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# Assessing circuit breaker performance using condition-based data and Bayesian approach

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ABSTRACT

This paper proposes a methodology to assess the performance of circuit breaker utilizing its control circuit data. Various performance indices are defined to assess the condition of breaker using probability distributions. Bayesian updating approach is implemented to update these indices as the new data becomes available. An approximation in implementing the Bayesian approach to deal with large amounts of data on-line is considered. The methodology is applied to data recorded at different times during both open and close operations on a group of similar circuit breakers. The methodology can be used to quantify the effect of maintenance making use of the defined performance indices, which further helps in developing system level risk-based decision approaches for maintenance optimization.



## 1. Introduction

Trying to cut down the budget spent on maintenance every year, utilities need to come up with optimized maintenance schedules with limited budget. This task involves quantifying maintenance impact, which is a bit challenging task. Existing system level maintenance strategies such as RCM approach, Risk-Based approach etc. reported in Refs. [1–6] require considering the effect of component maintenance quantitatively through models such as probabilistic maintenance models [7–10] and/or failure rate estimation models. These models depend on condition-based data and history of operation of power system equipment such as transmission lines, transformers or circuit breakers (CBs).

This paper proposes a probabilistic methodology to quantify the effect of device maintenance for circuit breakers. The proposed methodology utilizes the control circuit data of CB to define several performance indices. Fig. 1 shows the electrical representation of CB control circuit and the data consists of several voltage and current wave forms measured across trip coil, close coil and auxiliary contacts captured when the CB operates (either open or close operation). A sample representation of these signal waveforms measured during close operation of CB is shown in Fig. 2. The figure also shows several events (marked as Evt #1, Evt #2, etc.) which needs to occur in that order for correct operation of the breaker. The event definitions and the time instants ($t_1$, $t_2$, etc.) at which these events occur are shown in Table 1. These timing instants should occur within in manufacture specified tolerance bands to ensure that the CB is functioning properly. The proposed methodology defines performance indices using these time instants to reflect the health/condition of various assemblies such as trip coil, close coil,

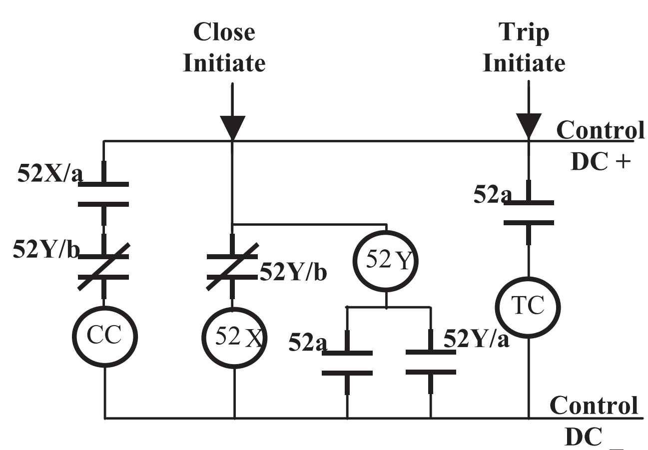


**Fig. 1.** Electrical representation of CB control circuit.

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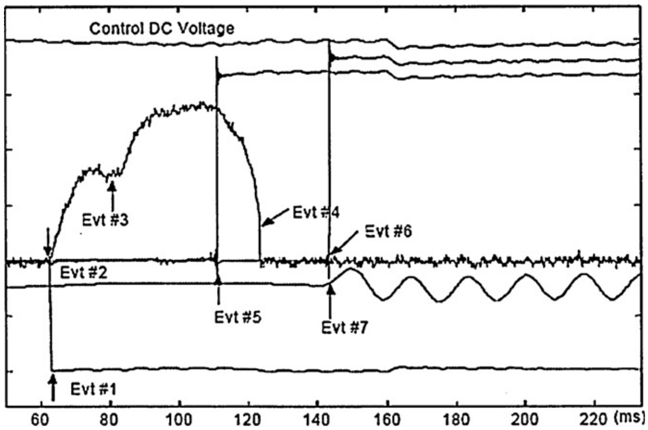


**Fig. 2.** CB control circuit signal waveforms during close operation.

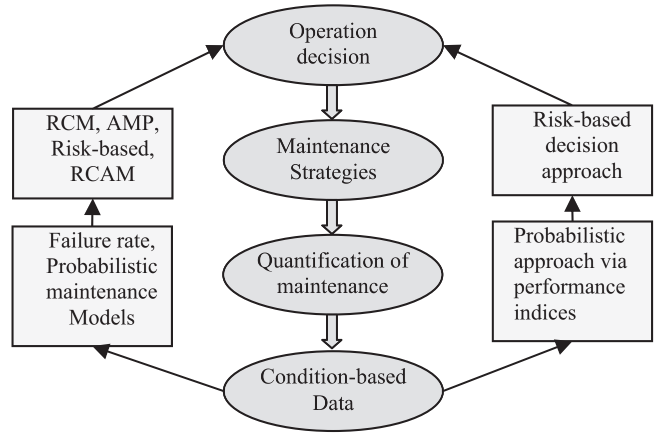


**Fig. 3.** Top–down approach.

auxiliary contacts etc. Whenever the CB operates, the control circuit data is captured and the proposed methodology updates the defined performance indices using Bayesian updating approach. An initial methodology to achieve this task was proposed earlier [11] but it lacks the ability of updating the computed performance indices on-line. To overcome this inability, we introduced Sequential Bayesian approach to make the proposed methodology suitable for practical applications so that it can be applied in real time using field condition-based data. The proposed methodology finds its use in development of optimized, system level, risk-based maintenance strategies. Though CB is considered in this work, the proposed concepts can be easily extended with few modifications to other devices such as power transformers.

This paper is organized as follows. Section 2 presents a brief background of the problem. The proposed methodology is presented in Section 3. Illustration of the methodology is presented in Section 4. An approximate procedure in implementing the Bayesian updating approach is presented in Section 4.3. Section 5 provides conclusions about the whole approach.

## 2. Background

A concept of "top–down" approach is introduced to summarize various steps in power system planning and operation affected by maintenance strategies. The flow of the process is shown in Fig. 3 and it links the operation decisions to condition-based data. Ultimately, the operator has to ensure required power flow while taking into account decisions regarding asset management and reliability constraints. Asset management policies and reliability of power system can be greatly affected by selected system level maintenance strategies [1–6]. This approach is summarized in the left side of the Fig. 3 and the quantification of maintenance is achieved through failure rate estimation models and probabilistic maintenance models [7–10]. A different approach may be taken

**Table 1**
List of events and signal parameters [16].

| Event | Event description | Signal parameter |
|---|---|---|
| 1 | Trip or close operation is initiated (trip or close initiate signal changes from low to high) | $t_1$ |
| 2 | Trip coil current picks up | $t_2$ |
| 3 | Trip coil current dips after saturation | $t_3$ |
| 4 | Trip coil current drops off | $t_4$ |
| 5 | B contact breaks or makes (a change of status from low to high or vice versa) | $t_5$ |
| 6 | A contact breaks or makes | $t_6$ |
| 7 | Phase current breaks or makes | $t_7$ |

by developing probabilistic models as shown in the right side of the Fig. 3. The quantification of maintenance is achieved through a probabilistic methodology which converts the condition-based data into performance indices. These indices can further be used in developing risk-based decision approaches. The contribution of this paper is to establish a link between the 'condition-based data' and 'risk-based decision approach' through the proposed probabilistic methodology.

## 3. Proposed methodology

The proposed methodology is shown in Fig. 4, and has the following steps: (i) develop a history of CB control signals and extract timings of each signal parameter using signal processing module (ii) analyze the relationship between the parameters using scatter plots and fit probability distribution to each parameter (iii) define performance indices using these distributions to assess the condition (health) of the breaker (iv) as the new data arrives, update the distributions and performance indices using Bayesian updating approach. The methodology is further discussed in the following subsections.

### 3.1. Condition-based Data

According to a failure survey conducted by CIGRE working group A3.12, majority of CB failures are due to malfunction of operating mechanism and control circuit in that order compared to other CB assemblies [12]. The condition-based data from the control circuit is used in this work, as it allows assessment of the performance of control circuit and the operating mechanism as well. A representation of control circuit is shown in Fig. 1. The condition monitoring techniques are relatively easy to develop since the secondary cir-

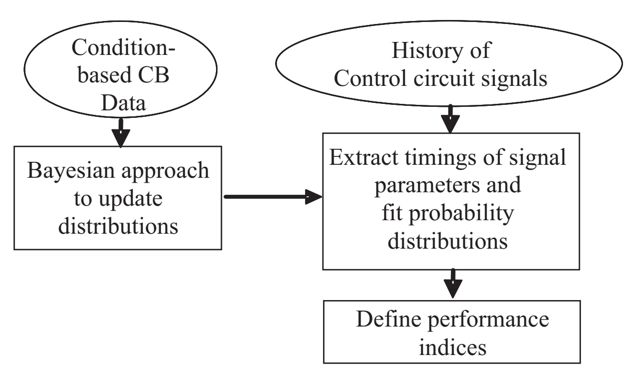


**Fig. 4.** Model to assess the condition of breaker.