FAULT LOCATION SYSTEM FOR PRIMARY FEEDERS BASED ON SHORT CIRCUIT MODEL CONSIDERING THE UNCERTAINTIES OF PARAMETERS INVOLVED

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ABSTRACT

The calculation of short- circuit currents in primary feeders is highly influenced by parameters which may have a considerable degree of uncertainty in their assessment. Thus, there is a reasonable possibility that the results of short-circuit calculated be inaccurate, compromising the adjustment of the protection system of primary feeders. Thereby, this paper presents a new methodology for locating faults on primary feeders that aims equalize these issues, providing basically proper treatment to the parameters that can accommodate uncertainties. This methodology was implemented in a software which presented great performance in localizing faults in the electric distribution network.

INTRODUCTION

Traditional methodologies for calculating short-circuit adopt simplified power system modeling, resulting for some important parameters the use of values with a reasonable degree of uncertainty.

Thus, the results of the calculation of short-circuit may result inaccurate, damaging the setting protection of primary feeders.

Moreover, the methodologies for fault location in electrical energy distribution networks usually do not consider these uncertainties, providing exact values at the location of a fault that hardly corresponds to reality.

Thereby, this paper presents a new methodology for locating faults on primary feeders which is based on the concept of calculating short-circuit considering uncertainties in the assessment of some of the influential parameters.

This methodology was implemented in software constituting a valuable tool to support adjustments protection of primary feeders and in the dispatch crews to repair contingencies.

This paper examines case studies linked to actual incidents recorded in the primary feeders of electric utility COPEL which constitutes one of the largest utilities in Brazil.

SOURCES OF UNCERTAINTY IN THE CALCULATION OF SHORT-CIRCUIT

Among the uncertainties related to the parameters that influence the calculation of short-circuit one can mention [1]:

- Fault impedance: There is a great difficulty in estimating this parameter in events that involve contact between phase conductor and ground. A typically recommended value is 40 Ω [1], [2]. However, numerous studies indicate varied values [1], [2] and, in some cases, much higher, being influenced by different conditions of humidity, temperature and soil type;
- Short-circuit power: The evaluation of this parameter requires an estimate of the upstream equivalent of the entire electrical system of the primary network, which is very difficult to be evaluated, given the uncertainty about the network topology, ground resistivity, information about the transposition of lines, etc.;
- Physical parameters of the electric distribution network: The main sources of uncertainties are related to the estimation of the arrangements and impedances of the conductors comprising the primary feeder, and the operating temperature.

Thus, in order to minimize the impact of these uncertainties is recommended to specify alternative methodologies based on the use of possible ranges of values instead of applying deterministic input data normally adopted.

TREATMENT OF INHERENT UNCERTAINTY CALCULATION OF SHORT-CIRCUIT

In order to establish an appropriate treatment for uncertainties in parameters that influence the calculation of short-circuit a technique called Fuzzy Logic was used, which has been widely applied in the resolution of problems of power systems [3], [4]. This technique consists in transforming the deterministic parameters over a range of values with their respective degrees of relevance.

Thereby, the proposed methodology is based on the representation of the parameters which present uncertainty and calculated values of short-circuit as Fuzzy Sets.

Fault Impedance

Usually, some values between 20 and 40 Ω are used [1], [2].

The methodology consists of transforming this deterministic value in a Fuzzy Set comprising five (5) pairs "value x degree of relevance" in order to involve a larger number of possible real situations.
This Fuzzy Set can be represented as shown below [1].

$$C_{RD} = \left\lfloor X_{(a)}; X_{(b)}; X_{(c)}; X_{(d)}; X_{(e)} \right\rfloor \quad (1)$$

Where:

C_{RD}: Fuzzy Set relating to fault impedance;

X(i): Value of fault impedance associated with the degree of relevance "i", where "V" ranges from "a" to "e".

The parameter values "X" that comprise the Fuzzy Set, as well as their respective degrees of relevance, should be arbitrated by the protection engineer, based on knowledge of the region under analysis.

Short-circuit power

Typically the short-circuit power is supplied by the substation bus that feeds the electrical energy distribution network under analysis.
The proposed Fuzzy Set for its representation is identical to that used for the treatment of fault impedance, including with the same number of components.

Physical parameters of the distribution network

Among others, the main factors stand are the physical arrangement of cables and operating temperature.
The model considers only the parameter representation of operating temperature as a Fuzzy Set since the impact of the arrangement of the cables is less relevant for this analysis.
The proposed Fuzzy Set is identical to the already presented one.

SHORT-CIRCUIT FUZZY

This item presents a method for calculating short-circuit in primary feeders based on the use of ranges of values ("fuzzy set") for each parameter subject to uncertainties.
The methodology proposes the calculation with the simultaneous treatment of the uncertainties of the parameters considered. The result is a series of short-circuit values with their respective degrees of relevance.
The basic formulas for calculating the "short-circuit fuzzy" are presented as follows [1].

a_1-) Three-Phase Short-Circuit

$$i_{3\Phi} = \frac{1}{z_{1,busi}} \text{(pu)} \quad (2)$$

Where:

$i_{3\Phi}$: Electric current three-phase short-circuit

$Z_{1,busi}$: Equivalent impedance of positive sequence for a fault at bus i.

b_1-) Two-Phase Short-Circuit

$$\left| i_{2\Phi} \right| = \frac{\sqrt{3}}{2} \left| i_{3\Phi} \right| \text{(pu)} \quad (3)$$

Where:

$i_{2\Phi}$: Electric current two-phase short-circuit

c_1-)Phase-to-Ground Short-Circuit

$$i_{\Phi T} = \frac{3}{2z_{1,busi} + z_{0,busi} + 3z_{Fault.}} \text{(pu)} \quad (4)$$

Where:

$i_{\Phi T}$: Electrical current short-circuit phase-to-ground

$Z_{0,barrai}$: Equivalent impedance of zero sequence for a fault at bus i.

$3Z_{Fault}$: Fault impedance.

The values of the sequence impedance can be dismembered, being composed of the sum of the impedance of the conductors (Z_1,conductor and Z_0,conductor) and the equivalent impedance of the electrical system upstream (Z_1, system and Z_0, system), resulting in:

a_2-) Three-Phase Short-Circuit

$$i_{3\Phi} = \frac{V_{pré-fault}}{z_{1,system} + z_{1,conductor}} \text{(pu)} \quad (5)$$

Where:

$V_{pré\text{-}fault}$: Pre-fault voltage at the point of fault.

b_2-) Two-Phase Short-Circuit

$$\left| i_{2\Phi} \right| = \frac{\sqrt{3}}{2} \left| i_{3\Phi} \right| \text{(pu)} \quad (6)$$

c_2-)Phase-to-Ground Short-Circuit

$$i_{\Phi T} = \frac{3xV_{pré-fault}}{2\left(z_{1,system} + z_{1,conductor}\right) + \left(z_{0,system} + z_{0,conductor}\right) + 3z_{Fault.}} \text{(pu)} \quad (7)$$

With the insertion of ranges of values for the uncertain parameters, rather than deterministic values, the formulation can be described as follows.

a3-) Three-Phase Short-Circuit

Electrical current of short-circuit:

$$i_{3\Phi} = \frac{1}{z^{i}_{1,system} + z^{i}_{1,conductor}} \text{(pu)} \quad (8)$$

One calculates the value of short-circuit for each possible combination of parameters. Thus, "i" varies from 1 to "n", and "n" is the number of values of short-circuits currents contained in the set.

Degree of relevance ($\mu_{SC3\theta}$):

$$\mu_{SC3\Phi} = \mu_A x \mu_B x \mu_C \qquad (9)$$

Where:

μ_A, μ_B, μ_C: Degrees of relevance associated to the fault impedance parameters, short-circuit power and operating temperature, respectively.

$\mu_{SC3\theta}$: Degree of relevance associated with the value calculated short-circuit.

b3-) Phase-to-Ground Short-Circuit

Electrical current of short-circuit:

$$i_{\Phi T} = \frac{3xV^{i}_{pré-fault}}{2\left(z^{i}_{1,system} + z^{i}_{1,conductor}\right) + \left(z^{i}_{0,system} + z^{i}_{0,conductor}\right) + 3z^{i}_{fault.}} \text{ (pu)} \qquad (10)$$

Degree of relevance ($\mu_{SC\theta T}$):

$$\mu_{SC\Phi T} = \mu_A x \mu_B x \mu_C \qquad (11)$$

METHODOLOGY FOR LOCATION FAULTS ON PRIMARY FEEDERS

This item presents a methodology for fault location in the system of distribution. This methodology uses the technique presented for treatment of the inherent uncertainties in the short-circuit calculations [1], [6].

The methodology of fault location is based on the calculation of the possible short-circuit electric currents in each branch, based on sets of values established for each parameter uncertain. Each value is calculated from the combination of values for the uncertain parameters.

Thereby, each combination consists of the short-circuit interval between the value minimum (end) and the maximum (beginning) in the branch. It follows that each set will have a degree of relevance associated resulting product of the degrees of relevance of the parameters adopted.

Therefore, one creates a database of possible values of electrical current fault, divided by branches primary feeders. In the case of a fault in the primary feeder, oscillographic fault current values are compared with the calculated values, thus enabling the determination of possible faulted branches of the electrical distribution network.

FAULT LOCATION SOFTWARE

The main features of the software developed software are presented as follow.

Graphic Interface

The software uses graphical representation on the topology of the primary feeder.

Location Faults

This module can be divided into three parts:

- Input data of the fault;
- Locating faults on primary feeders considering conventional calculation short-circuit;
- Locating faults on primary feeders considering calculation short-circuit based on Fuzzy Logic.

After importing the data files it is possible to visualize the type and fault values per cycle as calculated by the method of trapezoids, as shown in Figure 1.

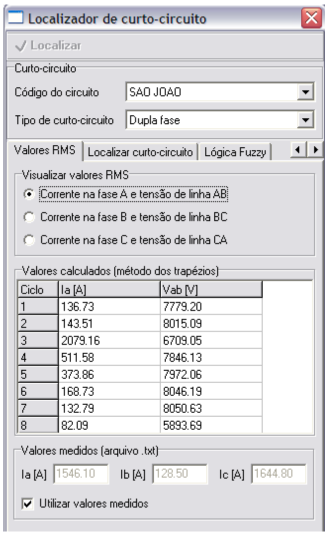

Figure 1 – Oscillographic Data

For each fault, it is necessary to indicate which parameters of uncertainty deserve to be treated in a probabilistic manner (figure 2). Once chosen parameters is necessary to inform the possible values in pu and their respective degrees of relevance, being 1 pu considered the value originally registered in the database.

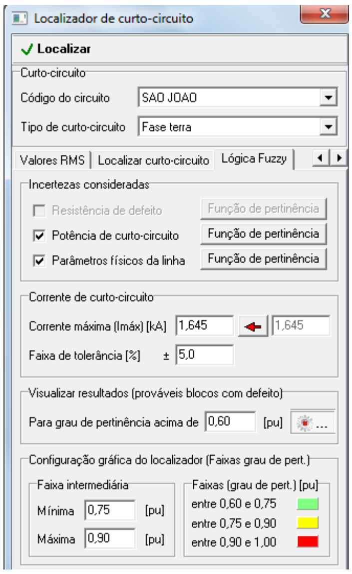

Figure2 – Configuration parameters

With all the aforementioned configurations, the user can perform the implemented fault location application.

CASE STUDY

In order to validate the developed methodology some cases were simulated in a real network of electric utility COPEL and the results compared with actual locations.

Example 1:

- Primary feeder: Anita Garibaldi
- Short-circuit current (by oscillography): 5,644 kA
- Type: Two-phase short-circuit

Figure 3 shows the result of software (likely fault sites highlighted in specific colors) and the actual location of the fault, indicated by the black arrow.

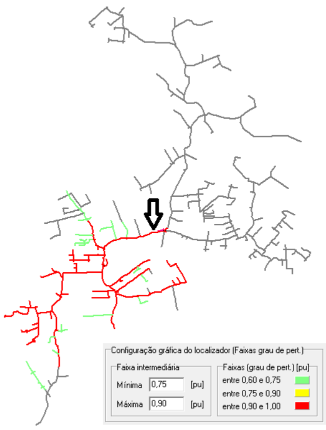

Figure 3 – Fault Location in the feeder Anita Garibaldi

Example 2:

- Primary feeder: Barreirinha
- Short-circuit current (by oscillography): 0,98 kA
- Type: Phase-ground impedance

Figure 4 shows the result of software.

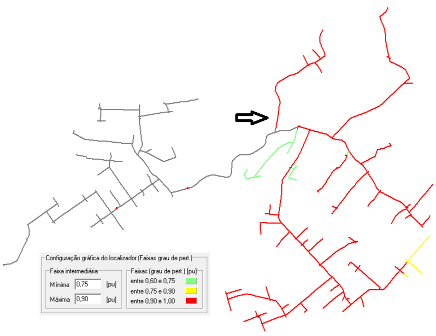

Figure 4 – Fault Location in the feeder Barreirinha

Example 3:

- Primary feeder: Tanguá
- Short-circuit current (by oscillography): 0,30 kA
- Type: Phase-ground impedance

Figure 5 shows the result of software.

As can be seen, considering the adoption of appropriate input data, the developed software shows good performance in localizing faults in electrical distribution network.

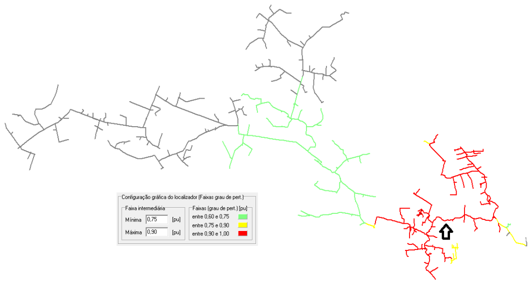

Figure 5 – Fault Location in the feeder Tanguá

CONCLUSION AND FINAL COMMENTS

There is a reasonable amount of influential parameters in the calculation of short-circuit in distribution feeders that may present uncertainties and thereby compromise the results used in adjusting the primary protection system.

The carried out studies indicate the real need for treatment of these uncertainties due to the impact they cause on the results.

The proposed methodology and developed software are interesting analysis tools for dealing with uncertainties since they give the possibility to the protection engineer to know the possible values of short-circuits at a specific point of the electric network and their probabilities of occurrence.

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