Comparative Study of Methods of Identification of Fault Location in Transmission Line

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Abstract

The rapid growth of the electric power system has in recent decades resulted in an increase of the number of transmission lines. The challenge of a fast growing electrical grid has also resulted in huge increases of overhead lines and their total length. These lines are experiencing faults due to various reasons that cause major disruptions and operating costs of the transmission system operator .Thus, it is important that the location of faults is either known or can be estimated with reasonably high accuracy. This allows the grid owner to save money and time for inspection and repair, as well as to provide a better service due to the possibility of faster restoration of power supply and avoiding blackouts.

Fault detection and classification on transmission lines are important tasks in order to protect the electrical power system. In recent years, the power system has become more complicated under competitive and deregulated environments and a fast fault location technique is needed to maintain security and supply in the grid.

This report provides the comparative study of methods of identification of fault location in transmission line. One end method requires the data like voltage and current from one end of the transmission line for the apparent impedance, which is key term to estimate the location of fault. Apparent impedance is consider with the neglecting the fault resistance. One end method gets affected by load flow and fault resistance. The drawbacks of one end method minimized in Takagi method by considering pre-fault and fault data. And the effect of fault resistance is reduced by superposition. If zero sequence component is used so, there would be no need of pre fault data. In Two end negative sequence method , the effect of pre –fault , load flow , fault resistance, zero sequence mutual impedance and zero sequence in-feed from transmission line taps overcomes.

Keywords - *Faults in transmission line, type of fault, methods of determining the location of fault, identifying the location of fault, comparison, and conclusion.*

I. INTRODUCTION

The rapid growth of the electric power system has in recent decades resulted in an increase of the number of transmission lines and may cause total power outage. The challenge of a fast growing electrical grid has also resulted in huge increases of overhead lines and their total length. These lines are experiencing faults due to various reasons that cause major disruptions and operating costs of the transmission system operator. Thus, it's important that the location of faults is either known or can be estimated with reasonably high accuracy. This allows the grid owner to save money and time for inspection and repair, as well as to provide a better service due to the possibility of faster restoration of power supply and avoiding blackouts. This report compares and evaluates different methods for classification of fault type and calculation of conventional one-side and two-side based fault location algorithms for distance to fault estimation. In this chapter, different types of fault location algorithms are presented. The most common fault location algorithm principles are based on impedance-based methods. One-ended impedance based fault location algorithm estimate distance to fault with the use of voltages and current at a particular end of the line. The technique is very simple and does not require any communication with the remote end. The algorithms presented in this chapter are designed for location of fault on single lines, double lines and series compensated lines. The one-ended fault-location algorithms are very simple and economical, compared to two-end methods

II. FAULTS ON TRANSMISSION LINES

Transmission system line faults are the most common faults, triggered by falling trees, lighting strikes or insulator string flashover and 85-87% of power system faults are occurring in the transmission lines. Most of the transmission system faults occur on overhead lines, due to their inherent characteristics of being exposed to atmospheric conditions. Faults on transmission overhead lines are in majority temporary single phase to ground, arcing faults [4] .The impedance of source connections are often very low, resulting in large currents flowing during faults.

Common fault on a transmission line

Line-to-line fault– short circuit between lines caused by
physical contact between two lines 60-75 % of all fault
in the system .
Line-to-line faults (For example, broken conductor or
strong wind).
Line-to-ground fault – short circuit between one phase
and ground caused by physical contact, 15-25 % are
line-to-ground fault (Ex. lightning and external factors).
Line-to-line-to ground fault – short circuit of two line
and ground, and 5-15 % are line line-to-line to ground
faults. (Ex. external factors)

III. METHOD FOR DETERMINING THE LOCATION OF FAULT

A. One-Ended fault location algorithm

The majority of one-end fault-location algorithm is based on calculation of fault loop composed to identify fault type, similar to the distance relay. One-ended impedance methods of fault location are a standard feature in most numerical relays. The methods use a simple algorithm, communication channel and remote data are not required. The impact of fault resistance on one-end impedance measurement is a key factor in deriving the majority of one-end fault-location algorithm. Fault locators calculate the fault location from the apparent impedance seen by looking from one end of the line [2]. Fault types usually coincide by the phase to ground voltages and current in each phase, it is also possible to locate phase to phase faults by the zero-sequence impedance (Z_{L0}).
The majority of all one-ended fault location is based on a "fault loop" composite for identified the fault type. The following formulas calculate the apparent impedance from the feeding bus bar (S) for distance relays [1][3] .

Fault calculation is laid down by the fault impedance with compensation for fault resistance drop. For determined fault where fault resistance (R_f = 0) is the apparent impedance equal to the positive sequence impedance (Z_{L1}) of the line segment by distance (m) from the measuring point .
If not taken account to the positive sequence line impedance at resistive fault, the calculation will probable estimate wrong distance to fault.

The other important aspect of this fault locator algorithm is the use of the pre-fault current in order to establish the variation of line current at fault. The first equation will return here as positive-sequence impedance equation. A voltage is the sum of the drop in the line to the fault point.
For a fault between two phases, the impedance can be obtained from the substations voltage and current in the involved phases. The difference between the two-phase voltages is divided by the difference between phases current. For a three-phase short circuit the voltage and current in any pair of phases can be used for distance to fault calculation.

$$m = \frac{V_s}{Z_L \times I_S}$$

1) Reactance Based Algorithm

Novosel simple reactance method, algorithms reported in [6][8][9] is extend simple reactance method by making assumptions to eliminate effect of remote in feed and fault resistance. One-ended impedance methods of fault location are standard feature in most numerical relay. The reactance fault location algorithms depend on accurate values of the positive (Z_{L1}) and zero –sequence impedance (Z_{L0}) to determine locations of faults on the transmission line. The positive –and zero-sequence impedance of the transmission line can be verified when a fault location relay is installed at each end of the transmission line. The positive-sequence impedance has verified that it can be used to check the values of the zero-sequence impedance of the line as used by each relay [6] .The method also uses the value of voltage drop from one side bus-bar of the line, and the value of current depend of type of fault and symmetrical components. Transmission line impedance (Z) is typically dominated by the reactive components (X) and the fault impedance is typically dominated by the resistive components(R). The current flowing through R_f is the sum of the local source I_S and the remote source I_R .
(V_S) Is the phase-to ground voltage for given fault,(I_S) is the compensated phase current for a phases-to-phases faults and equals phase current difference for a phases-to-phases faults.

2) Takagi method

Takagi impedance based algorithm, with uses of pre-fault and fault data [6][8][9] . Use pre-fault and fault data to reducing the effect of load flow and minimizing the effect of fault resistance.
Fault location algorithm by Takagi method calculates the reactance of faulty line using one-terminal voltage and current data of the transmission line. When a fault occurs on a transmission line the data of pre-fault current are stored immediately and the fault phases are selected. The Takagi method introduces superimposed current (I_{SUP}) to eliminate the effect of power flow. This method assume constant current load model and require both

pre-fault and post –fault data. The key to success of the Takagi method is that the angle of (I_S) is the same as the angle of(I_f). In an ideal homogeneous system, these angles will be identical. As the angle increases, the errors in fault location also increase.

Takagi method, one-terminal fault method, simply assumes that the three sequences network distribution factors are equal can lead to undesirable error because the zero-sequence current (I_0) is not known as reliably as the positive-sequence current (I_1) . In reality, the fault current is not uniformly distributed when a ground faults occurs [14]. Here we eliminate the need for pre-fault data and uses the zero sequence current (I_0) term or negative sequence current (I_2) for ground faults.
The zero-sequence Takagi method, which is suitable for single-phase-to-ground faults, has an advantage that does not require pre-fault current measurements.

$$m = \frac{\text{Imag.}(V_S \times 3\ I_0)}{\text{Imag.}(Z_L \times I_S \times 3I_0)}$$

B. Two-Ended fault location algorithm

Two-ended fault location estimation is fundamentally similar to the one-terminal algorithm. But the method can improve the accuracy of fault distance measurements significantly by using data from the two ends of the line to cancel the effect of fault resistance and in feed [3]. Two-end and multi-end fault location algorithms divided in two main categories, unsynchronized and synchronized measurement. The algorithms process signals from both terminals of the line and a large amount of information is utilized. Therefore, performance of the two-end algorithm is generally superior in comparison to the one-end approaches [10]

1) Two end negative sequence method

The developed method in[11] uses negative-sequence voltage obtained from both side of its symmetrical components at the fault point. By using negative-sequence components, the effects of pre-fault power flow and fault resistance are eliminated. Unlike one-end methods, negative sequence requires source impedance to perform fault location estimation. This Section introduces a double-ended fault location algorithm for high-voltage, overhead transmission lines. The algorithm uses synchronized voltage and current measurements from both ends of the line. The double-ended fault location does not have any problems with fault resistance or zero-sequence, mutual coupling due to the following:

Use of time-synchronized voltage and current measurements from both ends of the overhead transmission line. Only the negative-sequence voltage and current is used to calculate the fault location. Transform voltage and current measured during fault conditions to their respective positive-, negative-, and zero-sequence quantities. Negative-sequence quantities are present for single phase-to-ground, phase-to-phase, and phase-to-phase-to-ground faults. Therefore, negative-sequence quantities are very reliable. The following two equations demonstrate how to calculate the negative-sequence voltage and current from the three-phase voltage and current measurements

$V_2 = 0.333\ (V_a + \alpha^2 .V_b + \alpha.V_c)$

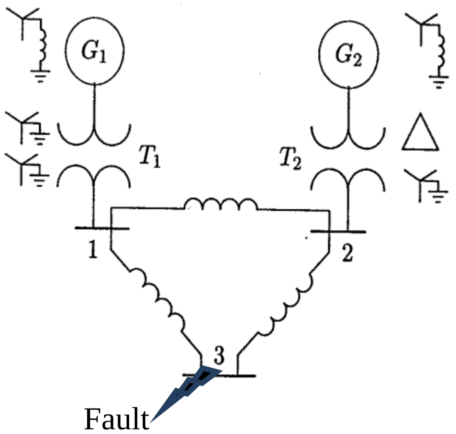
$I_2 = 0.333\ .(I_a + \alpha^2 .I_b + \alpha\ .I_c)$

Where:$\alpha= 1\angle\ 120°$ & $\alpha^2= 1\ \angle -120°$

V_{2S} and I_{2S} are the negative-sequence quantities measured at Substation S. V_{2R} and I_{2S} are the negative-sequence quantities measured at Substation R. The per-unit distance to the fault with respect to Substation S is "m".

$$m=\frac{V2s - V2R+ I2R\ .ZL}{I2\ .ZL}$$

C. Test System



1- Test System Data

Item	Base MVA	Voltage Rating	X^1	X^2	X^0
G_1	100	20 kV	0.15	0.15	0.05
G_2	100	20 kV	0.15	0.15	0.05
T_1	100	20/220kV	0.10	0.10	0.10
T_2	100	20/220kV	0.10	0.10	0.10
L_{12}	100	220 kV	0.125	0.125	0.30
L_{13}	100	220 kV	0.15	0.15	0.35
L_{23}	100	220 kV	0.25	0.25	0.7125

TABLE II (Transmission line data for the existence of line to ground fault at phase "a")

Tx^n Line	Fault type	I_a (pu)	I_b (pu)	I_c (pu)	I_0 (pu)
Tx^n Line(1-3)	L-G	1.6514∠-90°	0∠0°	0∠0°	0.9174∠- 90°
Tx^n Line(2-3)	L-G	1.1009∠-90°	0∠0°	0∠0°	0.9174∠- 90°
		V_a(pu)	V_b (pu)	V_c (pu)	
Tx^n Line(1-3)	L-G	0.633 ∠0°	1.0046∠- 120.45°	1.0647∠ +120.45°	
Tx^n Line(2-3)	L-G	0.2752 ∠0°	1.0647∠-125.56°	1.0647∠ +125.56	

IV. IDENTIFICATION OF FAULT LOCATION

Sr. No.	Fault estimation between Buses	Actual Fault Distance From End S(pu)	Fault estimation between Buses	Actual Fault Distance From End S(pu)
1	1-3	3pu	2-3	5pu
2	**Fault Distance From End S (pu) Cal. By One end method**	2.9452	**Fault Distance From End S (pu) Cal. By One end method**	5.4553
3	**Fault Distance From End S (pu) Cal. By Takagi method**	2.9452	**Fault Distance From End S (pu) Cal. By Takagi method**	5.4553
4	**Fault Distance From End S (pu) Cal. By Two end Negative sequence method**	2.9998	**Fault Distance From End S (pu) Cal. By Two end Negative sequence method**	5.2502
5	**%age Error Method-1**	1.8266%	**%age Error Method-1**	0.09106%
6	**%age Error Method-2**	1.8266%	**%age Error Method-2**	0.09106%
7	**%age Error Method-3**	0.0066%	**%age Error Method-3**	0.05004%

V. CONCLUSIONS

In this work, comparison between methods for locating faults is estimated on a transmission line. Higher fault resistance has negative affect on Takagi method this verification in accuracy depends on the methods reducing effect of load flow and effect of fault resistance with use pre-fault and fault data. After going through all methods, the error in the estimation of the location of fault in One end method and Takagi method is for transmission line connecting bus 1&3 and bus 2 &3 are 1.8266% and 0.09106% respectively. While in the two end negative sequence method the error in estimation of location of fault for the line connecting bus 1&3 and bus 2 &3 are 0.0066% and 0.05004% respectively. So, depending upon the result found in above said methods the Two-end negative sequence method provide better fault location estimation than One end method and Takagi method for a transmission line.
Two-end negative sequence methods are capable to provide very accurate results. Two-end Negative Sequence method better fault location estimation in the verification process than One end method and Takagi method for a transmission line model. Two-end Negative Sequence methods provide fault location estimation with acceptable error.

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