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METHODS OF INCREASING OF FUNCTIONAL STABILITY OF POWER SYSTEMS

This article highlights reservation as a method of increasing of functional stability of technological system "power system". This method enables predict reliability of secure functioning of technological system by choosing optimal meaning of failure-free operation probability, that allows to keep on a corresponding level and to promote functional stability of power systems. There are descriptions of measures at the expense of which provision of power systems functional sustainability is achieved. Also, there is description of constructive entity level which is appropriate for exercise of reservation. Majority reservation peculiarities in technological system "power system" are considered.

Keywords: technological system, power system, energy products, functional stability, reservation method, military security of facilities.

General definition of a problem. Powerful and reliable energetics of a country is one of the main functional conditions of all spheres of the activity and becomes the most important system of strategic facilities, "responsibility" for military security sphere of a country. Power system facilities always relate to security facilities("responsibility") of the biggest operational-strategic importance, which are the main target of destruction for the enemy. That is why military security of power stations(PS) is one of the most important and original task for a country and Armed Forces of this country. It is achieved by maintaining high functional stability (reliability) of "technological system"(TS) of PS, regular prophylaxis of TS malfunctions with ecologically dangerous consequences, protection of PS facilities from attacks by enemy means and rapid settlement of ecological consequences during emergencies of technological nature.

Maintenance of functional stability of TS PS is achieved by the following measures:

structural exaggeration of TS(reservation) regarding reliability of secure functioning;

availability of "own" control means for secure course of technological process(avoiding emergency modes);

availability of TS protection from dangerous errors and unauthorized actions of personnel;

modernization of security system of TS;

maintenance of appropriate level of personnel qualification, organizational measures and military safety concerns.

In this article we will deal with reservation as a method of increasing of functional stability of PS TS.

Exposition of the main material. Important meaning for PS is the issue of the level of constructive entities(CE) when it is relevant to use reservation. Reservation can be " simple" when function of "working" element *m* while breaking is operatively conducted by one of the reserve (*m-1*) elements. "Majority" reservation in "informational" systems is used when all *m* of the same "working" elements are functioning at the same time, and initial functional of this system is formed by "majority" element as the result of concurrency of initial functions of the most "working" elements.

Required multiplicity of PS subsystem reservation are grounded as following.

Failure-free operation probability(FFOP) of a system which is a sum of *n* of multifunctional subsystems is known to be equal to

$$PS = \prod_{j=1}^{n} P_j , \qquad (1)$$

Where P_j –is a FFOP of subsystem j. General meaning of product PS will be less than minimal meaning of accumulation factor because always $P_j < 1, j = \overline{1,n}$. Therethrough, FFOP subsystems should be made as close between each other (with the same medium meaning of *P*) while providing needed level of FFOP in general that measure up an irregularity

$$PS^{nomp} \leq \prod_{j=1}^{n} P = P^n . \tag{2}$$

From this moment meaning of FFOP subsystem should be

$$P \geq \sqrt[n]{PS} . \tag{3}$$

If for a subsystem $P_j < P$, "reservation" of this subsystem must be brought to the meaning of FFOP $P_j \geq P$. It is known, that during reservation with *m* multiplicity, FFOP of the subsystem will be

$$P_j^{(m)} = 1-(1-P_j)^m, \quad j = \overline{1,n} . \tag{4}$$

That is why needed multiplicity of subsystem reservation is defined by condition

$$P \leq 1-(1-P_j)^m . \tag{5}$$

From this irregularity we finally find

$$m_j \geq \frac{\log(1-P)}{\log(1-P_j)}, j = \overline{1,n} . \tag{6}$$

Lets consider ultimate cases of constructive entity level where "simple" reservation is conducted-"channels" and "subsystems"(which figure up each channel)

It is known, that during reservation of TS when it has only *m* "channels" as a part of *n* functional "subsystems" with FFOP of each reservation

$$p_j, j = \overline{1,n}, \tag{7}$$

General free-failure operation possibility of TS will be

$$PS^{(k)} = 1-\left(1-\prod_{j=1}^{n} p_j\right)^m . \tag{8}$$

For *m*-tuple reservation of each *j* functional "subsystem" in a sole channel the general free failure operation possibility will be

$$PS^{(e)} = \prod_{j=1}^{n}\left[1-\left(1-p_j\right)^m\right]. \tag{9}$$

Analysis of functions data shows that for $p_j > 0.5, j = \overline{1,n}$ (that almost always has place) the following irregularity is correct

$$PS^{(k)} < PS^{(e)} \tag{10}$$

For equal variants value of such TS.

Consequently, level of constructive entities for " simple" reservation should be lower (it is desirably on the level of "elements"), but at the same time difficulties of technical diagnosis and renewal capability of TS during malfunction of main or reserve constructive entities of "low" level become much higher and the process of transition from main constructive entity to reserve one becomes more complicated because of a great number of constructive entities. In such a way it is appropriate to use reservation on the lower level of "variable" constructive entity which could be changed while being used on new working one by forces and facilities of PS personnel.

Majority reservation is used in process control systems and TS control systems for functional stability of PS. Lets examine peculiarities of TS majority systems.

Lets analyze system with 3 elements in comparison with single-element system for which "majority" principle of system functional selection is confined by concurrency of initial function in any of two or all elements.

If elements of system are the same regarding their FFOP p and FFOP of majority element – $p^{м}$,from this follows that according to the theory of probability and event algebra FFOP will be

$$P("2/3","3/3") = \{3p^2(1-p) + p^3\} \cdot p^{м}. \qquad (11)$$

Diagram of this function in terms of the FFOP level of "working" elements p and majority element $p^{м}$ shown on fig.1.

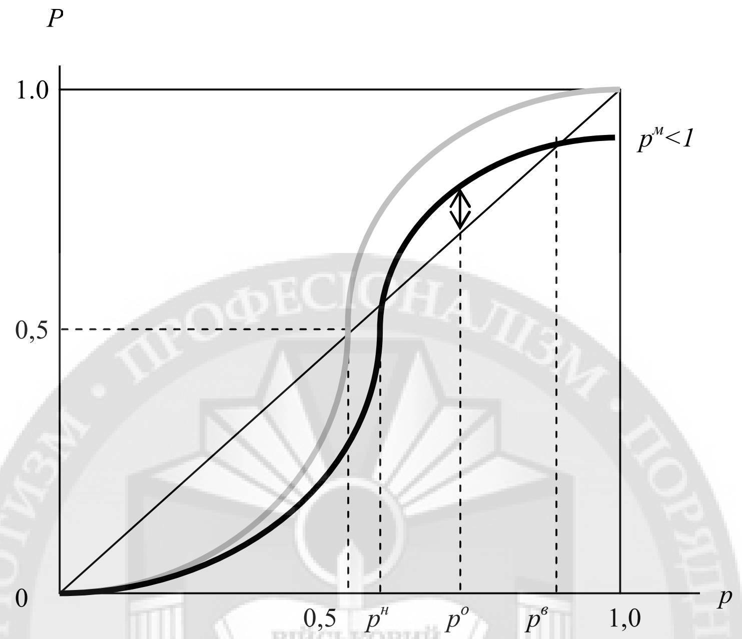

Fig. 1. Majority reservation on the principle («2/3»,»3/3»)

Grey color shows the diagram of this function for $p^{м} = 1$. It is easy to see that in this case majority reservation is appropriate only for FFOP working elements $p>0.5$, when the curve diagram $P=\{*\}$ is bigger than a straight line of non-reserve system. As far as real FFOP of majority element is always $p^{м} < 1$, then majority reservation will be appropriate only in the meaning range of working elements FFOP

$$p^{н} < p < p^{в}.$$

It is clear that "lower" and "upper" meaning of FFOP of working elements are "roots" of algebraic equation that reflects cross points of curve P (11) and straightforward line $P=p$ (single-channel system)

$$\{3p^2(1-p) + p^3\} \cdot p^{м} = p. \qquad (13)$$

Consequently

$$p^{н} = \frac{3p^{м} - \sqrt{9(p^{м})^2 - 8p^{м}}}{4p^{м}}; \quad p^{в} = \frac{3p^{м} + \sqrt{9(p^{м})^2 - 8p^{м}}}{4p^{м}}. \qquad (14)$$

There is optimal meaning of FFOP of working element for which "reward" of majority reservation (exceedance of system FFOP under FFOP of working element) is maximum; lets find it from compelling equation

$$P\{"2/3","3/3"\} - p = \{3p^2(1-p) + p^3\} \cdot p^{м} - p = \Delta. \qquad (15)$$

Maxima condition of contrast Δ is that the primitive for p will be equal to zero

$$\frac{d\Delta}{dp} = -(6p^{\text{м}})p^2 + (6p^{\text{м}})p - 1 = 0\,. \qquad (16)$$

Solution of this algebraic equation is an "optimal" meaning of working element FFOP for defined meaning of FFOP of majority element-

$$p^{o} = \frac{-6p^{\text{м}} - \sqrt{36(p^{\text{м}})^2 + 24p^{\text{м}}}}{-12p^{\text{м}}}\,. \qquad (17)$$

There is also minimum meaning for FFOP of " majority" element when majority reservation is appropriate ; it is provided by apparent condition when "upper" and "lower" meanings of interval (14) are equal , namely they are converged in " cross point" of the curve of "tripled" system *P(3)* to the straightforward line *P(1)=p* of non-reserved system. From (14) we have that

$$p^{\text{н}}=p^{\text{в}} \qquad (18)$$

when formula under radical is equal to zero for existing FFOP

$$9(p^{\text{м}})^2 - 8p^{\text{м}} = 0\,. \qquad (19)$$

Finally

$$p^{\text{м}} = 8/9 = 0.(8). \qquad (20)$$

Conclusions. Analyzed method gives us possibility to predict reliability of secure functioning of technological systems by selecting the optimal meaning of free-failure operation possibility , that allows to maintain on appropriate level and also increase functional stability of power system.

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Без рецензії.

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МЕТОДИ ПІДВИЩЕННЯ ФУНКЦІОНАЛЬНОЇ СТІЙКОСТІ ЕНЕРГОСИСТЕМ

У даній статті розглядається резервування як метод підвищення функціональної стійкості технологічної системи "енергосистема". Цей метод дозволяє прогнозувати надійність безпечного функціонування технологічної системи, вибираючи оптимальне значення безвідмовної роботи, що дозволяє підтримувати на відповідному рівні й сприяти функціональній стабільності енергосистем. Описуються критерії, за рахунок яких забезпечується функціональна стійкість енергосистем. Крім того, описаний конструктивний рівень, що розглядається для здійснення резервування. Розглядається велика кількість особливостей резервування в технологічній системі "енергосистеми".

Ключові слова: технологічна система, енергосистема, енергопродукти, функціональна стійкість, метод резервування, військова безпека об'єктів.

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МЕТОДЫ ПОВЫШЕНИЯ ФУНКЦИОНАЛЬНОЙ УСТОЙЧИВОСТИ ЭНЕРГОСИСТЕМ

В данной статье рассматривается резервирование как метод повышения функциональной устойчивости технологической системы "энергосистема". Этот метод позволяет прогнозировать надежность безопасного функционирования технологической системы, выбирая оптимальное значение безотказной работы, что позволяет поддерживать на соответствующем уровне и способствовать функциональной стабильности энергосистем. Описываются критерии, за счет которых обеспечивается функциональная устойчивость энергосистем. Кроме того, описан конструктивный уровень, который рассматривается для осуществления резервирования. Рассматривается большое количество особенностей резервирования в технологической системе "энергосистемы".

Ключевые слова: технологическая система, энергосистема, энергопродукты, функциональная устойчивость, метод резервирования, военная безопасность объектов.