Modeling Of The Random Process Of Changing The Structure Of An Engineering Network

Umarkhodzha Baxramov, Irkin Makhamataliev

Abstract: The article discusses one of the possible ways to increase the durability and operational characteristics of methods for determining reliability indicators and assessing the consequences of failures of system elements that have found application in the practice of designing power systems based on statistical modeling (Monte Carlo method). In this method, the natural course of the random process of occurrence of failures (and recoveries) is simulated and, with a sufficient duration of the simulation, estimates of reliability indicators can be obtained on this basis.

Index Terms: design, distribution function, engineering networks, failure, flows, loads, modeling, reliability, restoration, target product, schemes, stochastic process, passive and active elements,

1. INTRODUCTION

THE functioning of pipeline engineering networks occurs in the event of failure of various passive and active elements. In addition, each passive element can be in only two states: working and non-working, i.e. the state in which it should be excluded from the design scheme of the engineering network. Evaluation of the states of active elements can also be given simply if we are talking about one pump, compressor, throttle, etc. If the active source included in the scheme of the engineering network really consists of several pumps running in parallel, the assessment of its conditions is much more complicated, since the failure of one of the pumps can only slightly change the characteristics of the entire active element as a whole, and the availability of backup pumps can completely compensate for the consequences in a short time arising refusal. Therefore, the correct determination of the requirements for the hydraulic characteristics of the active elements (supply and pressure in all possible conditions of the network), the determination of a reasonable (minimum) reserve of equipment for pumping and compressor stations is one of the most important tasks in the design of engineering networks.

Despite the fact that the very concept of reliability of a technical system is defined quite simply - “reliability is the probability that the system will fully perform functions within a given period of time, under given operating conditions” [1], the definition of specific reliability parameters for a designed or operated An engineering network today presents a very complex theoretical and practical task. For complex energy systems, namely, they include the engineering networks of heat supply, water supply, gas supply systems, this problem is associated not only with the difficulties in determining reliability indicators in a series-parallel circuit of passive element connections, but with the very concept of a failure in an engineering network that provides transportation target product to many consumers in network circuit nodes. In this case, the normal supply to the target products of one of the circuit nodes is even violated, then, obviously, this condition cannot be considered a failure of the engineering network as a whole. This situation leads to the fact that in the analysis of complex systems in some cases it is proposed to determine not reliability indicators, but performance indicators [1,2].

However, in this case too, the difficulties are quite large when the question arises of choosing a certain norm of this efficiency for the operating conditions of a particular system. Currently, various recommendations [2,4] on determining the reliability indicators of pipeline engineering networks are quite contradictory, discussions and have not yet found widespread use in practice. In real conditions, design organizations carry out calculations of the steady flow distribution when a small number of passive elements with the highest values of flows in the complete scheme are excluded from the design scheme of the engineering network and, based on these data, the characteristics of the active elements are specified. At the same time, a significant part of the data on the failure flows of passive elements obtained in a number of studies [3,5] does not find practical application. In addition, the above calculations are performed only at the maximum design loads at the network nodes, although these loads have a very low probability of occurrence and therefore the results do not characterize the behavior of the system over the entire considered time period. One of the possible and already found application in the practice of designing electric power systems methods for determining reliability indicators and assessing the consequences of failure of system elements consists in statistical modeling (Monte Carlo method). In this method, the natural course of the random process of occurrence of failures (and recoveries) is simulated and, with a sufficient duration of the simulation, estimates of the reliability indices [2] can be obtained on this basis. In the Monte Carlo method, simulation consists in determining the moments of failure, depending on the given probability distributions of failure-free operation for all elements of the system. In principle, if we combine modeling of a random flow of failures with modeling of random processes of consumption of the target product in the nodes of the design scheme of the engineering network, we can find estimates of the consequences of failures of passive elements for given characteristics of active power sources or, conversely, determine the requirements for these characteristics based on the need to maintain pressure at all nodes of the network. However, a large (up to 1000-1500) number of passive elements in engineering networks, relatively small values of the intensity of failure flows (of the order of λ = 1-2 1/year.km [6] leads to the fact that the duration of the simulation period should be 20-30 years in order for the accuracy of the required reliability parameters of

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the system as a whole to be no worse than 10% [ ]. Moreover, it will be very difficult to model random processes of consumption of target products at such long intervals. Thus, the use of the Monte Carlo method for research is reliable STI designed utility networks not lead great effect as a consequence of the above provisions.

2 ACHIEVEMENT OF THE GOAL OF THE STUDY

The main goal of this work is to propose such a mathematical model of the engineering network that will provide the construction of probability distribution functions of the required pressure of the power sources. It is also necessary to take into account the random nature of the consumption processes of the target products and the random failure flows of passive elements of engineering networks. Failing elements are excluded from the logic circuit, and if the connection between the entry and exit points is violated, this is considered a system failure. When drawing up logical circuits, network elements are considered connected in series if the failure of each of them causes a failure of the system. With a parallel connection, a system failure is possible only if all the elements fail at the same time. Obviously, complex network systems are not unambiguously reduced to logic circuits with series-parallel connection of elements, and in this case they use methods to search for the set of minimal paths and minimal sections [4,7] in a network to simplify its logical scheme.

3 MODELING METHODOLOGY

To achieve the goal, it seems more appropriate not to use Monte Carlo simulation, but to combine network methods for studying reliability and the state space method [2,3]. The first step of network methods is to build a logical or structural diagram of a complex network system in which the sources of the target product and its consumers are connected by a transport network - in our case, a pipeline engineering network. There are significant differences between the design scheme of the network, which is built depending on its physical scheme, and the logical scheme, which consists in the fact that the latter is constructed so that it can be used to determine combinations of element failures that lead to the failure of the system as a whole. Failing elements are excluded from the logic circuit, and if the connection between the entry and exit points is violated, this is considered a system failure. When drawing up logical circuits, network elements are considered connected in series if the failure of each of them causes a failure of the system. With a parallel connection, a system failure is possible only if all the elements fail at the same time. Obviously, complex network systems are not unambiguously reduced to logic circuits with series-parallel connection of elements, and in this case they use methods to search for the set of minimal paths and minimal sections [4,7] in a network to simplify its logical scheme.

4 RESULTS AND DISCUSSION

Let us consider an algorithm for modeling states with failure flows for an engineering network using the example of networks of water supply systems. In a number of studies of the reliability of water supply systems [ ] it was found that passive elements (sections of pipelines) are suitable for carrying out repairs in it with exponential distributions of long-term work and restorations, that is

$F_1(t) = \lambda \cdot exp(-\lambda \cdot t)$

And $F_2(t) = \mu \cdot exp(-\mu \cdot t)$,

Where $F_1(t)$ - probability function of the duration of work;

$F_2(t)$- probability distribution function of downtime (recovery);

λ and μ - failure flow and recovery flow parameters, respectively;

t - time for which the value is determined $F_1(t)$ or $F_2(t)$.

For each of the network elements, the coefficients of readiness (K_1) and unavailability (K_2) can be determined, which at stationary values λ and μ a sufficiently large time are the probabilities of the element being in an operational state or in an idle state, respectively.

The coefficients of readiness and unavailability is determined by the formulas:

$$K_1 = \frac{\lambda}{\lambda + \mu}; \quad K_2 = \frac{\mu}{\lambda + \mu}.$$

The length of the period when there is not a single element in the idle state in the system can be easily determined based on its logical scheme in which all elements are connected in series. Since for each element failures and recovery occur regardless of the state of other elements, we can consider the system to have failed according to its logical scheme with a probability defined as the product of the failure probabilities for all elements. Thus, the algorithm for modeling random states of a complex engineering network (Fig.1) Can be represented as a sequence of determining the failure probabilities for each of the elements of the system based on the available data - parameters and shown in Fig.2. These probabilities are for determining the characteristics of stochastic flow distribution for each of the states of the system and, further, for all possible states during the estimated year of operation of the system.

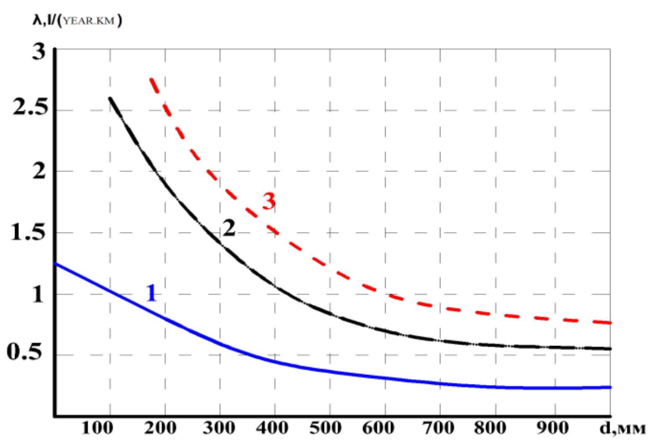

***Fig. 2**. A graph of averaged values obtained on the basis of statistical processing of observational data carried out in three climatic zones of our country (Tashkent region, Karakalpak Republic, Surkhandarinsk region — curves 1, 2, 3, respectively).*

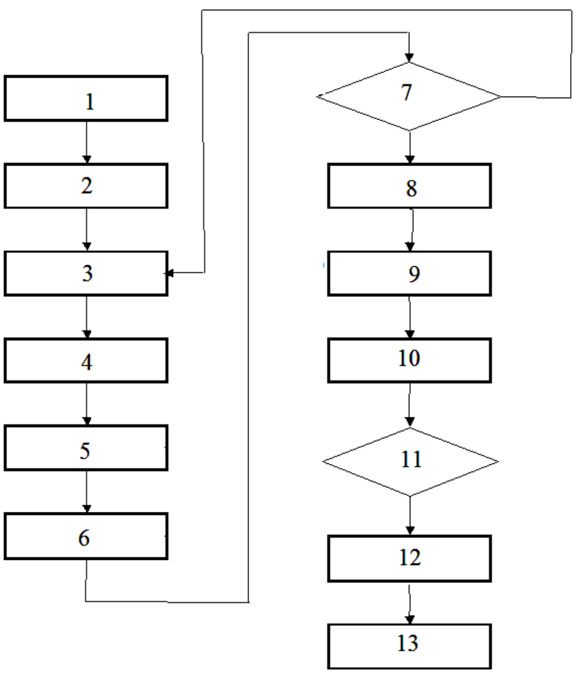

***Fig. 2**. The block diagram of the algorithm for modeling random states of a complex engineering network.*

The algorithm for modeling random states of a complex engineering network consists of the following steps:

1. Enter the program, control the program and the source data.
2. Assignment $I \to 0$ to start the operation of the cycle counter.
3. The cycle counter $I$for, is used for arithmetic operations.
4. Determination of the value of failure flow parameters for each network element according to the formula $\lambda_i = \lambda_d \cdot l_i$, where is the λ_d- parameter of failure flows of network elements, is the length of the network element, $i \in M$.
5. Determination of the value of the availability factors by the formula $K_1 = \frac{\lambda}{\lambda+\mu}$.
6. Determination of the values of unavailability coefficients by the formula $K_2 = \frac{\mu}{\lambda+\mu}$.
7. Checking the end of the cycle by the I - ith elements, if the condition is satisfied, then go to step 8, otherwise to step 3.
8. Assignment, to start $I \to 0$ the operation of the cycle counter.
9. The counter of cycles I, serves for carrying out arithmetic operations.
10. Determination of the total simulation time of the random state of the network according to the formula $T_{0i} = K_{1i} + K_{2i}$.
11. Checking the end of the cycle for the I - ith elements of the network, if the condition is met, then go to step 9, otherwise to step 12.
12. Printing the results.
13. The end of the account.

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