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Fault location method applied to transmission lines of general configuration

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ABSTRACT

Power quality is an important concern once automation is present in almost all industrial process. Since fault occurrences affects the power quality considerably, in this paper is proposed a new fault location method applied to transmission lines constituted of any configuration, as example double circuit, untransposed sections, and multiple derivations.

In order to locate the fault, the method uses voltage and current phasors gathered from terminals with measures, however the method does not need these measures from all terminals.

The proposed method is composed of three blocks to locate the fault, which are: Algorithm's Main Control, Grid Scanning Process, and Objective Function's Minimization Process.

A large number of simulations were conducted and the results show the accuracy and efficiency of the method, even in cases of high impedance faults.

Introduction

The demand for power quality is increasingly becoming a rule in almost all industrial processes, where automation is highly present. These processes demand for an adequate voltage level and power frequency. Hence, locating faults in transmission lines with accuracy is an important need, since the repair time, in the case of permanent faults, affects considerably the reliability of the system as well as causes economic damages by the industrial processes stopping.

In the literature there are many fault location methods, where it may be cited those that use data from one terminal [1–5], from two terminals [6–11], and those that use data from more than one terminal in transmission lines with derivations [12–17].

In the followings paragraphs will be briefly discussed some fault location methods.

The fault location method proposed in [2] is applied to parallel transmission lines. It is based on transmission line's distributed parameters model and require voltage and current measures from only one terminal. The method determine the fault point by means of the sequence networks (positive, negative and zero sequences), where are calculated the sequence voltages at the fault point in terms of the voltage and current measures and of the unknowns point and resistance of the fault. A concern about this method is that an increase in the fault location errors may occur when untransposed transmission lines and unknown tapped loads is present.

In [6] is proposed an adaptive fault location method that depends on synchronized measures gathered by Phasor Measurements Units (PMUs), being independent of measures that shall be provided by electric utilities. This method is applied only to single circuit transmission lines transmission without tapped loads.

The method proposed in [12] is based on traveling waves. Using the waves' arrival time in the terminals it is built a matrix whose coefficients are the ratio between the fault distance and the length of the branch formed by the pair of terminals considered. With this matrix the author determines the local of the fault and after the fault distance. The main concern about this method is that measurements from all terminals may not be available and as in [6] the method is applied only to single circuit transmission lines.

In [13] is proposed a two-stage fault location optimization model, along with defining a matching degree index. The method could be used in large transmission networks. It is also proposed the corresponding PMU placement strategy. Once the method uses only voltages in the calculations, the results obtained it may be wrong when faults with high impedance occur.

The method proposed by [14] locates faults on transmission lines constituted of single circuit. In the fault location, the method uses the current and voltage phasors measured at local and remote terminals of the transmission line. With these phasors, are calculated the current and voltage phasors at the tap points and so it

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is used some one terminal fault location method to determine the fault point. As in [6,12,13], the method is only applicable to single circuit transmission lines and the impedance of the loads have to be known, once the method is not capable to estimate them.

In [15] is proposed a fault location method to locate faults on single and double circuit transmission lines, with loads connected in taps. The method uses current and voltage phasors to locate the fault point. In order to locate the fault the method needs to use two different algorithms, one for data available in two terminals and another for data available from one terminal.

In order to locate the fault, the method proposed in this paper uses the current and voltage phasors gathered from terminals with measures, i.e., it is not necessary to use measures from all terminals. In this paper was considered that there are measures at two main terminals only. The main characteristic of this new method is the possibility to locate faults on transmission lines with any topology, as tapped loads, double circuits, and untransposed sections. In addition, no further examinations on fault data or the use of more than one fault location algorithm are necessary.

A large number of simulations were conducted aiming to show the efficiency and accuracy of the proposed method in locating the fault. The simulations were performed in ATP program [18].

Description of the proposed fault location method

The proposed method uses the following data to locate the fault: transmission line's parameters and length; transformer's rated data; pre-fault and post-fault current and voltage's phasors, gathered from terminals with measures; and terminal's equivalents, gathered from short-circuit programs.

It is also necessary to perform a correction in the angles of the current and voltage's phasors at the terminals, once the signals corresponding to these quantities may be unsynchronized among the terminals. This is done by taking one terminal as reference. It is also necessary to perform the load's impedance estimation. In 'Algorithm for estimation of loads' impedance and phasors' correction angle' is described the algorithm to accomplish these tasks.

In the proposed method all the quantities and models were developed in phase sequence (*abc* sequence), which allowed to address the fault location's issues in untransposed double-circuit transmission lines more appropriately than in symmetrical components.

The proposed fault location method is composed of three blocks, which are: Algorithm's Main Control, Grid Scanning Process, and Objective Function Minimization Process. These blocks are described in 'Proposed fault location algorithm'.

The grid depicted in Fig. 1 is used for description of the method. The notations for the quantities are summarized as follows:

t, ϕ, c, and n: respectively, number of terminals, phases, circuits, and line's sections;
p^n: sections' distance variables (or distance pointers);
$leng_n$: sections' length;
$[z_l]$ and $[y_l]$: line's series impedance and shunt admittance by length unit matrices.
$(V^i_j)^{mea}_{pre}$, $(V^i_j)^{calc}_{pre}$, $(V^i_j)^{mea}_{pos}$, and $(V^i_j)^{calc}_{pos}$: measured and calculated pre-fault and post-fault voltages at terminal i and phase j;
$(I^{ij}_k)^{mea}_{pre}$, $(I^{ij}_k)^{calc}_{pre}$, $(I^{ij}_k)^{mea}_{pos}$, and $(I^{ij}_k)^{calc}_{pos}$: measured and calculated pre-fault and post-fault currents at terminal i, circuit j, and phase k;
$[V_{bus}]^{pre}$, $[V_{bus}]^{pos}$, $[I_{bus}]^{pre}$, and $[I_{bus}]^{pos}$: vectors of pre-fault and post-fault voltages and currents at the grid's nodes;
$[Y_{bus}]$ and $[Z_{bus}]$: grid's admittance and impedance matrices;
$[Y^f]$: fault admittance matrix;
$[I^f_{abc}]$: vector of three phases' fault currents;
R_f: Fault resistance;
$\left[Z^{(1)}_{L-p^1}\right]$, $\left[Y^{(1)}_L\right]$, and $\left[Y^{(1)}_{p^1}\right]$: respectively, quadrupole's series impedance matrix between terminal L and point p^1, shunt admittance matrices of terminal L side and p^1 side of the section 1's first part;
$\left[A^{(1)}_{L-p^1}\right]$, $\left[B^{(1)}_{L-p^1}\right]$, and $\left[D^{(1)}_{L-p^1}\right]$: quadrupole's constants of the first part of the line's section 1;
$[Z^{p^1p^1}]$: grid's impedance matrix viewed from the point p^1;
$\left[V^{p^1}_{abc}\right]^{pre}$: vector of three phases' pre-fault voltages at the point p^1;
$\left[I^{L1}_{abc}\right]$, $\left[I^{L2}_{abc}\right]$, $[I^{R1}_{abc}]$, and $[I^{R2}_{abc}]$: vectors of three phases' post-fault currents injected into circuits 1 and 2 of the local (L) and remote (R) terminals;

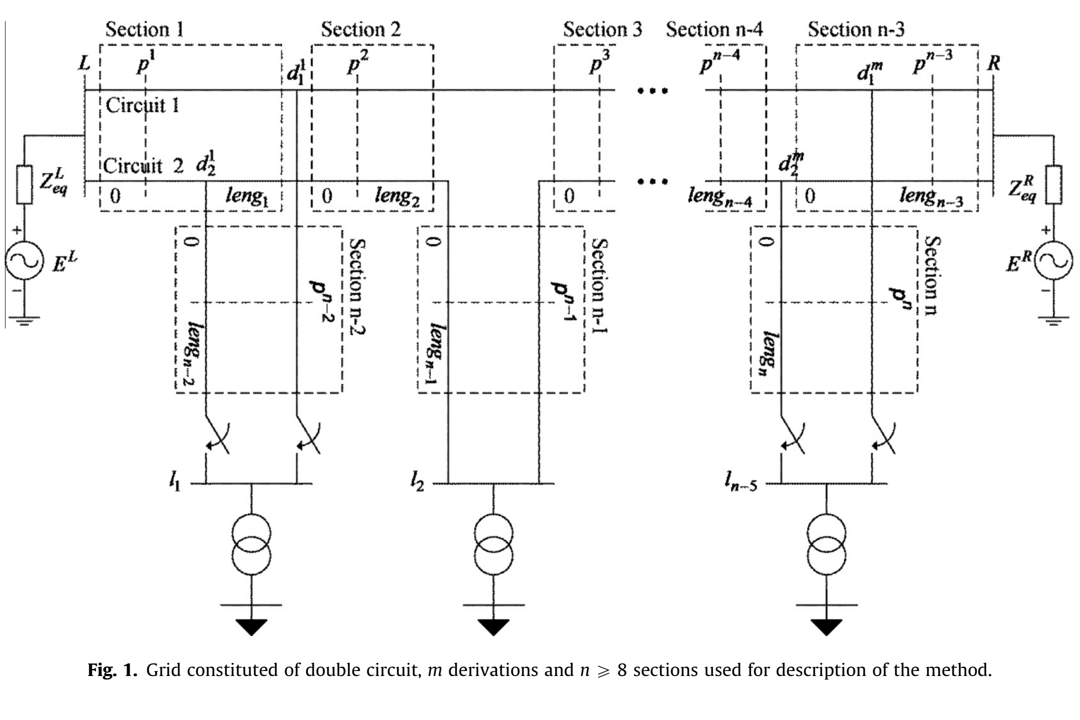

Fig. 1. Grid constituted of double circuit, m derivations and $n \geqslant 8$ sections used for description of the method.