

# New Approach to the Operation of the Power System under Discrete Multi Effects

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## **Abstract**

It is well known that many factors that affect the operation of the electric. Power systems beyond the control of the operator. Load switching, for example occurs in accordance with customers' needs and appears to have random. Characteristic. Environmental factors such as wind and temperature determines the capacity of overhead transmission lines. These factors create uncertainty in the planning and operation of power system. Most current methods for assessing reliability of electrical networks are based on the structural diagram of this system. As the structure of the power system operates in abnormal conditions and faults, these methods cannot be used effectively to assess the reliability of the system operation under abnormal operating. In the proposed approach, the power system will be modeled using the initial Information about the system during normal operation. All internal and external factors that affect the functioning of the electrical system will be modeled taking into account the probability of their occurrence and the strength of their impact on the normal operation of the power system. Any correlation between these factors will also be studied using the rules of probability theory.

**Keywords:** Reliability, electric power, transmission line, normal operation, functional relation

## **1. Introduction**

The electric power system consists of a complex structure of different elements as Generating stations, overhead transmission lines, transmission and distribution Substations and other elements. These power system elements are always subject

to the influence of thunderstorm, internal overstress, wind, ice-slick, extreme Temperatures, etc. Reliability analysis methods have been developed to evaluate the reliability of the Power system under normal operation. These methods can't be used in case of Influencing of external failure cause, as a single failure cause can simultaneously affect multiple system elements in different degrees [8, 6, 2] The system reliability analysis methods for normal operation are based on a structural Approach, in which the system reliability indicators are calculated by using known Element reliability indicators and the structural properties of the system under Consideration [9, 7]. As to the influence of external factors, the structural approach is unacceptable, as in This case the failure probability of the system has to be calculated using a single n-Dimensional integration of the density distribution functions of the influencing factor. Here the calculation procedure is complex because of the necessity to take into Consideration the probability characteristics of the influencing factors and the strength of their impacts upon the system normal operation.

## 2 The Proposed Approach

In the proposed approach, the influencing factors are represented by the n-Dimensional random vector  $\vec{x} = [x_1, x_2, x_3, \dots, x_n]$  of the influencing factors. Each element of this vector has its own distribution function  $F(x_i, i = 1, 2, 3, \dots, n)$  if there is no correlation between the elements of this vector, or with the conditional distribution function  $F(x_i | x_m)$  in case correlation exists between the dependent elements  $x_i$  and  $x_m$ . The output parameter of the system (electric voltages and mechanical stresses) on each element of the system is represented by the m-dimensional vector  $y$ . The dependency of the system output parameters vector,  $y$ , and the system influencing vector,  $x$ , is given as a functional relation  $y = \varphi(x)$  or as a pre-defined calculation algorithm. The structure of the system and the strength characteristic (electrical and mechanical) of its elements are described by the set of distribution functions  $F(R_i, i = 1, 2, 3, \dots, m)$ . In the idealized case, the strength of the system elements may be recorded by the values  $R_{0,i}$ ,  $i = 1, 2, 3, \dots, m$ , where  $F(R_i) = 0$  when  $R_i < R_{0,i}$  and  $F(R_i) = 1$  when  $R_i > R_{0,i}$ .

The probability of failure of a system having a number of elements, each having a random probability of strength  $R$  will be determined by the integral

$$p = \int_{D_{x,R}} \dots \int f(\vec{x}) \cdot \prod_{k=1}^n dx_k \cdot f(R), dR \quad (1)$$

Where  $D_{x,R}$  is the range of the dangerous values of the elements of vector  $x$ ,  $f(\vec{x})$  and  $f(R)$  is the density distribution function for the elements of  $(\vec{x})$  and  $(R)$ . For numerical evaluating the value of integral (1), and when no correlation exists between the elements of vector  $\vec{x}$ , we can write:

$$p = \sum_{x_1} \Delta F(x_1) \cdot \sum_{x_2} \Delta F(x_2) \dots \sum_{x_n} \Delta F(x_n) \cdot \sum_R \Delta F(R) \quad (2)$$

Where  $\Delta F(x)$  and  $\Delta F(R)$  are the increments in the distribution parameters  $\vec{x}$  and  $R$ , respectively.

Applying equation (2), to numerically calculate the probability  $P$  by changing the elements of vectors  $x$  and  $R$  has certain characteristics. When the values of the elements of vector  $x$  are changed, the values of the elements  $y = \varphi(\vec{x})$  are calculated and thus the values of the elements of  $R$  are found (if  $y > R$ ) till the range describing the dangerous operation of the system is reached. In this case equation (2) can be written as:

$$p = \sum_{x_1} \Delta F(x_1) \cdot \sum_{x_2} \Delta F(x_2) \dots \sum_{x_n} \Delta F(x_n) \cdot p(\vec{x}) \quad (3)$$

Where  $p(\vec{x}) = F(R)_{R=y=\varphi(\vec{x})} = F_K(\varphi(\vec{x}))$  is the value of the distribution function of the strength of elements when changing the value of the variable  $R$  produced by each integration step of the output  $y$ . At each step, when calculating  $p(\vec{x})$ , the values of the elements of vectors  $\vec{x}$  and  $R$  can be controlled, within the permitted values. When the permitted values are exceeded the value of  $p(\vec{x})$  becomes zero. When the element strength has a constant value  $R_0$ , thus  $p(\vec{x}) = F(R) = 1$ , if  $y > R_0$  and  $p(\vec{x}) = F(R) = 0$ , if  $y < R_0$ .

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When the mechanical components of the system are taken into consideration, equation (3) can be written as:

$$p_C = \sum_{x_1} \Delta F(x_1) \cdot \sum_{x_2} \Delta F(x_2) \dots \sum_{x_n} \Delta F(x_n) \cdot p_C(\vec{x}) \quad (4)$$

Where  $p_C(\bar{x}) = F_{RC}(\varphi(\bar{x})) = F(\bar{R}_C)_{\bar{R}_C=\bar{y}}$  is the partial probability of the system failure at given elements of vector  $\bar{x}$ . In case for m-serially connected elements, the partial probability of the system will be defined as:

$$p_C = 1 - \prod_{i=1}^m (1 - F_{R_i}(y_i)) = 1 - \prod_{i=1}^m (1 - F_{R_i}(\varphi(\bar{x}))) \quad (5)$$

For the case of m-parallel connected elements, the partial probability of the systems will be given as:

$$p_C = \prod_{i=1}^m F_{R_i}(y_i) = 1 - \prod_{i=1}^m F_{R_i}(\varphi(\bar{x})) \quad (6)$$

If the system consists of a combination of serially and parallel connected elements, the principles from probability theory can be used to simplify the case. A universal method for determining  $p_C(\bar{x})$  is given in equation 6 and 7; this method is based on the logical probability method, where the structure of the system is described by the logical function of the outage states of this system  $F_{\Pi}$ . By introducing of  $F^n$ , the probability of system failure can be defines as:

$$p_C = \sum_{x_1} \Delta F(x_1) \cdot \sum_{x_2} \Delta F(x_2) \dots \sum_{x_n} \Delta F(x_n) \cdot F_{\Pi} \quad (7)$$

In this equation,  $p_C$  will have only discrete values; (1) if ( $y_i \gg R_{0,i}$ ) and (0) otherwise. To calculate the probability of failure of an element or a system under the influence of many factors, the statistic test method can be used. This proposed method, usually requires high-speed computers to be applied for large power systems. To calculate the reliability of a given system, an  $n + m$  equally spaced random numbers in the range (0,1) are generated and assigned as the values of the elements of vectors  $x$  and  $R$ . The values of the output vector  $y$  is calculated and compared with vector  $R$ . The result of comparison will indicate the conditions of all system elements and thus the reliability of the entire system. The calculation difficulties will depend on the number of elements a system will have. To decrease the calculation time the system can be sectionalized to less number of parts and each will be treated as a standalone element. Another approach that can be used to reduce the amount of calculations required is to reduce the number of the influencing factors by eliminating the effect of less important ones. [3, 4, 5, 1]. For example if the probability of thunderstorm to cause a failure of a given substation is going to be studied, instead of taking into consideration all the parameters of the thunderstorm, i.e., amplitude, front rising time, wavelength and the location of the discharge, only two factors can be taken, these are the amplitude and the front rising time. In this case the partial probabilities of the elements have to be recalculated as:

$$p(x_1, x_2, \dots, x_k) = \sum_{x_{k+1}} \Delta F(x_{k+1}) \cdot \sum_{x_{k+2}} \Delta F(x_{k+2}) \dots \sum_{x_n} \Delta F(x_n) \cdot p(\bar{x}) \quad (8)$$

In this equation  $p(x_1, x_2, \dots, x_k)$  is a partial probability when only the factors  $x_1, x_2, \dots, x_k$  are taking into consideration. Then the probability of system failure will be given by:

$$p = \sum_{x_1} \Delta F(x_1) \cdot \sum_{x_2} \Delta F(x_2) \dots \sum_{x_k} \Delta F(x_k) \cdot p(x_1, x_2, \dots, x_k) \quad (9)$$

In order to further reduce the calculation time, simple distribution functions that describe the occurrence of the affecting factors can be used. For example instead of the normal distribution function that is usually used to describe the amplitude of the thunderstorm discharges current, two discrete values can be used. These are  $p(x) = 1$  if the amplitude is greater than or equal to some value, which is a destroying one. The value of  $p(x) = 0$  if the amplitude is less than destroying value referring to the equation 5 that describes the reliability of a system consisting of serially connected elements and assuming two discrete values mentioned above for the distribution function the system will become faulted if any element is getting faulted. This means that all the system can be treated as a single element system. Referring to the equation 6 that describes a parallel connection of elements a system will get faulty if all elements are becoming faulty. The system is healthy if at least one element is healthy. This gives as the ability to treat also a system as a single element one.

### 3 Conclusions

With increasing the size of modern power systems, the number of the factors that influencing the reliability of these systems is increasing. The proposed approach can be used to calculate the reliability of a given power system under the influence of discrete multi factors and can be used for building the reliability schemes of these systems. The proposed approach can also be used to build reliability models of for the overhead lines operated under ice-slick and wind impact as well as switching over voltages. The presented theoretical provisions show the absence of limitations in constructing mathematical reliability models of various electric power systems under various types of discrete multifactor influences.

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