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RELIABILITY ANALYSIS OF ELECTRIC POWER NETWORKS

Stanislav Rusek, Tadeusz Sikora, Vladimír Král, Radomír Goňo
VŠB- Technical University of Ostrava, Departement of Electrical Power Engineering
17. listopadu, 708 33, Ostrava-Poruba, Czech Republic
stanislav.rusek@vsb.cz, tadeusz.sikora@vsb.cz, vladimir.kral@vsb.cz, radomir.gono@vsb.cz

ABSTRACT
The paper depicts the description of a program for solving the reliability of electric power networks of all voltage levels. As input data reliability data on particular nodes and branches is used; power consumed in each node as well as power carrying capacity in each branch is taken. Then the result is the power balance of the network concerned, the resultant reliability parameters of all nodes and the value of electrical energy probably unsupplied to the nodes. We also further develop advanced model for reliability calculations, based on Weibull failure distribution function. By changing Weibull parameters can be simulated all three stages of units lifecycle – early-type (infant mortality), chance-type (equal to exponential distribution) and wear-out caused failures.

KEY WORDS
Reliability, program, simulation technique, electric power networks, Weibull reliability parameters

1. Introduction

The program SPOLEH, which is developed at department of Electrical power Engineering, VŠB-TU Ostrava, and deals with the reliability of electric networks of all voltage levels. As input data reliability data on particular nodes and particular branches is used. Because the program also includes the power balance into the calculation, it is necessary to determine the consumed (supplied) power of each node and the power carrying capacity of each branch.
The result of the calculation is then the total power balance of the network concerned and the resultant reliability parameters of all nodes. In addition, the program will determine the amounts of electrical energy probably unsupplied to particular nodes as well as the total value of probably unsupplied electrical energy in nodes.

2. The Adopted Method

The basis of the reliability calculation by using the simulation technique is (in contrast to analytical methods) the computer-assisted verification of reliability by means of many tests performed on a mathematical reliability model of the system. During these tests, the mathematical model simulates the behavior of the real system.
When calculating reliability by analytical methods, we use, for quantitative assessment, point values of parameters of system reliability and values of reliability indices found out statistically (failure rate, etc.). We calculate according to mathematical relations created by means of the system reliability model, i.e. by means of the mathematical model of the system. At statistical modeling, the reliability model, the knowledge of the failure rates of sub-blocks and the law of reliability distribution form the foundations.

2.1. Exponential Distribution

In program SPOLEH exponential distribution of time-to-failure is used. In development is implementation of Weibull distributed failures.
In both cases database analysis [5] can be used for obtaining input values for calculation using exponential distribution.
The second variable representing the component is the duration of outage, which is exponentially distributed with mean τ.

2.2. Weibull distribution

The Weibull distribution is one of the most widely used lifetime distributions in reliability engineering. It is a versatile distribution that can take on the characteristics of other types of distributions, based on the value of the shape parameter, β.
Dependent on shape parameter, β, we can describe all three life stages of the bathtub curve:

- Early-type failures, for which hazard function (e.g. failure rate) decreases with time. This is modeled by shape parameter $0 < \beta < 1$.
- Chance-type failures for useful life of units, when $\beta=1$. Hazard function is constant and equals $1/\eta$ (reciprocal value of characteristic life). This case of Weibull probability density function is consistent with the above mentioned exponential distribution.
- Wear-out failures, when failure rate increases as time increases ($\beta > 1$).

The scale parameter, η (eta), represents characteristic life of unit. In other words it is time, when approximately 63 % units will fail.
Location parameter γ indicates the earliest possible time at which failure may occur. During this period failures of unit must be simulated by other type of distribution.
Calculation of input values for this distribution is still in process at Department of Electrical Power Engineering at VŠB-TU Ostrava. For example partial outcomes we can present (for units wear-out) [5]:

Table 2: Some component's Weibull parameters

	β (–)	η (year)	γ (year)
Lightning arrester	2,55	26,2	7,4
Switch-disconnector	1,85	13,6	9,1
Discloser	2,55	26,2	7,4

3. Program Description

3.1. Calculation Procedure

The calculation is executed by using the simulation technique [2]. At the beginning of simulation, it is supposed that all components of the network are in operation. Then it is necessary to generate a random variable, which represents time of component failure, for each component. Of variables generated like that the smallest one is chosen; a relevant change in the model is made and a new condition of the system is assessed. For the component affected by the change a new value is generated – this time putting into operation – and is queued into waiting events. The system time is transferred to a new point – the instant of change. From the queue of waiting events the first one is chosen and the whole procedure repeats itself until the required number of tests is performed.

3.2. The Evaluation of Branch Reliability

The determination of branch reliability is one of the two objectives of simulation. A branch is understood to mean a connection defined by a user as one element, e.g. a series switch - transformer – switch connection, or 2 parallel lines. In the course of simulation, the durations of branch operation are being summed, and at the end the total time reached in the course of the process is available.

3.3. The Evaluation of Node Reliability

The evaluation of the reliability of supplies to the nodes is, as a matter of fact, the main reason why the calculation is performed.
To be able to decide whether the node is in normal service, or in outage, one must evaluate the condition of the whole network at each step of simulation. If the node has the demand P_i and the sum of load carrying capacities of branches leading to this node ΣP_{ij} is greater than this demand, all is right. Otherwise the node is disconnected.

4. Input Data for the Program

Input data [3] must contain reliability data on nodes and reliability data on branches. To enable by calculations also the compilation of a power balance, power demands (supplies) of particular nodes and further power carrying capacities of particular branches must be set as well.

5. Conclusion

The contribution describes the program for solving the reliability of electric power networks by means of the simulation technique. The program is still being extended by new possibilities. It is practically used in calculations of reliability of nodes in real electric networks in the Czech Republic (e.g. SME - North Moravian Distribution Company). We are able to compare different variants of network configuration eventually new investment on the base of Asymptotic reliability in nodes. At the end it is necessary to point out that acquiring reliable input data is a huge problem. Since 1999 we have been collecting failure data from majority of the Czech power-distribution companies. Some partial outcome is in [5] and [6].

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