Calculation of Fault Location in Transmission Lines Using Numerical Method

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Abstract: Transmission and distribution lines experience faults that are caused by lightning, snow loading, storms, faulty equipment, insulation breakdown and short circuits caused by birds and other external objects. In most cases, electrical faults manifest in mechanical damage, which may result in huge distortion not only to the electrical system but also to the normal life of human beings. Therefore it must be repaired before returning the line to service. The restoration of system can be done efficiently if the location of the fault is either known or can be estimated with reasonable accuracy. The accurate estimation of fault location eases the maintenance of transmission and distribution system. Fault locating method provides estimation for both sustained and transient faults. This paper focuses on the impedance based fault locating method using computer language which helps to identify these locations for early repairs to prevent recurrence and consequent major damages.

I. INTRODUCTION

Transmission lines are the elements of the electric power system that connect the load to the generation station joining the production facilities of energy over large geographic areas. Overhead transmission lines and underground transmission lines are the significant part of the transmission and distribution system. In an electric power system, a fault in mixed Line/ cable can be defined as any defect, inconsistency, weakness or non-homogeneity that affects the performance of mixed line/ cable. Fault occurrence is more on overhead transmission lines than on the cables. The main factors causing faults are given in below figure[1].

![Figure 1: Causes of faults on mixed line/transmission corridor](image)

Fault Determination in electric power lines is important for a reliable operation of power systems. Some advantages could be: quicker repair, improved system availability, reduced operating costs and shorter time for searching the fault during severe weather conditions. So far there have been many researches done on fault location. Impedance method, Using Time Domain Reflectometer, Travelling Wave Method are the three important fault location methods available for the future work.

So in this paper, an impedance-based parameter dependent algorithm programmed in C-language is presented. The results will be demonstrated for single-phase and three-phase fault current for different locations along a mixed line/cable transmission corridor.

II. IMPEDANCE BASED FAULT LOCATION ALGORITHM

The method consists of following principles and calculations: Telegraphers’ equation, Clarke’s transformation, Wave equation.

Based on the Telegraphers’ equations, voltages and currents at any place along a line can be evaluated by
\[
\frac{\partial \nu}{\partial x} + \frac{\partial \nu}{\partial t} = - R_i
\]
\[
\frac{\partial i}{\partial x} + \frac{\partial v}{\partial t} = -G_i
\]

Where \( R, L, C \) and \( G \) are resistance, inductance, capacitance and conductance per unit length of the line.

The solution of these equation is
\[
\begin{bmatrix}
V_s \\
I_s
\end{bmatrix} = \begin{bmatrix}
\cos(\gamma x)/Z_c & -Z_c \cos(\gamma x) \\
\sin(\gamma x)/Z_c & \cos(\gamma x)/Z_c
\end{bmatrix}\begin{bmatrix}
V_0 \\
I_0
\end{bmatrix}
\]

In which, \( V_s, I_s \) are the voltage and current at distance \( x \) from the sending end of the line and \( V_i, I_k \) are the voltages and currents at the sending end.

\[
Z_c = \sqrt{(R + jwL)/(G + jwC)} And \\
\gamma = \sqrt{(R + jwL)(G + jwC)}
\]

Above matrix equation can also be expressed in terms of the receiving end voltages and currents \( V_s, I_s \), as follows:
\[
\begin{bmatrix}
V_s \\
I_s
\end{bmatrix} = \begin{bmatrix}
\cos(\gamma x - \gamma x)/Z_c & -Z_c \cos(\gamma x - \gamma x) \\
\sin(\gamma x - \gamma x)/Z_c & \cos(\gamma x - \gamma x)/Z_c
\end{bmatrix}\begin{bmatrix}
V_0 \\
I_0
\end{bmatrix}
\]

Where \( I \) is the length of the line. When a fault occurs \( d \) km away from the sending end, by making use of matrix equations the distance to the fault can be determined by:
\[
d = \frac{1}{\gamma} \tanh^{-1} \left( \frac{A}{B} \right)
\]

Where \( A = V_i R \cosh(\gamma l) - Z_c \sinh(\gamma l) - V_s \)

\( B = I_k R \cosh(\gamma l) + V_s \sinh(\gamma l) - Z_c \cosh(\gamma l) \)

Clarke’s transformation is used to convert the original phase variables into a set of \( 0, \alpha \) and \( \beta \) variables, as follows:

Here we are considering \( V_A, VB, \) and \( VC \) instead of \( Ua, Ub, \) and \( Uc \).

\[
\begin{bmatrix}
V_a \\
V_b \\
V_c
\end{bmatrix} = T \begin{bmatrix}
V_o \\
I_o \\
I_b
\end{bmatrix} = T \begin{bmatrix}
I_a \\
I_b \\
I_c
\end{bmatrix}
\]

Where \( T = \begin{bmatrix} 1 & 1 & 1 \\ 2 & -1 & -1 \\ 0 & \sqrt{3} & -\sqrt{3} \end{bmatrix} \)

Where 0 stands for the ground mode, and \( \alpha \) and \( \beta \) are the two areal modes. By applying the Clarke transformation, the single-phase solution can be extended to three-phase solutions so that the characteristic impedance and the propagation constants can be expressed as:

\[
Z_{c0} = \sqrt{(Z_o + 2Z_m)/(Y_o - 2Y_m)} = \sqrt{Z_0/Y_0}
\]

\[
Z_{ca} = Z_{c\beta} = \sqrt{(Z_o - Z_m)/(Y_o + Y_m)} = \sqrt{Z_0/Y_1}
\]

\[
\gamma_0 = \sqrt{Z_0 Y_0} \quad \gamma_1 = \sqrt{Z_1 Y_1}
\]

For the three modal components, the fault location can be expressed as:
\[
d_s = \frac{1}{\gamma_1} \tanh^{-1} \left( \frac{A_i}{B_i} \right)
\]

Where \( A_i = V_{si} \cosh(\gamma_i l) - Z_c i_s \sinh(\gamma_i l) - V_{Ri} \)

\( B_i = I_{si} Z_{si} + V_{si} \sinh(\gamma_i l) - Z_c i_s \cosh(\gamma_i l) \)

And \( i=0, \alpha \) or \( \beta \) which stand for the modal components of the signals.[11]

**Wave equation:** We can put the voltage expression into the form of the Wave Equation by differentiating the first Telegrapher equation with respect to \( x \).

\[
-\frac{dV_x}{dx} = (R^* + jwC \gamma车位) \gamma (x) \text{ and } -\frac{d^2V(x)}{dx^2} = (R^* + jwC \gamma车位) \frac{d\gamma(x)}{dx}
\]

**III. ALGORITHM FOR STRASSEN’S METHOD:**

\[
P_1 = (A_{11} + A_{12} \cdot B_{11} + B_{12})
\]

\[
P_2 = (A_{11} + A_{12} \cdot B_{11}) \cdot B_{12}
\]

\[
P_3 = (A_{11} + A_{12} \cdot B_{12})
\]

\[
P_4 = (A_{11} \cdot A_{21} \cdot B_{11} + B_{12})
\]

\[
P_5 = (A_{11} \cdot A_{12} \cdot B_{21} + B_{22})
\]

\[
C_{11} = P_1 + P_2 + P_3 + P_7
\]

\[
C_{12} = P_9 + P_5
\]

\[
C_{13} = P_2 + P_4
\]

\[
C_{21} = P_1 + P_3 - P_2 + P_6
\]

\[
C_{11} = P_1 + P_2 + P_3 + P_7
\]

\[
= A_{11} \cdot B_{11} + A_{12} \cdot B_{21}
\]

This algorithm helps in multiplication of matrices of higher order. Normal matrix multiplication has more complexity towards higher order matrix multiplication. But this method is well suitable for those types of higher order. It can solve the matrix of order 32 to 132. It is very faster and efficient method towards matrix multiplication. It has been proved that the execution time taken by this method is very less compared with the other matrix multiplication method. [7]

**IV. RESULTS ANALYSIS:**

The given algorithm is tested for the different types of cables: PVC Cables, XLPE Cables, and Elastomeric Cables.
Figure 2: PVC insulated cable 1.1kV (Al)

From the above graph we conclude that as receiving end voltages increases, the fault distance from sending end increases. The graph can be used to know the fault distance in the given range of receiving end voltage. Similarly the below graphs shows the variation for different types of cables.

Figure 3: PVC insulated cable 1.1kV (Cu)

Figure 4: XLPE insulated cable 1.1kV (Cu)

Figure 5: PVC insulated cable 1.1kV (Al)

This graph predicts the variation of fault distance as a variation of receiving end current.

Here as current increases the fault distance from sending end voltage decreases. Here it has been verified for PVC cable with the standard values. [8]

V. CONCLUSION:

The proposed work presents an algorithm that can be used for calculation of fault location using in C language. The algorithm is based on the Telegrapher’s equation and Wave equation. Clarke’s transformation for transformation of single phase calculations to three phase calculations. The program is designed for symmetric type of faults that may occur in the combined line-cable system and can be efficiently used when the fault occurs either on the cable or the line. The codes are verified for four types of standard cables and can be extended to different types of cables using the standard values from the cable catalogue.

REFERENCES:

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