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Verification the Reliability of Using (Non-Nuclear Grade) Electronic Devices in Nuclear Installations

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Abstract

This paper describes the experimental approach to be performed to examine the reliability indicator of certain electrical devices manufactured by companies in the Russian Federation. The tests will be conducted according to technical specifications and test procedures which were prepared for these devices. In addition, a comparison referring to the reliability parameters between results and manufactured specifications will be provided or conducted.

Keywords: Reliability, Failure rate, Environmental condition., Radio-electronic devices.

1. Introduction

Reliability of a Nuclear power Plant (NPP) is a complex property, including reliability, durability and maintainability [1]. The use of high reliable mechanical and electrical components, among others, form the basis for safe and economical operation of nuclear power plants. Where, reliability is a property of an object to perform the required functions, under certain conditions and a specified period established in the terms of reference, or technical conditions.

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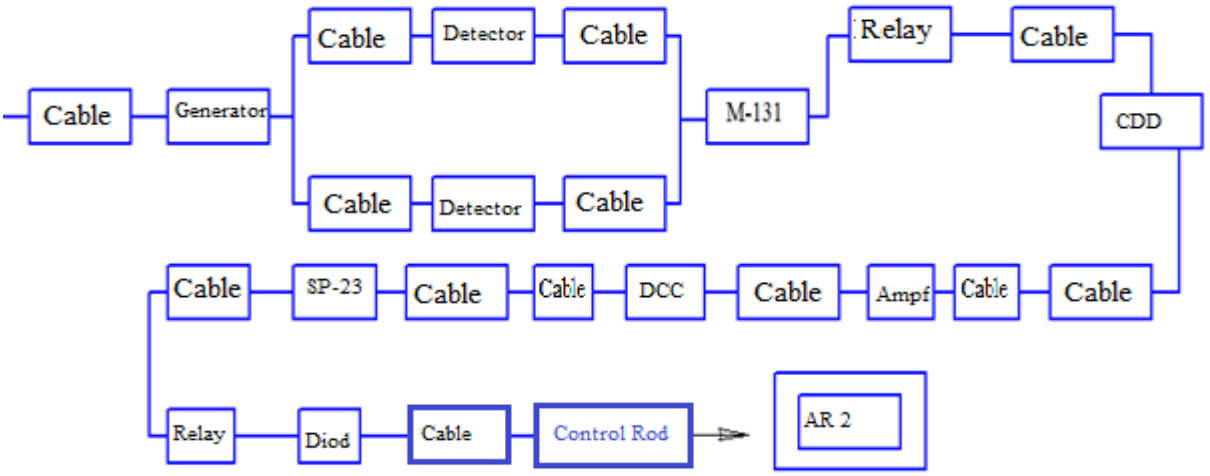
The information regarding the reliability of devices is obtained, in principle, by following the behaviour during the real operation or the laboratory tests. Each of these two ways presents, in the same way, advantages and limitations. In case of real operation all the phenomena appeared during product operating are recorded, [2].

Radio-electronic devices (RED) perform a very wide range of tasks in the operation of NPP. In the development of RED, the main task is to ensure the necessary level of reliability of this product.

Low level of reliability increases the risk of premature failure of the device, which entails additional economic costs for its replacement and repair, and can also adversely affect the dependent devices, which, in turn, will lead to serious damage of a large number of equipment thereby resulting in serious negative impacts in terms of economic and time.

To improve on reliability of a system redundancy is employed, for example, Automatic Regulating System in VVER 1000 (Russian PWR), work with two redundant regulating channels. Fig.1.Automatic Regulating channel AR2 of the VVER-1000 reactor. Which show the electrical schematic of AR2 and shows the RED used in this channel.

Fig.1. Automatic Regulating channel AR2 of the VVER-1000 reactor.



Commercial grade items of RED used in NPP shall be strictly tested and passed through laboratory qualification procedures related to nuclear industry. During the laboratory tests the samples (systems, modules) are operated in certain conditions close to the real ones, in the NPP, being necessary the existence of special testing devices and qualified personnel [3,4,5, 6].

2. Predict the operational reliability parameter (λ) of RED.

It should be noted that during calculation of reliability of RED, the reliability of any device can be affected by several factors, such as a decrease and increase in temperature, temperature spikes, and thermal shock. Thus, the need to consider failure rate of this type of element in real-world conditions, called operational failure rate, denoted as λ_o.

The relationship between devices reliability and affected factors mainly depends on the information obtained from operating experience or results from tests performed at laboratories, thus providing an understanding of the dependencies. In the general form, the dependence of the failure rate of components from the environment has the form:

$$\lambda = (T_o, h, X_g, P_p, \dots) \quad (1)$$

Where, T_o , h- ambient temperature and humidity of the ambient environment; X_g is the acceleration of the mechanical loads acting on the product; P_p-pressure load.

Assuming that these factors independent, the failure rate of components in the operating mode is determined by Eq. (2)

$$\lambda_o = \lambda_b * k_1 * k_2 \dots k_n \quad (2)$$

$k_1, k_2, \dots, k_n$— Coefficients characterizing the influence of certain types of impacts on the failure rate.

Eq. 2 can be rewritten in the form (3)

$$\lambda_o = \lambda_b * \prod_{i=1}^{n} K_i \quad (3)$$

Where:

λ_b - a Basic failure rate of an element.
K_i- Coefficients that take into account the change in the operational failure rate, depending on various factors;
n- Number of considered factors.

3. Test preparation and performance.

The test of RED for environmental effects is carried out to ensure the ability of devices to perform the assigned functions, to preserve parameters and/or appearance within the established standards during and after exposure. For the reproducibility of the test results, its complete and accurate description is necessary, excluding any uncertainty of interpretation. Proceeding from this, the standards and technical documentation (STD) has adopted such a sequence of operations (stages) of the RED test for environmental effects.

3.1. Environmental stress or examination:

- Testing for thermal stability during operation.
- Cold resistance test during operation.

3.2. Test Procedures:

To perform the examination test, systematically and logically it was necessary to establish and prepare a specific procedure for each test or examination based on the related international, local standards and technical specification of each RED, therefore a procedure for each test mentioned in *section 3.1* has been prepared according to the following standards:

- GOST 28198 (IEC 68-1), Basic methods of testing the impact of external factors. Part 1.
- GOST 28200 (IEC 68-2-2), Basic methods of testing the impact of external factors. Part 2.
- GOST 28216-89 (IEC 68-2-30-82), Basic methods of testing the impact of external factors. Part 2
- GOST 28199-89 (IEC 68-2-1-74), Basic methods of testing the impact of external factors. Part 2.
- AEC-Q200 REV D June 1, 2010, STRESS TEST QUALIFICATION FOR PASSIVE COMPONENTS
- MIL-HDBK-217F-Notice2, Reliability Prediction of Electrical Equipment
- MIL-STD-202G, Test Methods Stand Electric & Electronic Parts.

3.3. Selection of devices

The following RED was selected to be examined for our experiment, since they are commonly used in the design of regulation and control systems and other systems in nuclear power plants.

- Resistor :

Type: с5-5в-1вт
Operation limits:
Ambient temperature, °C:
- At rated electrical load ….....-60 to +70
- By reducing the electrical load to 0.05 PH ….....-60 to +155

Limit operating voltage of resistors, V….....400

- Capacitor :
  Type: К73-9
  Operation limits:
  - Ambient temperature…..... -60 to +100° C
  - Relative humidity at ……..35°C to 98%
  - Low atmospheric pressure…..... To 6.7 Gpa

4. The design of the experiment.

4.1. General description of examinations

The test of RED for environmental effects is carried out to test the ability of equipment to perform the required functions or to preserve parameters and/or appearance within the established standards under and after exposure.

For the reproducibility of the test results, its complete and accurate description is necessary, excluding any uncertainty of interpretation. Proceeding from this, the standards and technical documentation (STD) has adopted such a sequence of operations (stages) of the RED test for environmental effects:

- Pre-exposure equipment;
- Initial parameter measurements and external inspection;
- Installation of the device in the chamber and exposure there to the test mode;
- Removal of devices from the exposing chambers to restore the properties of equipment;
- External inspection and final product measurements;

Pre-exposure is carried out to completely or partially eliminate the effects of exposure to equipment in previous operating conditions. Equipment can withstand, as a rule, under normal climatic conditions. Exposure of equipment, whose measurement results can be significantly influenced by relative humidity, is performed. These conditions provide for strict maintenance of the temperature (permissible deviation ± 1 ° C) at a relative humidity of 73 ... 77%. The duration of the preliminary exposure is determined by the time sufficient to establish the thermal equilibrium of the equipment with the environment. Usually, it does not exceed 2 hours. Initial and final measurement equipment recommended to be conducted at the same environmental conditions (Temperature and humidity).

4.2. Testing for thermal stability during operation.

Testing the environmental effects of a high temperature of the ambient environment are carried out to examine the performance of RED and to preserve their properties under the influence of exposing to high temperature and after it. There are two methods of examining for elevated temperature: thermal and combined load (thermal and electrical). According to the first one, non-heat-releasing RED is tested, the temperature of which during operation depends only on the ambient temperature. See Table.1; on the second – the heat-generating RED, is heated in the operating state due to the power released under the action of an electric load. See Table 2.

Table 1. Test of high Temperature without an electrical load

Testing Temp. °C	Duration (h)	No. of tested devices	No. of failures

30	96	30	
50	96	30	
70	96	30	
100	96	30	

Table.2. Test of High Temperature with electrical load (0.3, 0.6, and 0.9 of rated load)

Testing Temp. °C	Duration (h)	No. of tested devices	No. of failures
30	96	30	
50	96	30	
70	96	30	

4.3. Cold resistance test during operation

Tests for the impact of a reduced temperature of the ambient environment are carried out to check the performance of the RED and to preserve their appearance under the influence of reduced temperature and after it. During the test, the same parameters are measured as during the test for high temperatures. At the same time, to check the efficiency of the RED, it is provided to withstand them under an electric load at a given temperature. First, the RED parameters are measured under normal conditions, and then the equipment is placed in a cold chamber, set the temperature limit according to the data specified in the Technical Specifications. Presented in Table 3.

Table 3. Test of cold Temperature without an electrical load

Testing Temp. °C	Duration (h)	No. of tested devices	No. of failures
-10	24	30	
-30	24	30	
-40	24	30	
-60	24	30	

Conclusion

When using commercial (non-nuclear grade) RED in the nuclear industry, it is required to have complete information about the behaviour of the equipment during operation. To prevent and predict failures of components of the used system equipment it is necessary to be aware of the characteristics of the reliability of the products used. Applying this type of examination on these type of RED will help to allow for using commercial elements, once they passed the examination and other qualification examination, and reduce the number of failures of RED, as well as come with economic benefits on the design and construction of NPP.

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