The use of low hydropower possibilities for the increase of the NPP auxiliaries redundancy reliability

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Abstract **It is considered the problem of the reliability increase of the emergency power system of major energy objects auxiliaries with the supply of various energy sources (diesel and hydroelectric generators). The effect of the additional redundancy on the probability of emergency power system fault is studied.**

Keywords **Hydropower, Emergency power supply, Failure probability.**

I. Introduction

The experience of energy objects exploitation shows that the failures of the power generating units, power transfer systems and loads can lead to the necessity of hitch and sometimes to the loss of power plant auxiliaries supply.

The accident at Fukusima-1 NPP shows that the consequences of nuclear reactor accidents connected with the de-energization of the reactor shut-down cooling system are of a global character. De-energization is the initiating event of more than a half of accidents that lead to the reactor core damage.

By tradition the NPP and other major objects auxiliaries redundancy is supplied with diesel generators. But insufficient reliability of high-power diesel generators, oil and fuel supply systems and pneumatic or electric starting systems reduce the possibility of fast and full-scale energy supply and accident development prevention.

In [1], on the base of diesel generator failure data, it is given the estimation of the failure probability of a system consisting of three diesel generators considering common cause failures. In the case of independent elements of the system the startup failure probability is $2{,}7\cdot 10^{-5}$, including common cause failures. The system failure probability is estimated as $6\cdot 10^{-4}$. That is why we can't consider the diesel generator failures independent. To receive the objective definition of the NPP safety systems reliability it is necessary to consider the common cause failures. These failures can be caused by the integration of safety systems and equipment and auxiliaries, maintenance ways, fabrication methods, materials etc.

The use of systems of various operation principle allows to avoid the common cause failures. If the NPP has a cooling pond, hydroelectric generators of nearby low-power hydroplant can be used as an additional independent power source [2].

II. Method of estimation of emergency power system failure

To develop the emergency power system estimation method given in [1], we consider the possibility to increase the system reliability by the introduction of various operation principle sources for the redundancy.

The systems of high reliability specifications use the redundancy from several sources. Each unit is able to fulfill the system functions. In the case of outward de-energizing the independent redundancy power supply channels come into operation by turn. The startup failure probability of a system consisting of m independent sources is:

$$Q_i = q^m, \tag{1}$$

where q – is a single source failure probability.

The system of one-type elements can fail due to both independent failures (q_i) and common cause failures (q_c), the failure probability appears as a sum of $q=q_i+q_c$. The common cause failure probability is defined as a function of a number of independent single failures: $q_c=\delta\cdot q_i$.

Considering the common cause failures the fault probability of a system consysting of m single-type elements is defined as:

$$Q_m = q_i^m + q_c. \tag{2}$$

The use of polytipic elements is a way to reduce the common cause failure probability. In the case of elements of n types, the failure probability is:

$$Q_{m,n} = \prod_{j=1}^{n} \left(q_{i\ j}^m + q_{c\ j}\right). \tag{3}$$

III. Analyses of auxiliaries supply system with consideration of common cause failures

According to [1] the probability of a single diesel generator failure is $3\cdot 10^{-2}$. There is $\delta_2\approx 8.2\%$ and $\delta_3\approx 0.72\%$ failures of two- and three-unit system, respectively, per one independent failure.

The failure probability of the system consisting of three diesel-generators considering possible common cause failures can be calculated from (2). The common cause failure probability of one of single-type elements q_c can be evaluated from:

$$\delta_3 \cdot q_i = q_i^3 + q_c. \tag{4}$$

The considered system of three elements has $q_c=1.9\cdot 10^{-4}$ (Fig. 1). The comparison of the diesel generators [1] and independent elements failure probabilities is given in the Table I. It results from the comparison that the contribution of common cause failures is crucial and it is necessary to guard the system from such failures.

The failure probability of a system of various-typed sources shown on Fig. 2 considering the common cause failure of syngle-type elements can be evaluated from:

$$Q_{3D+H} = Q_{3D} \cdot q_H, \quad (5)$$

where q_H – a hydropower unit failure probability.

TABLE I
THE THREE DIESEL-GENERATOR SYSTEM FAILURE PROBABILITIES

	Statistic data [1]	The case of independent elements
Failure probability	$2.16\cdot10^{-4}$	$2.7\cdot10^{-5}$

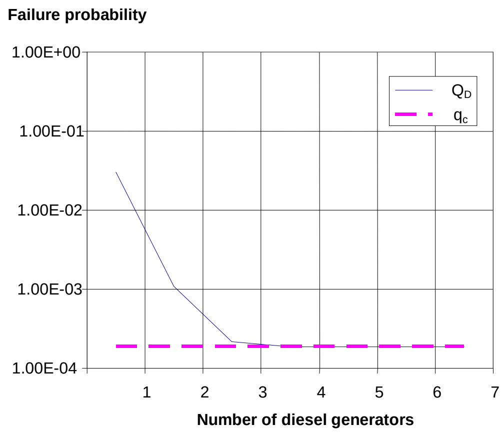

Fig. 1. A system of single-typed elements failure probability as a function of number of diesel generators considering the common cause failure probability

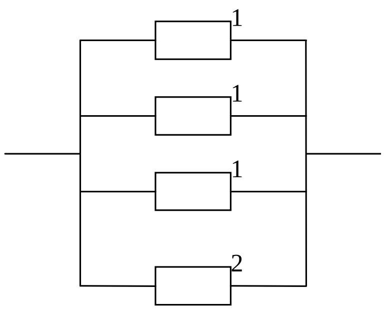

Fig. 2. The scheme of an emergency power system with sources of various operating principle:
1 – diesel generator; 2 – hydropower unit

If $q_H=q_D=q_i+q_c=3.02\cdot10^{-2}$, then the system (Fig. 2) has $Q_{3D+H}=6.5\cdot10^{-6}$. The system of four diesel generators has $Q_{4D}=1.9\cdot10^{-4}$.

The increase in the number of hydropower units leads to the reduction of the system failure probability. For example, the system of three diesel generators and three hydropower units has $Q_{3D+3H}=4.7\cdot10^{-8}$. Further increase in the number of hydropower units does not give any considerable effect on the failure probability due to the impact of common cause failures.

The reduction of failure probability to $10^{-7}\ldots10^{-8}$ corresponds to the reliability requirements of the up-to-date and prospective types of nuclear energy equipment.

The performed calculation shows that the equipping of storage ponds with gated outlets with additional hydropower plants can essentially raise the reliability and safety of Sverdlovsk region major energy objects, such as Beloyarskaya NPP, Reftinskaya and Sredneuralskaya thermal power plants etc.

IV. CONCLUSION

The existing methods of the emergency power systems reliability estimation do not consider the impact of the diversity of elements. The offered method considers the failures of single-type elements by the introduction of common cause failure probability. The developed method can be used to estimate the failure probability of the systems consisting of polytypic elements because of the relative model simplicity and the sufficient result accuracy.

The results of the NPP auxiliaries emergency power system analyses afford ground for the conclusion that high value of the diesel generator common cause failure probability ($\sim1.9\cdot10^{-4}$) essentially limits the achievable value of reliability. The use of cooling pond potential with hydropower units can provide the additional growth of reliability. Considering the made assumptions, the use of three additional units of low-power hydroelectric plant in the system of three diesel generators can reduce the failure probability by order of magnitude greater than 1000 and achieve the value of $4.7\cdot10^{-8}$.

V. REFERENCES

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