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Reliability And Operational Performance Indicators Of Expanded Functional Capability Electromagnetic Current Converters.

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Abstract
In general, reliability refers to the ability of an object (equipment, system components) to perform its designated functions within a specified volume and time under the observed conditions while maintaining its operational state within the intervals specified in normative documents
Keywords:

In general, reliability refers to the ability of an object (equipment, system components) to perform its designated functions within a specified volume and time under the observed conditions while maintaining its operational state within the intervals specified in normative documents.

Failures can be classified as follows:

1) By the degree of operational capability failure: complete and partial;
2) By the nature of the process: abrupt and gradual;
3) By dependency on other failures: dependent and independent;
4) By time: stable and unstable (malfunctions).

Partial failures result in the object operating partially, while complete failures lead to the object's shutdown (requiring repairs for restoring operational capability). If the failure of certain elements in a system does not cause the failure of other elements, this is referred to as an independent failure.

Abrupt failures arise from sudden changes in the system's key parameters and elements. In contrast, persistent failures occur due to gradual changes in parameters resulting from wear and tear of the elements.

The stable failure of an object's operational capability can only be mitigated through repairs (for reparable objects). Malfunction (shutdown) refers to a failure that can resolve itself, leading to a temporary state of inactivity (where no repairs are necessary).

Persistent failures are repeated failures of the same nature that occur multiple times.

In objects that do not operate continuously, failures can manifest in the following forms over time:

- Failures resulting from the inability to perform the required operations;
- Unwanted operation at undesired times — deceptive functioning;
- The startup of the object when the operation of other elements is required — excessive functioning.

Examples of such objects include various systems of relay protection and emergency automation, and in some cases, switches.

Failures of equipment can be attributed to their damage and malfunction.

"In the field of energy, a failure refers to the degradation of equipment, the rupture of components, the integrity of electrical and magnetic circuits being compromised, and the failure of insulation.

A malfunction, on the other hand, is defined as the inability of mechanisms to operate normally without physical damage or breakdown, arising from errors in assembly or servicing and the oversight of personnel.

Failures are characterized by their random occurrence; therefore, they can be considered as stochastic events. The study of failures is conducted using probability theory.

In a series connection, the failure of a single simple element leads to the failure of the entire complex element. The failure rate of a complex element made up of N series-connected simple elements is equal to the sum of the failure rates of all the simple elements."

$$\omega_{мур} = \sum_{i}^{n} \omega_i \ ,$$

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Based on the definitions of probability theory, for events A and B (failures of the elements):"

$$P_{\text{мур}} = P(A) + P(B) - P(A \cdot B) ,$$

The probability of failure for simple elements is a product of probabilities, an event that is rarely observed in electrical engineering.

Thus, the probability of failure of a complex element composed of serially connected simple elements is equal to the sum of the failure probabilities of these elements.

$$P_{\text{мур}} = P(A) + P(B) ,$$

The maintenance frequency of a complex element in a system is considered to be equal to that of the simple element with the highest maintenance frequency.

$$\mu_{\text{мур}} = \max \mu_i ,$$

"The planned maintenance of a complex element."

$$P_{\text{мур}}^{\text{таъм}} = \mu_{\text{мур}} \cdot T_{\text{таъм.мур}} ,$$

Here, it refers to the average time spent on the repair of a complex element. During this time, all the serially connected elements that require maintenance are repaired simultaneously.

$$T_{\text{таъм.мур}} = \left[\max \cdot T_{\text{таъм.}j} \cdot \mu_j + \sum_{\nu}^{n-1} T_{\nu} \cdot (\mu_{\nu} - \mu_i) \right] ,$$

The reliability indicators of extended functional capabilities of electromagnetic voltage converters are one of the main characteristics, which account for the reliable operation of reactive power control and regulation devices in the electrical supply system, as well as being factors that determine the technical and economic performance indicators.

The calculation of the overall reliability indicators of extended functional capabilities of electromagnetic voltage converters consists of specific components, which are dependent on the main reliability indicators of the parts of the electromagnetic converters – mechanical indicators (R_mechanical), the indicators of converter elements (R_element), and metrological indicators (R_metrological). Based on these, the overall reliability can be determined as follows:

$$P_{\text{у}} = P_{\text{м}} \text{ x } P_{\text{э}} \text{ x } P_{\text{мет}} ,$$

$$P(t) = P_{\text{ш}}(t) \text{x} P_{\text{п}}(t) \text{x } P_{\text{ў}}(t) ,$$

The overall reliability of extended functional capabilities of electromagnetic voltage converters is determined based on parametric and variable factors, where the continuous operating probability of the converter is set to Rparametric(t)=0.99R_{parametric}(t) = 0.99Rparametric(t)=0.99 and Rvariable(t)=0.99R_{variable}(t) = 0.99Rvariable(t)=0.99. Additionally, the probability of failure-related factors for the converter is independent of the time change law, ensuring that the reliability of the converter parts remains consistent.

The metrological reliability of the extended functional capabilities of electromagnetic voltage converters and their components is characterized by the probability that the transformation errors of secondary signals, in the form of voltage, do not exceed the specified normative values during the operation of the converter with alternating primary reactive power currents in the electrical supply system.

The analysis of the operation principle of converters that transform primary currents in electrical supply system networks into secondary signals in the form of voltage allows for the identification of the reliability of the relevant converter components. A table of possible scenarios for these components has been developed (Table 1). Based on the table, it can be concluded that the reliable operation conditions of the

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sensitive part of the electromagnetic voltage converters are considered to be factors that determine the overall reliability of the converter's operation.

The probability of the operational states of the existing components of the extended functional capabilities of electromagnetic voltage converters is derived from the reliability of the converter parts (Table 2). For the primary currents of electrical supply system networks being transformed into secondary voltage by the main conversion components of the electromagnetic voltage converters (including the primary current conductor, magnetic transformation part, and sensitive part), the probabilities of their operational states have been accepted as follows:"

$$P_{ў,б,ч} = 0.99;$$

$$P_{м,ў,к} = 0.99;$$

$$P_{сез,э} = 0.99;$$

The probabilities of the operational states of the components of the extended functional capabilities of electromagnetic voltage converters are generalized to determine the operational reliability probability of the converter (Table 2). In this context, P1,P2,P3P_1, P_2, P_3P1,P2,P3 denote the probabilities of the working state of the following components: the primary current conductor – the primary winding of the converter, the excitation part, the magnetic transformation part, and the sensitive part.

1-Table

The probability of the operational state of the conversion components

№	"FIKEMO unit state."	"FIKEMO unit operational state probability."	"FIKEMO transformation parts and their overall states."
1	C_1	$P_1P_2P_3$	1-Primary current conductor – primary winding of the converter – excitation part, 2-Magnetic transformation part, 3-Sensitive part.
2	C_2	$P_1P_2(1-P_3)$	"1; 2 – that is, the sensitive part is in a failure state."
3	C_3	$P_1P_3(1-P_2)$	"1; 3 – that is, the magnetic transformation part is in a failure state."
4	C_4	$P_2P_3(1-P_1)$	"2; 3 – that is, the excitation part is in a failure state."
5	C_5	$P_1(1-P_2)(1-P_3)$	"1 - the magnetic transformation part and the sensitive part are in a failure state."
6	C_6	$P_2(1-P_1)(1-P_3)$	"2 - the excitation part and the sensitive part are in a failure state."
7	C_6	$P_3(1-P_1)(1-P_2)$	"3 - the excitation part and the magnetic transformation part are in a failure state."

2-Table

Extended functional capability of the electromagnetic current converters' components state operation probability

$P_1P_2P_3 = 0{,}970299$

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$P_1P_2(1-P_3)$ = 0,009801
$P_1P_3(1-P_2)$ = 0,009801
$P_2 P_3(1-P_1)$ = 0,009801
$P_1(1-P_2)(1-P_3)$ = 0,000099
$P_2(1-P_1)(1-P_3)$ = 0,000099
$P_3(1-P_1)(1-P_2)$ = 0,000099

If all elements of the electromagnetic current converters with extended functional capabilities shown in Figure 3.15 are in operational condition, the circuit will be in operational condition

Figure 1. Structural diagram of electromagnetic current converters with extended functional capabilities.

PW - primary winding, EC - electromagnetic core, SE - sensitive element.

Accordingly, we assume that the operational state probability of the elements follows the multiplication probability law.

Puzg=Pu,b,ch×Pu,m,o×Psez,e=0.99×0.99×0.99=0.97."

The failure probability of electromagnetic current converters with extended functional capabilities is:

Quzg=1−Puzg=1−0.97=0.03

Based on the calculated data, it can be concluded that the functional capability of the reactive power control system in electrical supply systems, which utilizes electromagnetic current converters with extended functional capabilities, leads to an overall operational probability Pum,uzg=0.97P_{um, uzg} = 0.97Pum,uzg=0.97 for the primary currents of electrical networks being transformed into secondary voltages.

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