Circuit breaker replacement strategy based on the substation risk assessment

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Abstract

Using statistical data of 427 circuit breakers gathered in past 10 years, Weibull probability distribution of contact resistance for breakers on both overhead and underground feeders is determined.

Other data regarding to circuit breakers that are collected are: voltage level, feeder type, manufacturing year, number of fault trips, number of short circuit current trips, number of customers, and annual consumption.

Substations reliability is calculated using minimal path and minimal cuts method.
With this methodology **influence** of CB's condition on substations reliability can be observed by using real field data. Influence of CB removal on substations reliability is presented, together with cost justification of such investment.

Example of calculation will be shown on 35/10kV substation.

Introduction

Circuit breaker is a device used for switching feeder power supply in any working mode (normal load, no load, short circuit current…), and therefore represents the vital element of power system stability. CB failure threatens work of other equipment, which directly affects reliability of whole substation. This makes good reason of finding correlation between CB condition and substations reliability.

Utilities, grid operators and industrial power consumers are facing unprecedented challenges. With increasingly aging infrastructure combined with cost-cutting pressures to operate into today's competitive environment, prioritizing investment has never been so important. [16]

Weibull distribution

Weibull distribution is most commonly used method for equipment failure, ageing and reliability analysis [23]. It can describe three types of equipment states (infant mortality, normal work, wear out), through bathtub curve [24].

Weibull cumulative distribution function represents probability of failure in given period of time (1). It is two-parametric distribution, with slop parameter η and shape parameter β.

$$F(t) = 1 - e^{\left(\frac{t}{\eta}\right)^{\beta}} \qquad (1)$$

Slop parameter shows time at which 63.2% of analyzed units are failed. Shape parameter represents failure rate behavior. Its value tells whether failures are decreasing or increasing. β<1 indicates infant mortality, while β>1 shows wear out failures. Higher value of beta indicates greater rate of failure. In table 1 Weibull parameters for different criteria are shown.

Table 1. Weibull parameters

CB feeder type	η	β	Fail \ Suspens
Overhead	37.1	4.8	131 \ 56
Underground	38.1	6.1	97 \ 135
10 kV feeders	40.4	5.1	135 \ 176
35 kV feeders	33.8	5.6	96 \ 14
all feeders	38.0	5.3	231 \ 190

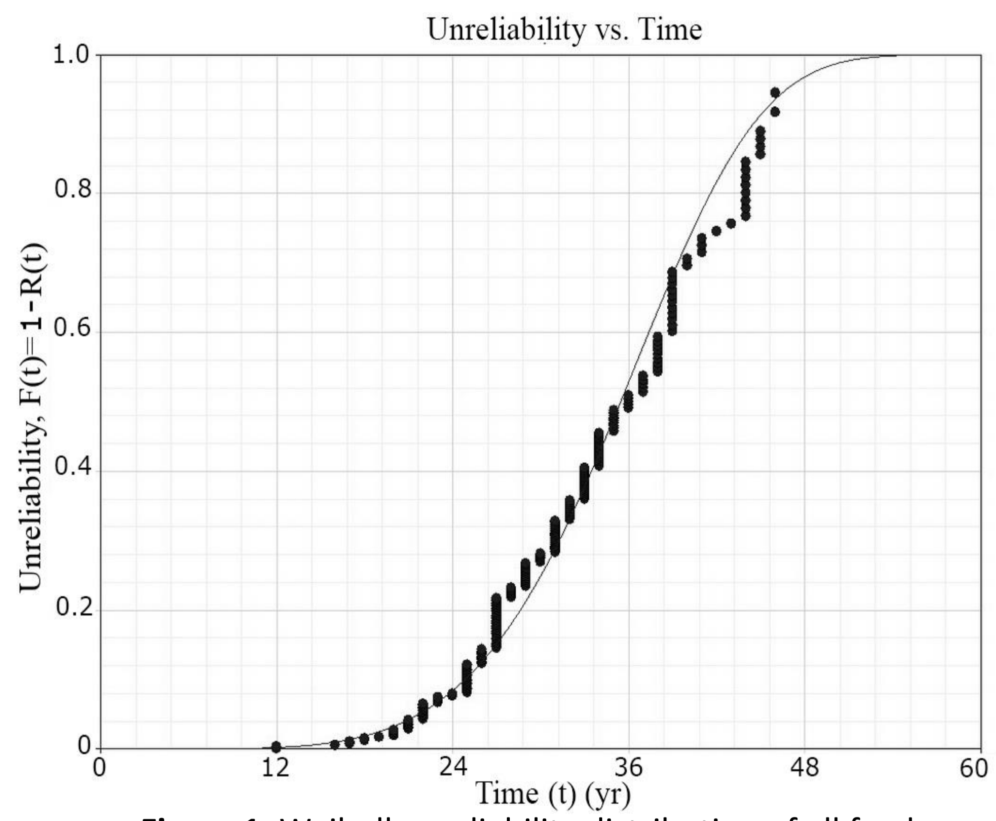

Figure 1. Weibull unreliability distribution of all feeders

Unreliability analysis

In this example 35/10kV substation will be used, which has two 8MVA power transformers, two 35kV supply feeders and ten 10kV feeders. Functional block (Fig. 2) consists of elements which would be out of supply if only one of them fails.
From Fig. 2, functional graph can be created (Fig. 3). In this case it is considered that 10kV feeders can supply the same load (ring connection).

Substations reliability is calculated with minimal path and minimal cuts method [26].

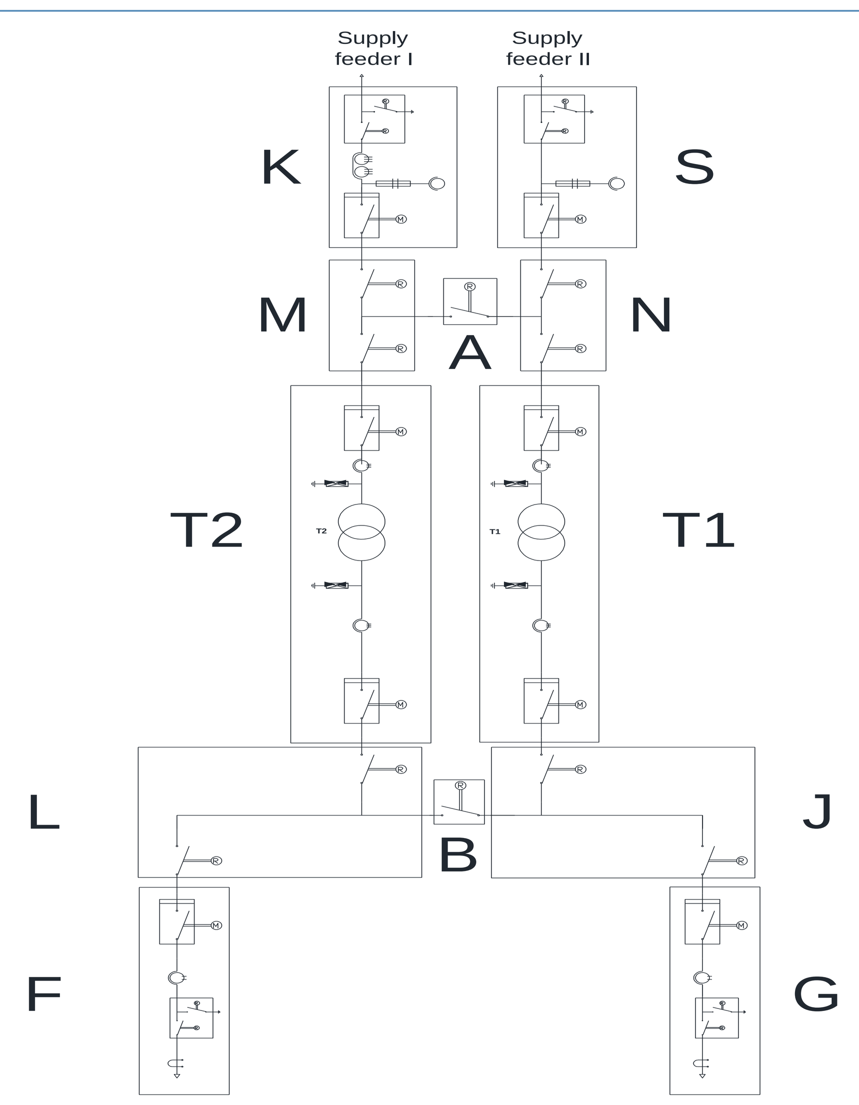

Figure 2. Functional blocks of substation.

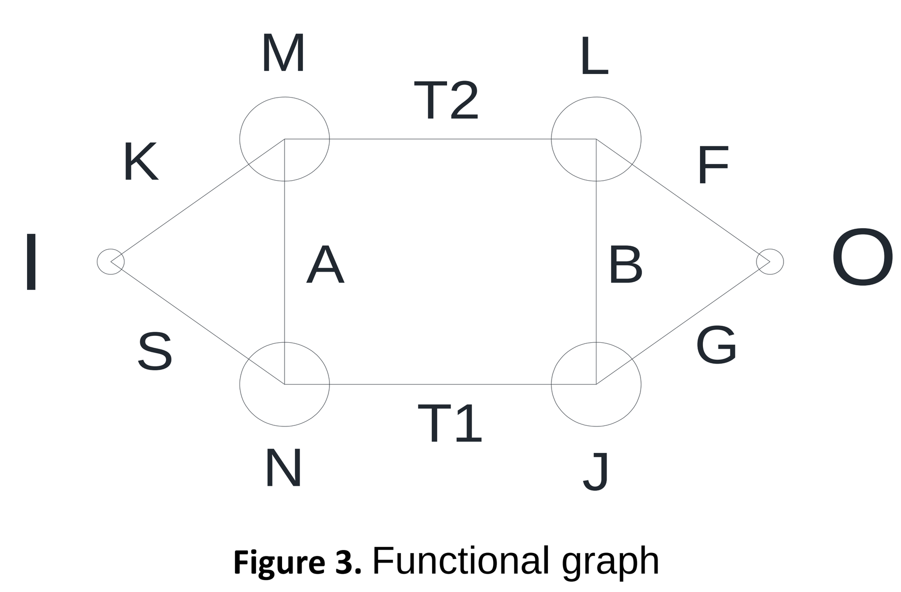

Figure 3. Functional graph

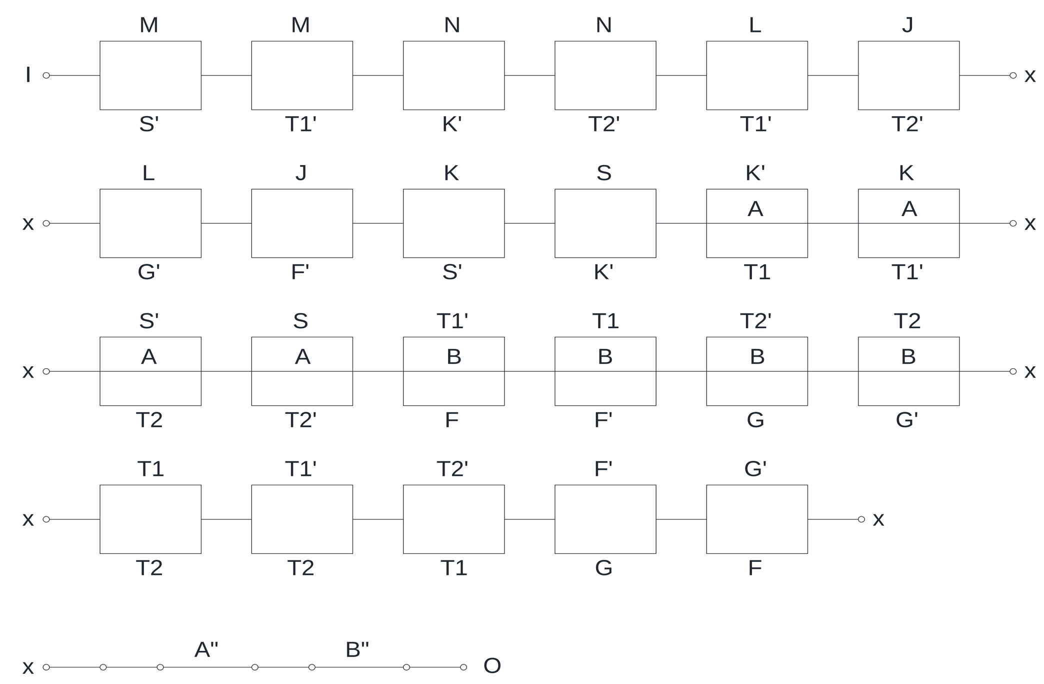

Figure 4. Equivalent minimal paths graph

Unreliability and cost calculation

After creating connection matrix and the matrix of minimal paths from fig. 3, and corresponding calculations, minimal paths are:

III: FKT_2, SGT_1
IV: KAT_1G, KT_2BG, SAT_2F, ST_1BF
V: KAT_1BF, SAT_2BG

And minimal cuts of second and third order are:
II: K-S, T1-T2, F-G
III: K-A-T1, S-A-T2, T1-B-F, T2-B-G
With all results that are obtained so far, equivalent minimal paths graph of substation can be made (Fig. 4).

Analysis of CB replacement profitability and its influence on substations unreliability will be shown through 4 different scenarios: **I** – no CB replacement; **II** – replacement of CB's on supplying feeders; **III** – replacement of CB's on power transformers; **IV** – replacement of all CB's on 10kv feeders; **V** – replacement of all CB's

Considering price of CB replacement of 5 000 € for 35kV CB and 2 000 € for 10kV feeder (including labor cost) with average time of replacement of 6h (from decision making, transporting and mounting), cost of different actions are presented in Table 2.

Table 2. Cost and unavailability results of different scenarios

	Results of different actions (%)			
Parameter	***Action II***	***Action III***	***Action IV***	***Action V***
Unavailability reduction (%)	5.07	91.57	3.36	99,99
Failure frequency	6.59	80.26	8.73	95.59
Number of CB's	2x35	2x35, 2x10	2x10	4x35, 4x10
Costs (€)	10 000	14 000	4 000	28 000

Conclusions

Substations reliability analysis can be used for determining size of new investments and their financial justifications.

Used methodology is easy to utilize because all data are already available and there is no need for extra investments or labor cost in order calculation to be carried out.

CB's removal can be assessed by risk assessment and substation's reliability improvement calculation. Substations reliability is better from investment point of view, because in that way, best case scenario in which CB's have biggest influence on substations reliability considering invested money, can be observed.

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