity at the nodes of the calculated scheme, taking into account their interaction, at each discrete time interval, in order to provide maximum possible reliability of power supply to consumers throughout the entire interconnection, and reliability of power supply to the feeding nodes not below the standard level, let us call it guaranteed. The maintenance reserve capacity obtained after optimization at each time interval provides during a year full planned maintenance of generating equipment without reliability violation. Meeting the constraints on capacity balance, on the value of operating and maintenance reserve capacity at the nodes and on transfer capabilities of tie lines makes it possible in the process of optimization to take into account the interests of system operator and consumers, possibilities of generation and network companies.

Solving the problem at the set values of $P_{\mu j}, N_{\mu j}, \underline{PL}_l, \overline{PL}_l, \underline{RO}_\mu, \overline{RO}_\mu, V_\mu, \underline{\pi}_\mu, \overline{\pi}_\mu$ we determine optimal, in terms of reliability, values of $RO_{\mu j}$, $RR_{\mu j}$, PL_{lj} and the values of the guaranteed reliability index $\pi_{\mu j}$ in the feeding nodes by time intervals. For consumers connected to the feeding nodes the level of guaranteed reliability will be average weighted. Here the system operator receives information on: what maximum possible level of power supply reliability throughout the entire interconnection and what level of guaranteed reliability at the feeding nodes under given conditions can be provided in the coming year; what nodes in the calculated scheme are surplus and what are deficient; what amount of electric power and at what time interval should be transmitted to the deficient nodes to ensure there the reliability of power supply to the feeding nodes no lower than the standard level and what nodes from the view point of reliability in the interconnection should be involved. This information can be used to conclude the contracts for selling-buying electric power and system services between the participants of the market (system operator, generation, network and power supply companies and consumers).

As a result, the maximum possible reliability of power supply provides to consumers in the interconnection, and guaranteed reliability of power supply to the feeding nodes at each node in the calculated scheme. Thus, using the system means the problem of maintaining reliable power supply to consumers is solved at a system level. Further the problem of maintaining reliable power supply at the level of feeding nodes is solved for each individual consumer. In a market environment this problem should be solved by power supply companies. Estimating power supply reliability for an individual consumer connected to the feeding node the latter is considered as the basic power source.

Having received the system operator's forecast on the guaranteed reliability level for power supply to the feeding nodes for the coming year power supply, companies analyze if it meets the reliability requirements of consumers served by them. Taking into account the current situation in the industry and high reliability requirements the level of guaranteed reliability may turn out to be insufficient for all the consumers connected to the feeding nodes. As a result power undersupply and its consequences may cause huge losses for large consumers. In a market environment consumers may affect the power supply reliability level. Having estimated potential losses from insufficient reliability they decide what is more profitable – to have a required power supply reliability level or take a risk of possible losses. Taking into account the price of reliability and their financial capacities consumers specify the desired reliability level.

In their turn, power supply companies group consumers on the basis of the reliability levels they require. The consumers can be divided, for example, into three main groups. The first group includes the consumers asking for the reliability level lower than the standard reliability level of power supply to the feeding nodes, the second − those with the level above the standard one but not exceeding the level of guaranteed reliability, and the third − the consumers with the reliability level higher than the guaranteed reliability level. Ensuring the reliability level specified by consumers from each group calls for different means and expenses on the part of power companies that in a market environment have to be compensated by consumers for example via surcharge to the base tariff[1] [5,6]. Here the consumers pay only for additional services related to the increase of the reliability level of power supply to them. Direct participation of consumers in funding the measures on ensuring system reliability (introduction of new technological equipment and modernization of operating equipment, construction (reconstruction) of electric networks and reconstruction of power supply schemes, etc.) is not foreseen. These measures are funded in a centralized manner through the investment component in the base tariff, consumer's payment for electricity, fee for connection to the network and its use.

For consumers of the first group with low reliability requirements power supply companies choose measures to decrease reliability (change in the order, periodicity and duration of disconnections or limitations of consumers in the hours of maximum loads, in the post-emergency conditions, etc.),

[1] In this case base tariff corresponds the standard reliability level of power supply to the feeding nodes.

estimate savings on costs required for these measures and give a discount on the electricity tariff. Should the consumers be satisfied with the standard level of power supply reliability, surcharges to the base tariff are not established. The tariff surcharges are established for the consumers that require the reliability level of power supply higher than the standard one, i.e. for the consumers of the second and third groups. For each of the groups the costs (saving) are estimated and the scale of surcharges (discounts) to base tariff is developed. It should be noted that the consumers of the third group will have higher surcharges than the consumers of the second group because ensuring reliability required for them may call for additional expenses related to the improvement of reliability of power supply to feeding nodes or introduction of additional power sources.

Tariff discounts are introduced in the contract between a power supply company and consumers. Payment for reliability organizes the activity of both parties. Power supply companies become more responsible for timely supply of electric power in a required volume to each specific consumer taking into account the requirements to power supply reliability. Consumers get opportunity to participate in the process of tariff formation and through the tariffs protect themselves from power supply interruption and potential losses. However, the system operator and federal agencies for tariffs should control the payment for reliability and the use of these funds as well as the settlement of conflicts and disputes between consumers and power supply companies. Thus, by using different methods and means power companies provide consumers with the desired level of power supply reliability for a certain payment. In doing so the consumers that are satisfied with the standard level of power supply reliability pay for electric power according to a base tariff. If the specified reliability level is lower than the standard one the consumers are given a discount, if higher – the consumers have a surcharge to the tariff. The value of the surcharge is determined by the cost of reliability improvement. For the calculation of surcharges (discounts) to the tariff in a market environment there should be a mechanism allowing power companies and consumers to take into account the interests and requirements of each other while pursuing their own interests [7]. Consumers requiring higher reliability should realistically assess the costs necessary to ensure it and their own financial capacities. Power supply companies should not overstate the price for reliability not to lose their consumers since in a market environment consumers have a right to choose power company according to their financial capacities and offers of power companies.

Mechanism of coordination power supply company and consumer's interests

Reliability is a characteristic that determines the quality of an object, therefore ensuring some level of reliability requires resources and efforts that have certain utility for power supply company. The company is ready to invest these resources and efforts since it understands that consumer will pay for electricity provided the required power supply reliability is ensured. Otherwise consumer will search for another power supply company or construct its own power source. The power supply company should receive certain compensation for the efforts and resources on maintaining power supply reliability. Power consumer buying electricity from the power supply company understands that he has to pay for power supply reliability since insufficient reliability of power supply may lead to losses. If power supply company is unable to provide the consumer with the required reliability it can compensate consumer's losses due to insufficient reliability.

In a general case both subjects of relations – a power supply company and a consumer have different economic criteria for reliability and the criteria do not coincide. Let us consider possible mechanism of interrelations between the subjects of relations in order to find a compromise solution on power supply reliability. The criterion of maximum net present value is the most common criterion for all subjects. For the power supply company the economic criterion of power supply reliability can be written as follows:

$$NPV_S = I_E + I_R - C - D^* \rightarrow \max \ , \qquad (12)$$

where: NPV_S – a net present value of power supply company;

I_E – the total reduced revenue from selling electric power in time period T;

I_R – the total reduced revenue from consumer's payment for reliability in time period T;

C – the total reduced costs of power supply company operation that include a reduced share of capital investments and current costs in time period T;

D^* – the total reduced loss (payment to consumer for an insufficient power supply reliability level against the level stipulated in the contract for power supply between power supply company and consumer) in time period T.

For consumers the criterion is the following form:

$$NPV_C = P_C - C_E - C_R - D + D^* \rightarrow \max \, , \qquad (13)$$

where: NPV_C – a net present value of a consumer;

P_c – the total reduced profit of a consumer excluding power supply costs;

C_E – the total reduced costs of power supply taking into account the fact that the consumer not only buys electric power but takes some measures to receive it;

C_R – the total reduced costs of power supply reliability payment;

D – the full total reduced losses of consumer due to unreliable power supply;

D^* – the total reduced losses due to unreliable power supply compensated by power supply company.

From (13) it follows that the part of full losses due to unreliable power supply to consumers, that corresponds to the insufficient level of power supply reliability with respect to an agreed level stipulated in the contract for power supply between a power supply company and a consumer is compensated by the power supply company. With the set amount of electricity to be sold and costs the interest of power supply company will be determined by the criterion

$$I_R - D^* \rightarrow \max \ , \qquad (14)$$

the interest of a consumer by

$$D^* - D - C_R \rightarrow \max. \qquad (15)$$

For aggregate consumer, that totally represents all consumers, served by the given power supply company,

$$I_R = C_R . \qquad (16)$$

From the analysis of the reduced relationships from the view point of the interests of power supply company and aggregate consumer it follows that if power supply company is able to efficiently use the funds I_R and improve reliability of power supply and while decreasing the losses to a greater extent than the costs incurred to provide reliability from the funds I_R, the company will gain additional profit. Hence, there appears an incentive for the power supply company to improve reliability. Consumer is interested in receiving larger compensation D^*, than the costs of reliability C_R. If consumer establishes the required reliability through the value of specific losses due to sudden disconnection of power, d_p (rub/kW), and due to power undersupply, d_e (rub/kWh), then the rise in compensation D^* can be provided by increasing d_p and d_e. However, in this case the payment for reliability, that depends on d_p and d_e, will grow for consumer. In its turn power supply company will try to improve power supply reliability of exactly this consumer, in order to decrease D^*.

Thus, the suggested mechanism of interrelations between power supply company and consumer provides an economic balance of their interests. Consumer may specify any level of reliability by setting the values of specific losses d_p and d_e. Power supply company may stimulate the consumer to set real values of d_p and d_e by appropriately establishing payment for power supply reliability for consumers, since their overstatement calls for higher payment for reliability, whereas their understatement does not completely compensate the losses due to insufficient power supply reliability level.

Conclusion

Taking into account the increased power supply reliability requirements in a new economic environment it is possible to formulate the main difficulties in solving the changing and newly appearing reliability problems.

The problem occurred during coordination of the economic solutions taking into account different interests of different subjects of the EPS control. It is necessary to revise the criteria of choosing the optimal control solutions taking into account the reliability factor. There is a need for a new system of reliability control that should be based on combination of normative approaches and economic mechanisms. Economic control of reliability can be organized by different methods including differentiation of electricity tariffs for consumers, creation of insurance reliability funds, etc. Thus, it is necessary to develop the mechanisms of economic relations between different subjects of electricity market and put them into practice.

The current reliability standards should be revised, in particular the standards for reserves and maintenance. There is a need for the expanded legal framework for the power supply reliability indices, uniformity of all reliability standards for all power systems operating on the territory or Russia and their approaching to the international ones.

The existing models of reliability analysis, remaining operable in principle, can in some cases be upgraded in the context of new conditions. First of all, this concerns the market participants interrelations to be taken into account. Here it is necessary to be able to determine and take into account fair distribution of costs and profit among the market participants. Previously developed models of reliability synthesis should be improved taking into account the conditions and criteria of reliability control problems, methodical approaches, legal frameworks that will be implemented in practice. These models should be based on the new mathematical methods and information technologies. The newly developed approaches to the analysis and synthesis of reliability when controlling expansion and operation of EPS should be based on the need to coordinate the actions of jointly operating subjects in the competitive environment.

For the power supply reliability to be ensured in a market environment it is necessary to coordinate different interests of power supply companies and consumers, develop an applicable economic mechanism for their interrelations.

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