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Reliability analysis in Electrical Distribution System considering preventive Maintenance Applications on Circuit Breakers

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***Abstract*—**This paper presents the results of a preventive maintenance application-based study and modeling of failure rates in breakers of electrical distribution systems. This is a critical issue in the reliability assessment of a system. In the analysis conducted in this paper, the impacts of failure rate variations caused by a preventive maintenance are examined. This is considered as a part of a Reliability Centered Maintenance (RCM) application program. A number of load point reliability indices is derived using the mathematical model of the failure rate, which is established using the observed data in a distribution system.

***Keywords*—**Reliability-Centered Maintenance (RCM), failure rate, preventive maintenance (PM), Distribution System Reliability.

I. INTRODUCTION

THE importance of analyzing component failure rates has recently been under consideration, among electric utilities around the world. The quality of supply can considerably be improved, by incorporating reliability considerations in the system design and in the system expansion planning, operation and maintenance.

To obtain useful results from system reliability assessments, reasonable values of component reliability parameters need to be used. However, the required accuracy of the reliability data depends on the purpose of the assessment, i.e., more accurate parameter values are required when determining actual system performance than when comparing different system configurations.

II. MATHEMATICAL MODELING

Two kinds of failures are used in distribution system reliability analysis. They are classified into sustained Failures and temporary failures. Sustained failures require some kind of repair work to restore the function of the component into a normal position, while temporary failures will clear themselves if the component is de-energized, the fault location is de-ionized and then the component is re-energized.

CIGRE Working Group has conducted two worldwide reliability surveys of the Reliability of high-voltage circuit breakers in the voltage range 20 kV and above [3]. This working group has divided all failures in these CB's into two categories of major or minor failures. In this failure categorization, a major failure occurs when the breaker can no longer perform all of its fundamental functions, or when intervention is necessary for more than 30 minutes. All other failures are referred to as minor failures

Using the data chosen for the analysis, a mathematical expression for the average failure rate versus time is established, assuming that all failures are considered as major type and they only occurred by malfunction of the motorized system. The data is shown in Table I [1].

In order to fit the data to a standard function and due to the approximation of the data, some degrees of polynomial are used in the proposed model. The functional relationship between failure rate and time, using a 4 degree polynomial is expressed as follow:

$$\lambda(t) = \begin{cases} 0 & t\langle 1 \\ f(t) & 1 \le t \le 10 \\ f(10) & t\rangle 10 \end{cases} \tag{1}$$

where
f(t) is a 4 degree polynomial function shown below:

$$f(t) = 0.0032t^4 - 0.0055t^3 + 0.0342t^2 - 0.0113t + 2.8667$$

It is clear that the higher degrees of polynomials are more accurate, but coefficients of terms more than 2 are close to zero. Then, we can consider a 2 degree polynomial to achieve a mathematical relationship between failure rate and time.

$$f(t) = 0.1939t + 2.5814 \tag{2}$$

factors such as:
- Weather conditions (storms, lightning, snow, ice, temperature and air humidity)
- Contamination
- Vegetation
- Animals
- Humans
- Excessive ambient temperature
- Moisture
- Excessive load
- Lack of maintenance
- Ageing

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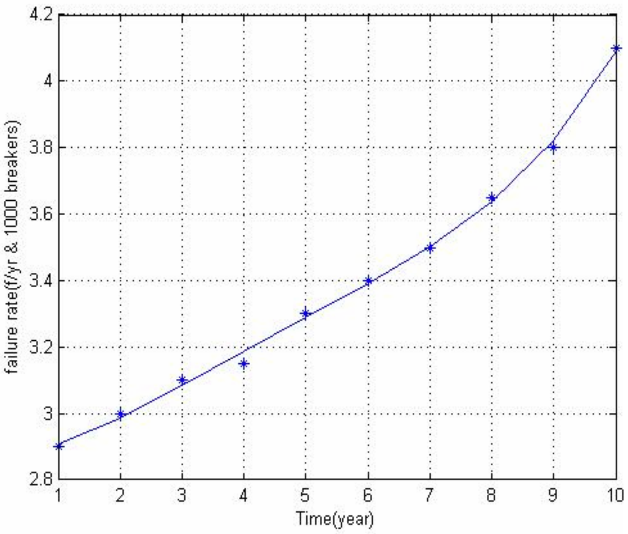

Fig. 1 Approximation of Major failures of the sample to a function (stars are the observed data and solid line is the proposed model)

These factors cause the component failure rates to vary with time and location. Therefore, it is sometimes not accurate enough to assign identical average failure rate values to all Components of a particular type. Ideally, each component should be treated as an individual one with a unique failure rate. However, by considering information sources providing valid average failure rates for a variety of conditions within which it is reasonable to expect the average failure rates to vary, can be derived. It should be noted that the causes of incorrect behavior of protection and control systems and of circuit breakers are somewhat more complicated.

III. APPLICATION OF PM IN A CASE STUDY

By applying a Preventive Maintenance (PM) as a part of RCM studies to the same sample at year T = 7, the results shown in Table II are obtained. The following data show the results derived from the modeling of failure rate versus time using the data presented in Table I [1].

It can be seen from the results that failure rate at T = 7 is close to the failure rate in T =1. This implies that applying some PMs reduces the major failure rates in the next coming years.

Using the same mathematical modeling for failure rates, we can generate a graphical illustration for the sample after applying a PM at year T=7 as shown in Fig. 2.

In this series of PM activities, economical studies are more important to be considered in determining the optimum number of PMs. Fig. 2 shows a graphical illustration of the Effect of one PM application at year T = 7 compare to that of CB replacement.

IV. SYSTEM RELIABILITY ANALYSIS

Fig. 3 shows a part of the distribution test system used for the study analysis in this paper [4]. In this analysis, it is assumed that bus c1 (source point) is fully reliable and bus c35 (Load point) reliability indices address the local impact of bulk transmission outages by quantifying the frequency, duration, and severity of interruptions at the source point. Generally, both deterministic and probabilistic assessments should be performed and measures of reliability could be estimated [5].

The load point reliability indices address the local impact of bulk transmission outages in the form of frequency, duration, and severity of interruptions at the source point. Generally, both deterministic and probabilistic assessments should be performed and measures of reliability could be estimated.

TABLE II
MAJOR FAILURE RATE FOUND IN A SAMPLE OF 1000 CB'S IN A DISTRIBUTION SYSTEM AFTER APPLYING A PM AT YEAR T =7

year	1	2	3	4	5	6	7	8	9	10
Failure Rate(f/yr and 1000breakers)	2.89	3.0004	3.099	3.186	3.276	3.377	2.94	3.05	3.14	3.38

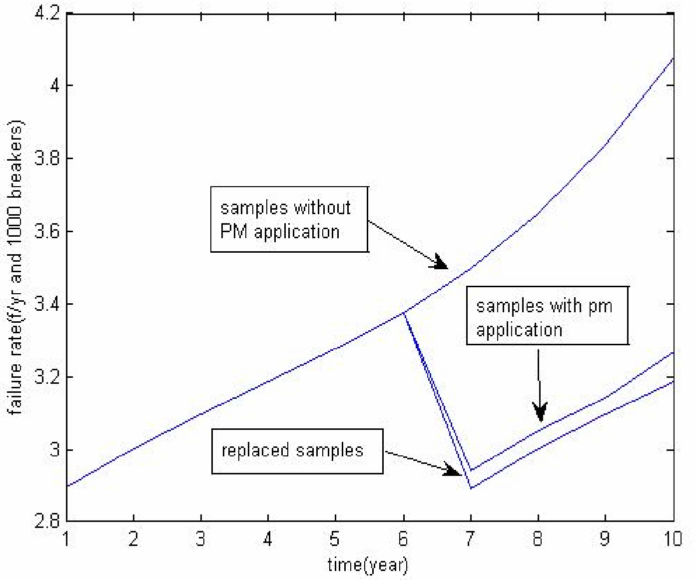

Fig. 2 Approximation of Major failures in a sample to a function (stars are the real data and solid line is the model)

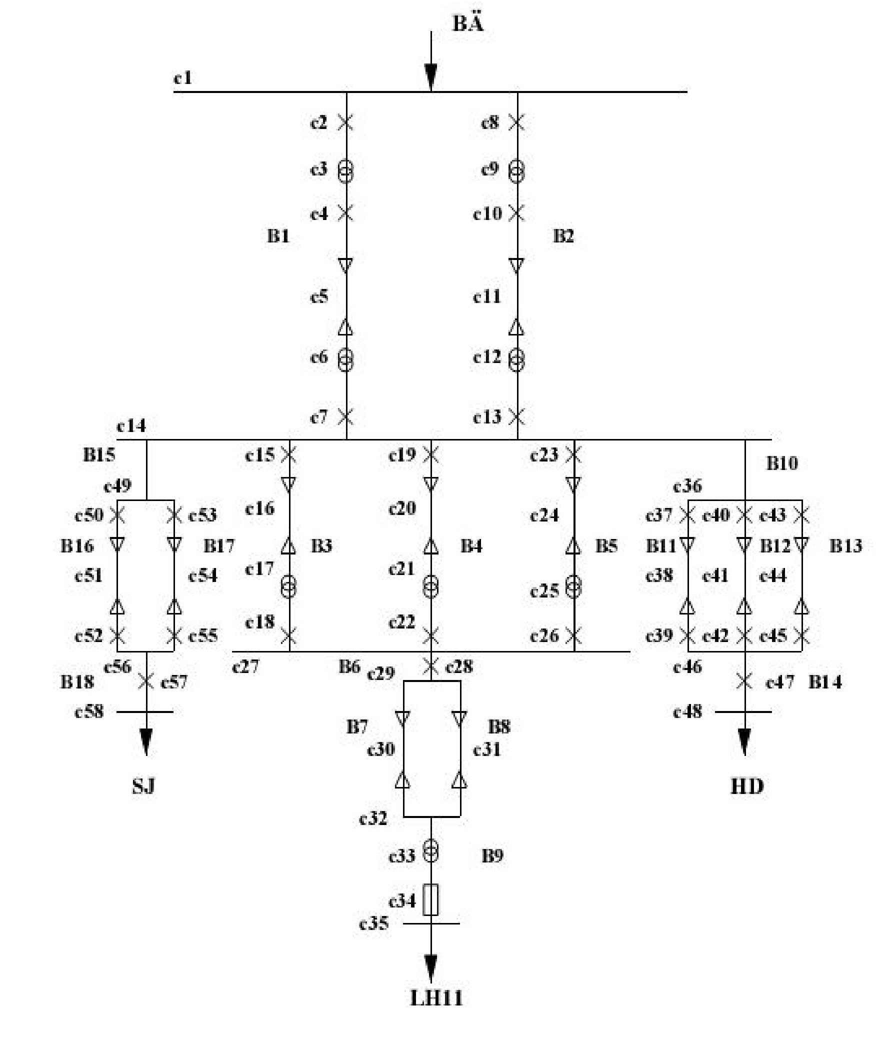

Fig. 3 Part of the distribution test system

Some specific indices used to measure system reliability performance are loss of load expectation (LOLE), loss of load probability (LOLP), expected load curtailed (ELC), and expected energy not supplied (EENS). The LOLP corresponds to the expected value of a load state function $P(x)$, where $P(x)=1$ when the x is a failure state and $P(x)=0$ when x is an operational state. The ELC corresponds to the function $E(x)$, the amount of load that is curtailed.

LOLE can be obtained by multiplying the duration of a given contingency and the associated probability of that contingency. The frequency of failure is denoted by LOLF, and corresponds to the function $F(x)$ such that $F(x)=0$ when the system is in the operational state, and $F(x)$ is the sum of the transition rates between x and all operational states that can be reached from x in one state transition. Finally, loss of load duration (LOLD) is obtained by computing the ratio of LOLP/LOLF.

Considering the distribution test system shown in Fig. 3 and applying PM activity on breakers c2, c8 and c28,some of the load point indices for bus c35 are obtained as shown in Fig. 4 and Fig. 5. The calculated indices are Expected Energy Not Supplied and Unavailability repeatedly.

It should be noted that application of another PM at ages around year T = 10 could result in a decrease in failure rates to less than one in CB replacement in these years. However, economical studies could help us to get the optimum number of PM applications.

V. CONCLUSION

It was shown that the PM activities on a breaker sample in an electrical distribution system could considerably affect the failure rate. The load point reliability indices are affected from the PM application. However the economical studies should be carried out to determine the optimum number of the PM applications on a sample.

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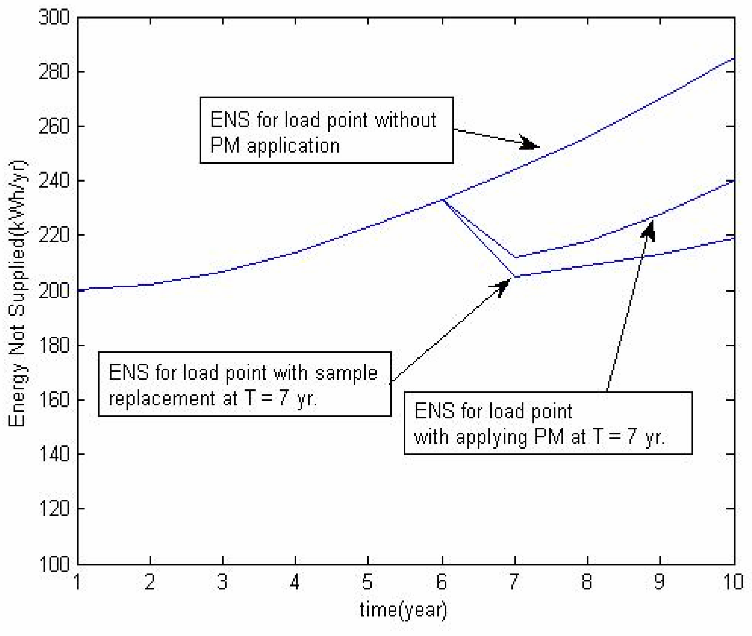

Fig. 4 ENS for load point C35 (a 4 degree polynomial curve fitting

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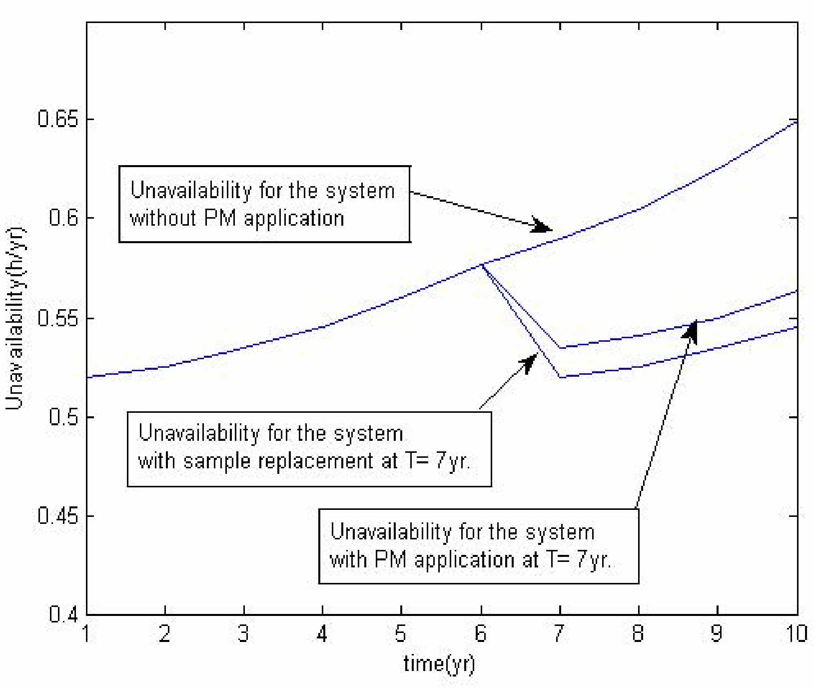

Fig. 5 *Unavailability for load point C35* (a 4 degree polynomial curve fitting)