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ELECTRICITY SUPPLY MANAGEMENT UNDER CONDITIONS OF MARKET RELATIONS

The paper investigates the influence of market transformations in the energy sector on electricity supply reliability. A system approach to solving the tasks of ensuring and controlling reliability of electricity supply to the consumers under market conditions is proposed.

Keywords: *electric energy systems, electricity supply reliability, electric energy markets.*

Introduction

The task of ensuring reliable operation of electric energy systems (EES) has been always given special attention [1]. In the conditions of multinational liberalized electric energy markets and corresponding dispatching control complications the problem of ensuring reliable and safe electricity supply to the consumers has become especially relevant. In-depth analysis of various aspects of reforming energy sector in many countries has revealed both positive and negative features of the impact of such reforms on providing sufficient level of the electricity supply reliability.

Research aim is to develop methods for evaluating efficiency of the measures on electricity supply reliability assurance as an indispensable part of the electric energy market operation.

Research results

With implementation of market relations, changes in legal, economic, structural and organizational forms of functioning of the electric energy sector entities occur. Therefore, the problems of ensuring reliability of EES and electricity supply to the consumers should be considered taking into account these changes, their technical, legal, management, economic and informational aspects. Market relations require development of such reliability assurance concept, which would take into account the market mechanisms along with administrative methods of production management, electric energy transmission and distribution.

New reliability assurance concept should be based on the methodology of *system approach,* which takes into account market relations between market entities, comprises a set of tasks facing the energy sector according to the decision making criteria as well as the procedure for joint participation of the market entities in ensuring reliability of electricity supply to the consumers.

The system approach methodology includes the following main concepts [4]:

1. There should be a system view as to joint work of the energy enterprises – the energy market entities. They should be regarded as an integral system rather than a set of separate elements, which corresponds to the “system approach” term.

2. The above system is in hierarchic interconnection with the systems of a different kind, it is under the influence of these other systems and, correspondingly, this system management is hierarchic as well.

3. Management of the system should be based on clear, preliminary formulated objectives.

4. The management model should be capable to adapt to the changes of internal and external conditions.

Ranking the objectives of solving system tasks of ensuring reliability under market conditions is determined by certain independence in the operation of separate market entities, when their management objectives, criteria of their development and operation may not correspond or even contradict general criteria as to reliability assurance. In addition, legal base of reliability assurance should not be of a declarative character but rather define the measure of actual responsibility of each market entity for ensuring the pre-determined level of the system reliability as well as reliability of electricity supply to the consumers.

Structural hierarchic model of reliability management is presented in Fig. 1.

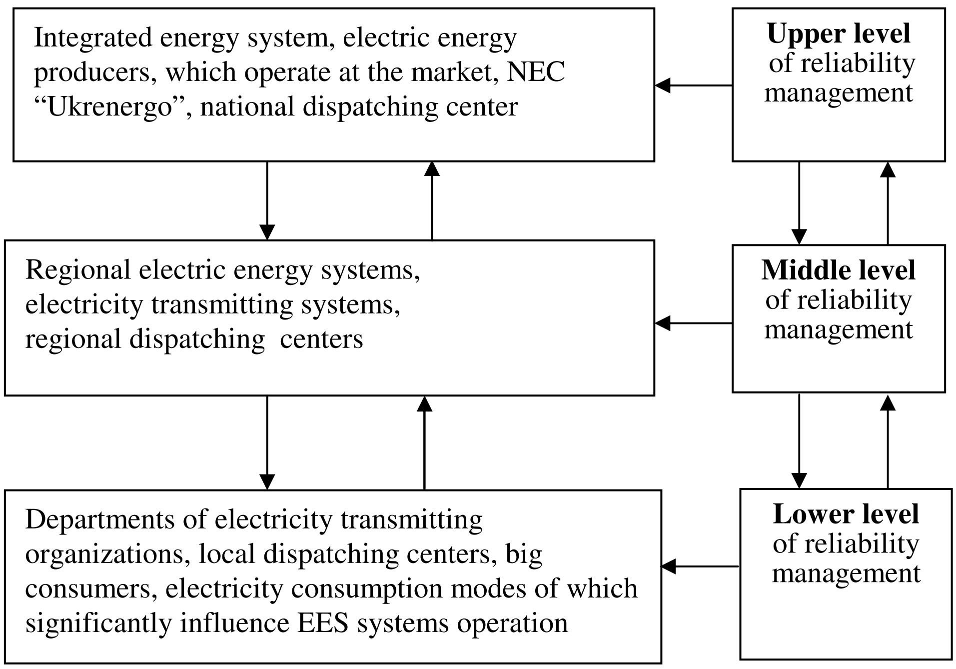

Fig. 1. Structural hierarchic model of reliability management

Hierarchic principle of reliability assurance was successfully used for operative management of the Integrated Energy System of former USSR and was considered to be one of the effective approaches to the system reliability assurance. Under the conditions of the electric energy market operation the dispatching operative control system aims at maintaining integrity of the complex technological process through compensating separation of functions and tasks of individual entities, introduced by the market.

When considering the problem of electricity supply reliability assurance under market conditions, it is the consumer who should be given primary attention [5]. Reliability of the electricity supply system itself, which is evaluated by the cost indicators such as total expenses for its provision, repairing damaged equipment, etc. becomes one of the internal supplier's problems.

When the electric energy sector is being reformed with implementation of market competitive relations, responsibility for reliable electricity supply is distributed between many market entities, which increases the role of coordination, elaboration of the rules and principles of reliability assurance.

The system of operative reliability evaluation comprises the following components:

– obtaining data about the current operating mode;
– current state evaluation;
– calculation of the steady-state modes;
– the steady-state mode limiting control;
– determination of the possible mode changes;
– calculation of transient processes and evaluation of the dynamic stability reserves;
– calculation of the short-circuit currents.

At the *first stage* reliability of the planned mode is analyzed. The task of dispatching services and services of the modes is to check the set mode and in case of certain deviations (caused, for instance, by the change of power balance as a result of signing two-side agreements between producers and suppliers), to determine the possibility (or to substantiate the impossibility) of maintaining such a mode and to issue corresponding recommendations.

In order to provide the electric energy system operation or to improve its reliability, a regulated reserve as to generation and transfer capabilities of the networks is created as well as that of electricity supply sources of the responsible consumers. Permissible modes of the equipment operation are also determined.

At the *second stage*, when the planned mode is implemented, the task of the dispatching service is to provide the planned indicators. If certain market entities do not keep to the pre-defined parameters, the dispatching service task is to identify them, to take measures on the mode normalization and try to minimize deviations of the parameters from the planned indicators for other participants of the market. In addition, dispatching service must perform its traditional functions: to realize switchings, to work with equipment repair requests, fixing local failures, etc.

Given the above, reliability is the main criterion as to a certain mode implementation because provision of the planned indicators depends on the reliability assurance. To prevent emergencies, current mode should be constantly analyzed with its reliability evaluation. It should be noted that, in a general case, it is not enough to analyze cases when the mode parameters are beyond the pre-defined ranges or to compare them with the pre-defined standard modes. Such an approach could be used only if all the modes have large stability reserve. Under market conditions, however, nobody can guarantee this. Therefore, reliability analysis should be performed taking into account current mode of the electric energy system operation as well as reliability criteria for the current state of the system.

The modes could be analyzed in the following way. Using the devices of telemechanics, current mode parameters are transferred to the dispatching station. Then, by means of the state evaluation unit computation model, parameters are corrected. Further, the current mode is checked for permissibility of the pre-defined parameters (current, voltage) as well as for static stability. After that the mode is checked for dynamic stability in relation to most probable and most dangerous events. Then various computations of steady-state modes are performed for reliability analysis according to the criterion (n-1) and for certain equipment - also according to the criterion (n-2). In addition, computations of the possible transient and emergency modes are conducted in order to analyze correctness of RPA (relay protection and automatics) equipment settings. According to the results of these computations, integral reliability parameters should be provided for the dispatching personnel also if reliability is not maintained as well as in case of possible emergencies. If necessary, detailed analysis of the most dangerous and most probable situations and modes could be carried out.

Structural scheme of the operative reliability assessment is presented in Fig. 2.

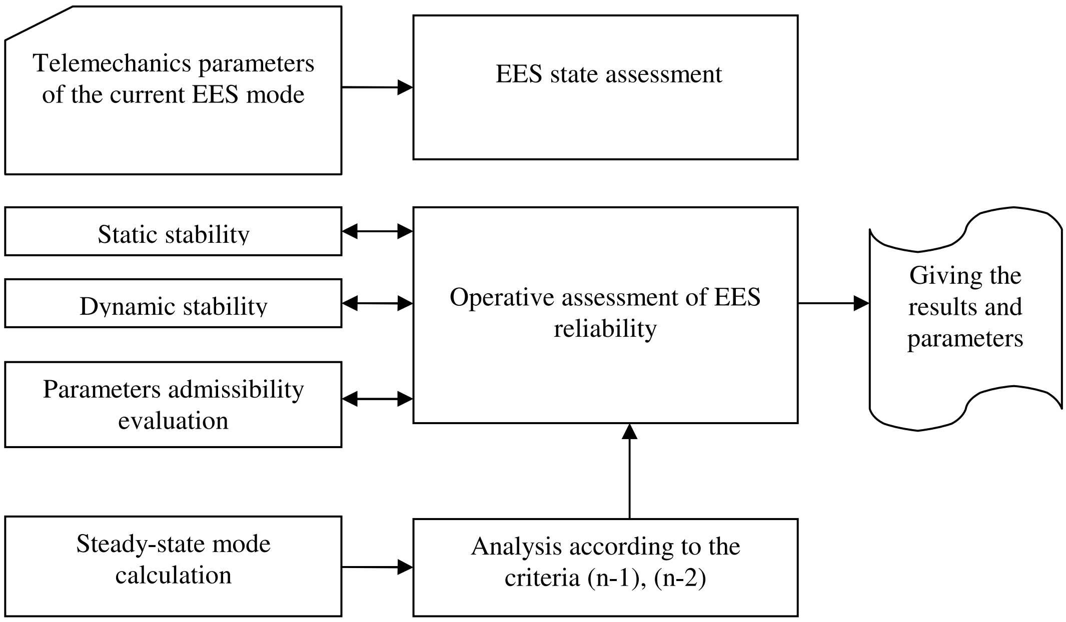

Fig. 2 . Structural scheme of the operative stability assessment

It should be taken into account that it is impossible to build a fully universal reliability assessment system. At the same time the existing system requires careful adjustment, based on the experience of monitoring the components that compose general reliability assessment system.

Attention should be paid to the fact that total cost of the software and hardware means for building operative reliability assessment system could turn to be rather high compared to the stand-alone software package for steady-state mode computations. The cost will be influenced by the requirements to the system response speed as well as by the computation model dimensionality. However, implementation of such a system at the most dispatching stations is expedient and can give significant economic effect.

As a criterion of ensuring reliable electricity supply to the consumers, minimum expenses per unit of the consumed energy can be used. This criterion does not contradict the interests of producers, transmitting organizations and corresponds to the interests of consumers. In this case calculation relationships for evaluating electricity supply reliability assurance can be determined taking into account variant efficiency of energy supply, i.e. comparing expenses of the market entities for increasing reliability of electricity generation and transmission, on the one hand, and consumers' losses caused by unreliable electricity supply by the power supplier, on the other. As for EES, which have been constantly developing and improving their activities by implementing reliability assurance measures, efficiency of the variants could be compared considering the cost of measures for development and maintenance of the generating capacities and electric networks, on the one hand, and losses of the electricity consumers taking into account the cost of under-supplied electric energy for each consumer, on the other.

Reliability of EES electricity supply for its consumers is determined by the ratio of the difference between electricity generation during the consumers' full-supply periods E_{full} and during the periods of electricity under-supply due to emergencies and other accidental events, E_{under}, to electricity generation during E_{full} periods:

$$H_{rel} = \frac{E_{full} - E_{under}}{E_{full}} \cdot 100\,\%, \tag{1}$$

where E_{full} – total amount of electric energy, provided by all generating capacities, kW·h; $E_{\text{under.}}$ –

total amount of under-supplied energy to all EES consumers, kW·h.

It is expedient to calculate this indicator of electricity supply for EES as an integral one for the one-year interval as:

$$H_{rel}^{yr} = \frac{E_{full}^{yr} - E_{under}^{yr}}{E_{full}^{yr}} \cdot 100\ \%. \tag{2}$$

Integral effect E_{int}, or net discounted profit within the calculated period, can be considered to be a criterion for economic evaluation of the effectiveness of implementing reliability improvement measures, which is calculated by the formula:

$$E_{int} = \sum_{t=0}^{T} (R_t - B_t) \frac{1}{(1+E_t)^t}, \tag{3}$$

where T – calculation period; t – number of the step in implementing the reliability improvement measures; R_t – resulting effect, achieved at the t^{th} implementation step; B_t – expenses for implementation of the electricity supply reliability improvement measures at the t^{th} step.

Profitability index, internal return rate, capital investment pay-back period and other indicators can be used as additional efficiency criteria.

Total expenses B_t for electricity supply reliability assurance comprise the following components:

$$B_t = B^{gen} + B^{trans} + B^{fuel} + B^{add}, \tag{4}$$

where B^{gen} – expenses for development of the generating capacities; B^{trans} – expenses for development of the electricity transportation systems (electrical networks); B^{fuel} – fuel expenses taking into account development of the fuel bases, transportation and processing of the fuel; B^{add} – additional expenses during implementation of the reliability assurance measures.

The cost of additionally generated energy as a result of reducing the amount of under-supplied electricity per W units is taken as a resulting effect R_t from implementation of the measures on electricity supply reliability improvement.

Expenses for the development and operation of the generating capacities are determined by installed power level N by the formula:

$$N = \frac{W}{h(1-\alpha_{pn})(1-\gamma_{losses})}, \tag{5}$$

where W – the amount of additionally generated and consumed electric energy as a result of implementing measures for electricity supply reliability improvement; h – the number of hours during which installed power of TES-type electric station was used, hours; α_{pn} – part of the electric energy consumed for TES personal needs; γ_{losses} – relative electric energy losses in the electrical networks.

Expenses B^{gen} for EES with electric stations (e. g. TES) can be calculated in the following way:

$$\begin{aligned} B^{gen} &= K^N + B^{fixed} + B^{fuel} = \\ &= K^P + (B^{repair} + B^{sal} + B^{total} + B^{ecol} + B^{res} + B^{system} + B^{credit}) + B^{fuel}, \end{aligned} \tag{6}$$

where K^P– capital investments for building or development of TES with power P; B^{fixed} – semi-fixed expenses for TES; B^{fuel} – fuel component of the expenses; B^{repair} – expenses for capital and current repairs; B^{sal} – expenses for salary; B^{total} – total station-level expenses for TES; B^{ecol} – ecological component of the expenses or harmful emission charge; B^{res}– charge for using natural resources and land; B^{system}– system component of the expenses (taxes, payments, etc.); B^{credit} – annual credit and credit interest payments.

Expenses for development and operation of the electric energy transmission systems may be written in the following form:

$$B^{trans} = +K^{trans} + B^{transW}, \tag{7}$$

where K^{trans}– capital expenditures for development of the electrical networks; $B^{transpW}$ – total expenses for electric energy transportation to the consumers.

Expenses for the development of electrical networks can be approximately evaluated according to the relationship between the expenses for development of the generating capacities and electrical networks, based on the actual data of the past years or design data for future prospects.

Conclusions

The presented methods for assessing the efficiency of the measures on the improvement of electricity supply reliability (reliability management) enables the reliability category consideration as an indispensable component of the electric energy market operation and its efficiency evaluation.

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