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Expected Costs for Service Interruption.

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EXPECTED COSTS FOR SERVICE INTERRUPTION

BY

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ABSTRACT:

This paper introduces a mathematical model for expecting the value of cost of service interruptions. Since, this cost is affected mainly by reliability level of the power system, the forced and scheduled outages for the different elements are considered. Mathematical relations for the determination of reliability indices are derviated and the factors affecting these reliability indices are studied. Then relations relating the expected cost of service interruption and reliability indices are proposed.

1-INTRODUCTION

Reliability prediction is a method of quantitively stating what is expected to occur and can be used to indicate the relative merits of alternate design proposals with regard to a predetermined. level of performance adequacy. Reliability engineering is therefore both a measure and discipline.

Methods are available for estimating the service reliability which any particular power system can be expected to provide. Therefore, the cost of constructing a power system which will provide any specified level of service reliability can be determined. The cost of obtaining a specified level of reliability can be one side of the equation, however the other side involves the elusive quantity of reliability worth or the cost of service interruptions.

Tho cost of power interruptions which has been developed is used to assess and discuss power system reliability economics.

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2- THE PROBLEM:

For the propose of expecting the cost of service interruptions in electrical power systems, the forced and scheduled outagee must be considered. Also the duration of these outages should be taken into considerations.

So, by the use of mathematical formulas relating the reliability indices of the system, specific losses of consumer and cost of service interruptions, the expected cost of service interruption could be determined.

3- RELIABILITY INDICES OF THE SYSTEM

It is clear that the expected down-time ratio of suppling load-point (the probability that load-point will be disconnected at some remote moment and the expected frequency of outages for load-point are two indicea sufficient to determine the expected value of losses due to load-disconnections.

3.1 Factors affecting reliability indices of power systems.

The different factors affecting reliability indices for complex power networks are:-

1- Maintenance outages.

2- Busbars failures.

3- Malfunction of circuit breakers.

4- Overlapping of simultaneous independent outages.

5- Influence of weather conditions.

6- Overloading conditions for the different elements in the power networks.

All these factors must be considered for the propose of reliability indices calculations.

3.2 Mathematical Formulation of Reliability Indices

3.2.1 General

Complex networks may be classified to nodes and branches. The branches may be simple seriea or parallel elements.

3.2.2 Notations

F expected frequency of outages for load-point.

D expected down-tim ratio of sappling load-point.

f_b busbars forced outages rate in per hundred circuits and year.

N number of circuits.

r_b average repair time.

K_{cb} probability of lacking openings in cases of short-circuits on paths directly connected to the node.

S_{cb} average switching time.

f_l specific outage rate per hundred KM of line and year.

l_i lengths of individual lines.

f_t specific outage rate per hundred transformers and year.

n_t number of transformers.

f_i forced outage rate of i series elements.

d_i down-time ratio of i series elements.

r_i average component repair times.

m_1&m_2 yearly maintenance - time hours.

W weather conditions

N_w length of normal weather period.

A_w length of adverse weather period.

tm manual reclosing times.

tr outage time caused by overlapping.

3.2.3 Networknodes

The factors affecting on the calculation of the forced outage rate and the down-time ratio (F, D) on nods of power system are the busbare failures which equal f_b N, the malfunctions of circuit breakers and the total number of primary failures in the appurtenant region which equal K_{cb} $(f_l \sum_{i=1}^{n} l_i + f_t\ n_t)$.

Then the equations represents the forced outage rate and the down-time ratio becomes

$$f_n = \frac{f_b}{100} N + \frac{K_{cb}}{100} (f_l \sum_{i=1}^{n} l_i + f_t n_t) \quad \ldots\ldots\ldots (1)$$

$$d_n = \frac{f_b}{100} N r_b + \frac{K_{cb} S_{cb}}{100} (f_l \sum_{i=1}^{n} l_i + f_t n_t) \quad \ldots (2)$$

3.2.4 Network branches

I. Series elements arrangements

The determination of forced outage rate and downtime ratio in series elements neglecting the maintenance outages are given by the following equations

$$f_s = \sum_{i=1}^{n} f_i \quad \ldots\ldots(3)$$

$$d_s = \sum_{i=1}^{n} d_i = \sum_{i=1}^{n} \frac{f_i r_i}{T} \quad \ldots\ldots(4)$$

II. Parallel elements arrangements

For the parallel elements arrangements and taking the maintenance into considerations, the factors $(1 - \frac{m_1 + m_2}{T})$ will represent the fractionof time T with no scheduled outages.

By considering the weather conditions, we have a two-state model, normal weather N_w and adverse weather A_w.

For the two-state model the consideration of weather influence on failure rates[2] (W) which defined as the ratio of the expected value of simultaneous outages of n parallel elements to the expected value calculated with one average failure rate is given by

$$W = \frac{\alpha\left(\frac{1}{1+\gamma} + \frac{\gamma}{1+\gamma} B\right) + (1-\alpha)\left(\frac{1-\alpha}{1-\alpha+\alpha\gamma} B^2 + \frac{\alpha\gamma}{1-\alpha+\alpha\gamma} B\right)}{(\alpha + (1-\alpha)B)^2}$$

$$\text{where } \alpha = \frac{N_w}{N_w + A_w} \quad , \quad \beta = \frac{\lambda_A}{\lambda_N} \quad , \quad \gamma = \frac{r}{N_w}$$

and λ -failure rates , r-average repair time of element

For calculating the reliability indices (F, D), we must consider the following correlating factors[4]:-

a) Correlation factor K_c due to constructional aspects

This factor is for considering the mult-circuits in transmission lines, cables, and busbars in multiple-busbar stations. K_c = 0 for all other arrangements.

b) Correlation facter due to nonselective trippings of protective devices

The disconnection due to nonselective trippings are determined by the lay-out and quality of the applied protective devices, and by extent of autoreclosing and its efficiency.

Failure correlation of this kind was observed only for neighbouring element, i.e. connected to the same node.

c) Correlation factor K_o due to component overloads at forced disconnection of parallel paths:-

For the parallel transformer arrangement in Fig. (1 a) and the curves shown in Fig.(1 b) the relations between the probability of exceeding looding and the transformer KVA per Ann. peak KVA demand are given[5].

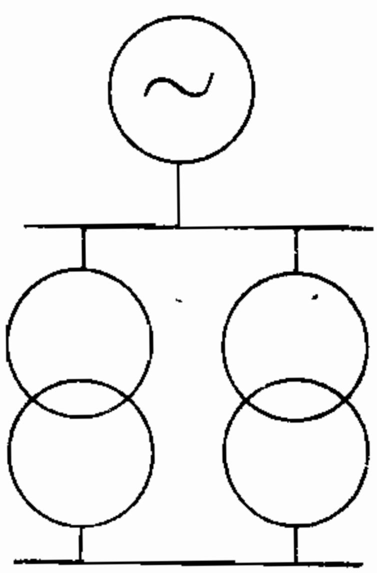


Fig. 1 a

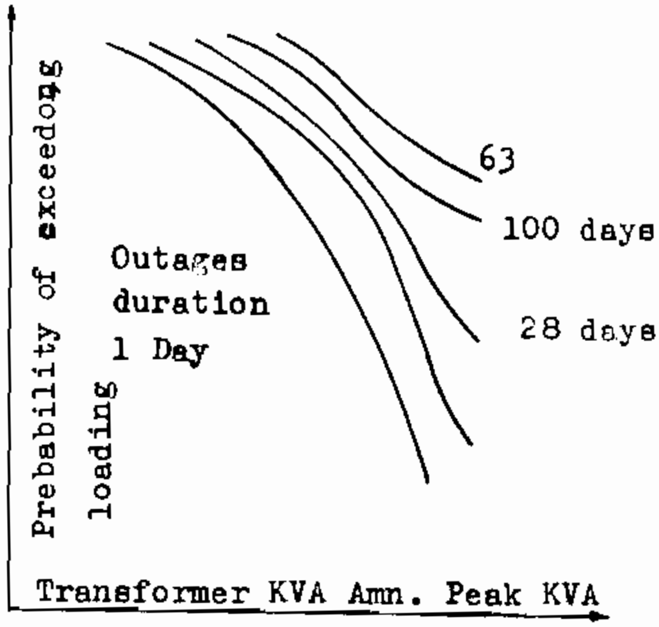


Fig. 1b Overloads Contingency Curves.

For a commen node in the network , whose outage totally interrupts the supply to the load (L), over load controls are effected. For the successive states of single, double, and triple-outages, the degree of overloading ψ for the elements is computed as

$$\psi = \frac{P_k}{\sum_{i=1}^{i=m} C_i}$$

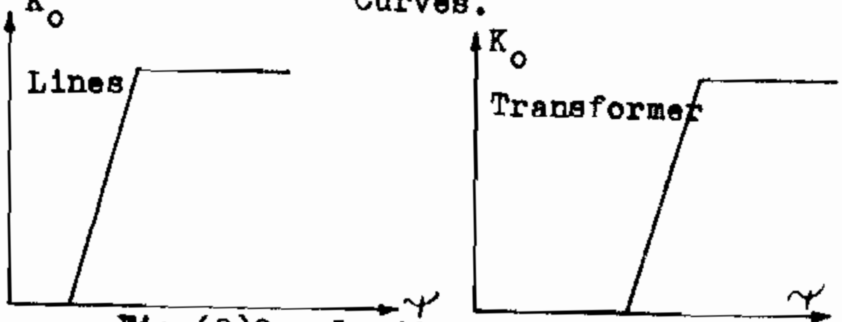


Fig.(2) Overloading outages characteristics.

Where P_k - peak lood at L $\sum_{i=1}^{m} C_i$ -summation of capacity for m elements

Then, from the assumed relation $K_o = f(\psi)$, Fig. (2), the probability of overload outage is found.

The equations of parallel elements arrangements which takes into account of all factors discribed above and in additional to frequency of outages if both paths have overlapping independent forced outages and frequency of a forced outage over lapping a scheduled outages becomes:-

$$f_p = W f_1 f_2 \left(\frac{r_1+r_2}{T}\right)\left(1 - \frac{m_1+m_2}{T}\right) + \left(f_1 \frac{m_2}{T} + f_2 \frac{m_1}{T}\right) + (f_1+f_2)\left(1- \frac{m_1+m_2}{T}\right)(k_c+k_r) + \left(1- \frac{m_1+m_2}{T}\right)(f_1 k_{02} + f_2 k_{01}) \quad \ldots (5)$$

$$d_p = W f_1 f_2 \left(\frac{r_1 r_2}{T^2}\right)\left(1- \frac{m_1+m_2}{T}\right) + \frac{1}{T^2}(f_1 t_{1r} m_2 + f_2 t_{2r} m_1) + \frac{1}{T}\left(1-\frac{m_1+m_2}{T}\right)(f_1 t_{2m} + f_2 t_{1m})(k_c+k_r) + \frac{1}{T}\left(1 - \frac{m_1+m_2}{T}\right)(f_1 t_{2m} k_{02} + f_2 t_{1m} k_{01}) \quad \ldots\ldots\ldots\ldots (6)$$

Fig. (3) gives the flow charts for reliability indices calculations.

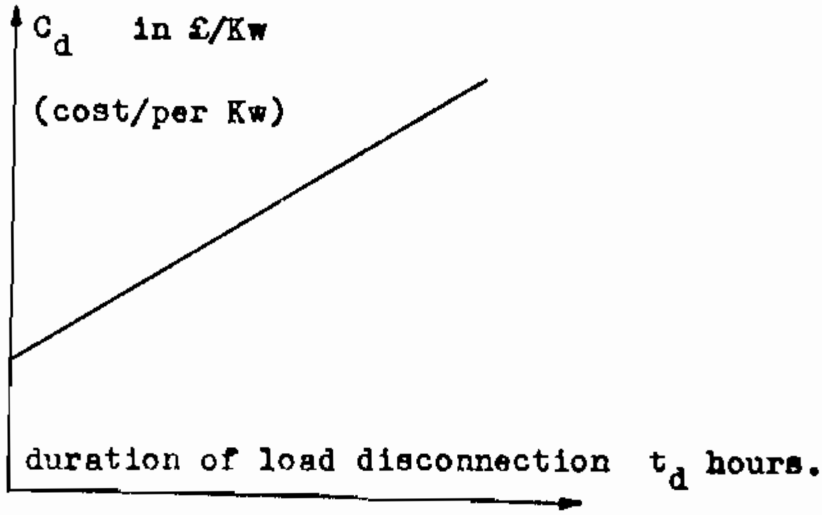
4. The Specific Losses of Customer

The specific losses[7,8] in terms of KW lost, Cd, and interruption duration is proposed to be expressed as

$$C_d = a + bt_d \qquad \text{......(7)}$$

where

C_d is the cost of specific load-disconnection
a is the cost per kW lost.
b is the cost per kwh
t_d is the duration of load disconnection



Appling the reliability indices in the above equation of loss-characteristics, the expected value of costs for service interruptions due to load disconnec tions at a station with average load p_{av} in MW is

$$\text{Expected Cost} = (A_r\ F + B_r\ DT)\ P_{av} \qquad \text{.......(8)}$$

5. Conclusion

It could be concluded that the cost of servicc inturrption is affected mainly by the reliability indices for power systems. Different factors must be taken into consideration for calculating the reliability indices.

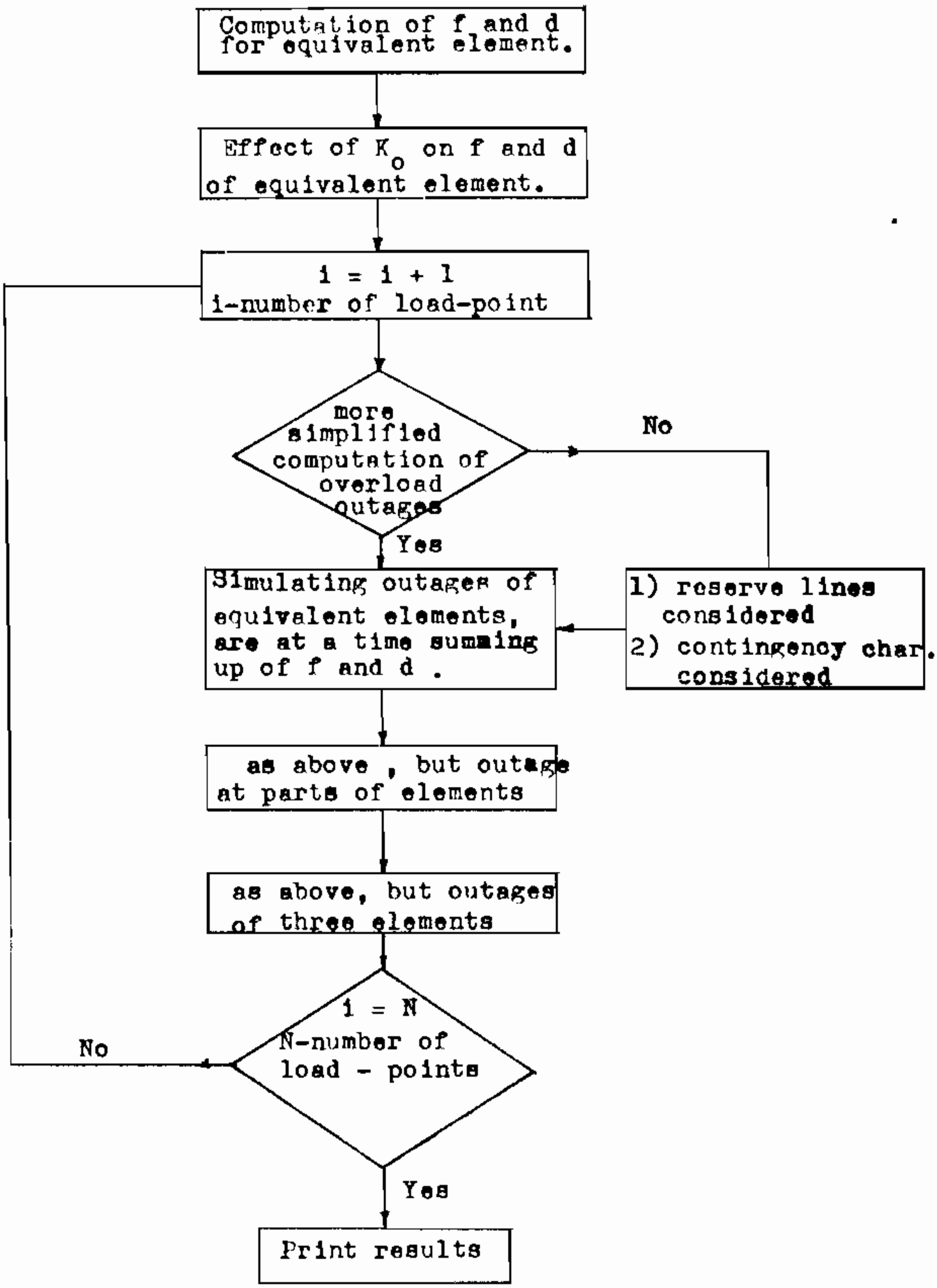


Fig. (3). Flow chart of reliability indices calculations.

The studies and analysis of these factors makes it possible to formulate equations for computing the reliability indices. Also, from the analysis given, it is shown that two indices are sufficient to express the reliability of the power system.

The proposed linear equation representsthe expected cost of service interruption as a function of the computed reliability indices appears to be a simple and sufficient accurate equation of this purpose.

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