Analysis Of Fault Location For Transmission Lines

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Abstract- This paper presents Fault location information is critical for operating and maintaining transmission networks. Some of the challenges in calculating accurate fault location include fault resistance, zero-sequence mutual coupling, load, system non homogeneity, and transmission lines composed of multiple sections with considerably different characteristics. The Overhead line combined with underground cable is an intricate part of power system and is depend on for reliable transmission and distribution services. Locating transmission line faults quickly and accurately is very important for economy, safety and reliability point of view. Both fault-detection and fault-location indices are derived by using two-terminal synchronized measurements incorporated with distributed line model. PMU units provides real time measurement of positive sequence voltages and currents at power system substation. Extensive simulation studies carried out using MATLAB show that the proposed scheme provides a high accuracy in fault location under various system and fault conditions.
Keywords: digital protection, global positioning system (GPS), phasor measurement unit (PMU), transmission-line protection, Fault Location Algorithm.

1. Introduction

1.1 General

An integral part of such algorithms is the fault locator, which determines the distance to the fault from the local line terminal(s). Various methods of fault location have been developed in the past, some of which use data from one line terminal and some of which use data from two or more line terminals. Contemporary methods for fault location on overhead and underground lines can be classified in two main types:

- Methods based on the measurement of post fault line impedance called phasor-based algorithms that use only the fundamental components of the signals.
- Methods based on the measurement of the fault generated travelling waves

Fault location in protective relays has been available for over 20 years. These relays use impedance-based fault location algorithms, typically from one terminal of the transmission line. While these relays have been very useful in locating the majority of faults, the following conditions can affect their fault location accuracy:

• High-resistance faults
• Heavy load conditions
• Zero-sequence mutual coupling

Phasors are basic tools of ac circuit analysis, usually introduced as a means of representing steady state sinusoidal wave forms of fundamental power frequency. Even when a power system is not quite in a steady state, phasors are often useful in describing the behavior of the power system. Typically, distance protection is one common method to protect transmission lines. However, various conditions such as remote in-feed currents, fault-path resistance, and shunt capacitance, etc. degrade the performance. Recently, adaptive protection concepts were proposed to make relays adapt for changing system conditions and the performance of relays is to be improved.

1.2 Specific

Synchronized Phasor Measurements were introduced in mid-1980s. Synchrophasor technology is promising; especially in applications with fast fault-clearing times. Alternative traveling wave fault location technology is available and provides good results, but deployment has been limited to extra-high-voltage applications because of its high cost. Since then, the subject of wide-area measurements in power systems using PMUs and other measuring instruments has been receiving considerable attention from researchers in the field. Phasor measurement units (PMUs) using synchronization signals from the GPS satellite system have evolved into mature tools and are now being manufactured commercially.

In this paper, fault location is added to the PMU-based state estimator as a new ability. In normal condition, linear state estimation can be carried out by PMU data. When an event like a short circuit fault occurs, the fault can be detected using the ability of bad data identification in state estimation. In the new state vector, fault location and voltage of fault point are added as the new state variable. Finally, fault location is estimated as well as other state variables. This method can be used in that case two PMUs are installed at two terminals of transmission line.

A brand-new adaptive phasor measurement unit (PMU) based protection scheme for both transposed and untransposed parallel transmission lines are presented. The development of the scheme is based on the distributed line model and the synchronized phasor measurements at both ends of lines. By means of eigenvalue/eigenvector theory to decouple the mutual coupling effects between parallel lines, the fault detection and location indices are derived. The two proposed indices are used in coordination such that the internal and external fault events can be distinguished completely.

1.3 Motivation

The power system has the complicated network of the electrical devices and components. The traditional measurement system does not measure the phasor value due to synchronizing difficulties. PMUs remove these difficulties by measuring accurate phasor value through GPS system. Due to the evolution of the high-speed microprocessor and digital communication technology, the computer-based measurement, protection, and control system have become common features of electric power substations. Therefore, it is feasible to develop new communication-aided digital techniques for high-speed transmission-line protection. Better relaying and fault-location performance can be achieved using two-terminal synchronized measurements. Some algorithms are based on global positioning system (GPS) synchronized measurements are proposed.

2. Aim and Objectives

2.1 Aim

To develop a new numerical algorithm that can determine the distance to the fault on a transmission line, the unknown fault location will be determined

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from voltage and current phasors, synchronously measured at both line terminals.

2.2 Objectives

- To retrieves all triggered event reports from relays and digital fault recorders (DFRs) automatically. With these reports, the system identifies the faulted transmission line(s) within the transmission network.
- To determine the fault type and calculates the fault location and fault resistance using multi-terminal fault location methods for different types of power lines, including overhead lines, underground cables, and composite lines that include both overhead line and underground cable sections.
- To uses fault location methods that are accurate under fault resistance, parallel-line mutual coupling, system nonhomogeneity, and load.
- To introduce a real-time fault location system that uses line protection relays and displays fault location information at the control center within less time after the fault occurrence when using Ethernet-based communication.

3. LITERATURE REVIEW

3.1 Introduction

A proper methodology is required to find the fault locations of the synchrophasor. This chapter reviews the research work and studies that have been done in the area of fault location technique Following are the list of researchers who have worked in area of fault location algorithm.

3.2 Classification of Literature Review:

C. S. Yu [2] July 2010, had done the proposed technique based on PMU is evaluated by considerable simulation cases simulated by MATLAB/ Power System Block set. This paper presents a method to correct the unsynchronized measurements for two-terminal fault-location problems. First, a synchronization index is defined to check whether the measurements are synchronized. A modified secant method-based algorithm is then developed to obtain a synchronization angle and correct the unsynchronized measurements. When the unsynchronized measurements are corrected, the fault location can be simultaneously obtained from the intermediate result of the proposed computation.

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A. L. Dalcastagnê, S. N. Filho, H. H. Zürn, and R. Seara [4] Oct 2008, They have implemented the algorithm utilizes unsynchronized measurement of voltage and currents from two ends of a line and is formulated in terms of the fundamental frequency phasors of symmetrical components of the measured signals This paper presents a two-terminal fault-location method which works with unsynchronized phasors. The algorithm is iterative and takes a distributed line model into account. At each iteration, the voltage magnitudes computed from the voltage and two straight lines approximate current phasors measured at the sending and receiving ends, and the intersection point of these two lines obtains the fault-location estimate.reaches a threshold stipulated by the user. Since the search process is based on voltage magnitudes, the proposed approach does not require synchronism between the measurements obtained at each transmission line terminal.

C. W. Liu, K. P. Lien, C. S. Chen, and J. A. Jiang [3] July 2008,had done the universal fault location technique for N-terminal (N>-3) Transmission line based on synchronized phasors measurement unit. The proposed algorithm is different from traditional multiterminal fault location techniques. The proposed approach provides an analytical solution and its computational burden is very low since it does not require iterative operations. An extensive series of simulations were conducted to verify the accuracy of the proposed algorithm

X. Yang, M. S. Choi, S. J. Lee, C. W. Ten, and S. I. Lim [5] Nov. 2008, The authors have proposed an extensive fault location model for underground power cable in distribution system using voltage and current measurements at the sending-end. First, an equivalent circuit that models a faulted underground cable system is analyzed using distributed parameter approach. Then, the analysis of sequence networks in three-phase network is obtained by applying the boundary conditions. This analysis is used to calculate a fault distance in single section using voltage and current equations.

C. S. Chen, C.W. Liu, and J. A. Jiang [6] Apr.2006,The authors have presented the application of a combined adaptive Fourier filtering technique and fault detector to fast distance protection of transmission lines. The filtering technique is extended from the Fourier filters and can be applied under arbitrary data window length. The proposed filtering technique possesses the advantage of recursive computing, and a decaying dc offset component is

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removed from fault signals by using an adaptive compensation method.

C. J. Lee, J. B. Park, J. R. Shin, and Z. M. Radojevie [7] Aug.2006,had done in this letter a new numerical algorithm for fault location calculation and arcing faults recognition.

M. Gilany, E. S. T. Eldin, M. M. A. Aziz, and D. K. Ibrahim [8] June 2005, They had focused on the accurate fault location scheme for transmission systems consisting of an overhead line in combination with an underground power cable. The algorithm requires phasors measurements data from one end of the transmission line and the synchronised measurements at the most far end of the power cable.

J.A Jiang, C.S.Chen, and C.W.Liu [9] Jan. 2003,proposes a new adaptive approach for accurately locating faults on three terminal lines are proposed using the data measured from two terminals of three terminal lines. The proposed scheme also combines online parameter estimation to ensure protection scheme performance and achieve adaptive protection.

C.S.Chen, C.W.Liu, and J.A.Jiang [10] Apr.2002, had proposed a brand-new adaptive phasor measurement unit (PMU) based protection scheme for both transposed and untransposed parallel transmission lines. The development of the scheme is based on the distributed line model and the synchronized phasor measurements at both ends of lines. By means of eigenvalue/eigenvector theory to decouple the mutual coupling effects between parallel lines, the fault detection and location indices are derived. The two proposed indices are used in coordination such that the internal and external fault events can be distinguished completely.

FAULT LOCATION TECHNIQUE

Review of Two-Terminal Fault Location Technique

Fig. 1 shows a single-circuit transposed transmission line. In Fig.1, total line length between buses and is assumed to be L, and the synchronized voltage and current phasors measured on buses S and R are V_S ,I_S ,V_R , and I_R respectively.

Using symmetrical components transformation to decouple three-phase quantities [12] and to consider only the variation of a distance variable (km), the relation between the voltages and currents at a distance away from bus can be expressed by the following sequence equations [12]

$$\frac{dV_{012}}{dx} = Z_{012} I_{012} \quad (1)$$

$$\frac{dI_{012}}{dx} = Y_{012} V_{012} \quad (2)$$

Where Z_{012} and Y_{012} are the per-unit length sequence impedance (Ohm/km) and admittance (Mho/km) of the transmission line, respectively. The matrices of Z_{012} and Y_{012} are all diagonal matrices, and the diagonal entries of matrices Z_{012} and Y_{012} are (Z_0 Z_1 Z_2) and (Y_0 Y_1 Y_2) respectively. Furthermore, $I_{012} = [I_0\ I_1\ I_2]^T$ and $V_{012} = [V_0\ V_1\ V_2]^T$. The variables with the subscripts 0, 1, 2 denote the zero-, positive-, and negative-sequence variables respectively.

The solutions of voltages and currents of the three decoupled sequence systems can be written as [13], [14].

$$V_{xi} = A_i \exp(\Gamma i\ x) + B_i \exp(-\Gamma i\ x) \quad (3)$$

$$I_{xi} = 1/ Z_{Ci} [A_i \exp(\Gamma i\ x) - B_i \exp(-\Gamma i\ x)] \quad (4)$$

Where, the subscript i denotes 0, 1, and 2 sequence variables, $Z_{Ci} = \sqrt{Zi/Yi}$ denotes the characteristic impedance, and $\Gamma i = \sqrt{ZiYi}$ is the propagation constant. The constants A_i and B_i can be obtained by the boundary conditions of voltages and currents measured at bus R and S bus, respectively. Therefore, voltage (3) can be further rewritten as

$$V_{xi,R} = (V_{i,R} + Z_{ci}\ I_{i,R})\ /2 * e^{\Gamma_{i,x}} + (V_{i,R} - Z_{ci}\ I_{i,R})\ /2 * e^{-\Gamma_{i,x}} \quad (5)$$

$$V_{xi,S} = 1/2 * e^{-\Gamma_{i,L}}\ (V_{i,,S} + Z_{ci}\ I_{i,S}) * e^{\Gamma_{i,x}} + 1/2 * e^{\Gamma_{i,L}} (V_{i,S} - Z_{Ci}\ I_{i,S}) * e^{-\Gamma_{i,x}} \quad (6)$$

Equations (5) and (6) represent the voltages at point *x*, which are expressed in terms of the two data sets ($V_{i,R}$,$I_{i,R}$) and ($V_{i,S}$,$I_{i,S}$) measured at the receiving end R and sending end S of the line, respectively. Meanwhile, the positive-sequence quantities can respond to all fault types; thus, they are chosen to determine the fault locations in the current study to avoid fault type identification. For ease of illustration, subscript i = 1, which denotes the positive-sequence quantities, is dropped.

A fault is assumed to occur at point F with a distance x = DL km away from the receiving end R on a transmission line, where D is termed as the per-unit fault location index. Using the relationship $V_{F,R}$ and $V_{F,S}$ equating (5) to (6), the index can be solved as follows [13]–[3]

$$\mathbf{D} = \frac{\ln\left(\frac{\mathbf{N}}{\mathbf{M}}\right)}{\mathbf{2rL}} \quad (7)$$

$$M = 1/2(V_S + Z_C\, I_S) * e^{-rL} - 1/2(V_R + Z_C\, I_R)$$
(8)

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$N = 1/2(V_R - Z_C I_R) - 1/2(V_S - Z_C I_S) * e^{\gamma L}$
(9)

When a fault occurs between buses S and R, the obtained value of D is between 0 and 1. When no fault or an external fault occurs, the value of D is indefinite. It is worth mentioning that there is no assumption made in the procedure of derivation for the fault location index D. Thus, the index D is unaffected by the variations in source impedance, loading change, fault impedance, fault inception angle, and fault type.

Fault Location Technique for Two-Terminal Multi-Section Compound Transmission Lines:

3.2.1 Two-Section Compound Lines: First, we consider a two section compound transmission line in which a section of overhead line is connected with the other section of underground power cable, PMUs or digital relays are assumed to be installed at buses S and R. Therefore, we can acquire two-terminal synchronized voltage and current phasors using GPS technique or fault-on relay data synchronization algorithms. Lengths of the overhead line and underground power cable are denoted as L_S and L_R respectively. Total line length between buses S and R is L. Tap point P of the transmission line is selected as the junction point between the L_S and L_R which can be defined as the virtual receiving end of the overhead line or the virtual sending end of the cable.

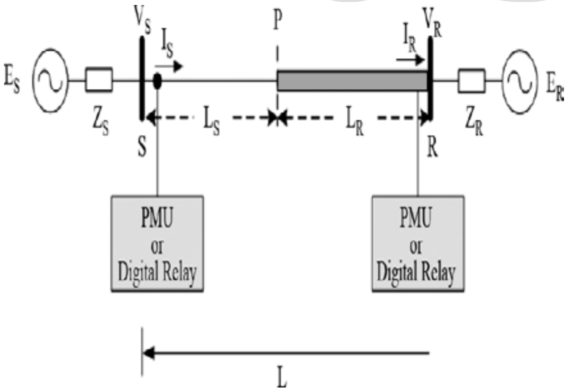

Fig 1. One line diagram of a two-section compound transmission line; the thin line denotes the overhead line and the bold line denotes the power cable.

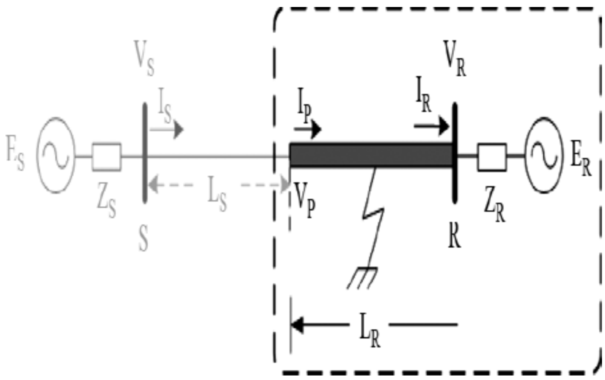

Fig 2. A fault on the underground power cable section

A nonuniform line impedance is obtained in this case due to the nature of compound lines. For example, the surge impedance of the cable is approximately 10% that of an overhead line [26]. The proposed fault location technique in this case is expressed using the following steps:

Step 1: Assume a fault on the right side of tap point P. As shown in Fig. 2, we assume that the fault is situated on the underground power cable L_R. Since the healthy section is the overhead line L_S, the voltage and current at any point in the overhead line can be derived by applying boundary conditions of bus S into (3) and (4). Consequently, we can obtain the voltage and current phasors at tap point P in terms of the sending end data sets (V_S, I_S) as

$V_{P,S} = 1/2 * e^{-\gamma_S L_S} (V_S + Z_{C,S} I_S) + 1/2 * e^{\gamma_S L_S} (V_S - Z_{C,S} I_S)$
(10)

$I_{P,S} = 1/ Z_{C,S} [1/2 * e^{-\gamma_S L_S} (V_S + Z_{C,S} I_S) - 1/2 * e^{\gamma_S L_S} (V_S - Z_{C,S} I_S)]$ (11)

Where $Z_{C,S} = \sqrt{Zs/Ys}$ and $\Gamma s = \sqrt{ZsYs}$ denote the characteristic impedance and the propagation constants of the overhead line section, respectively. Z_S and Y_S are the positive sequence impedance and admittance of the L_S, respectively. Now we derive the fault location index, D_1 using voltage and current phasors at tap point P and bus R and the line length L_R. Substituting, $V_{P,S}$, $I_{P,S}$ expressed in (13), (14) into V_S, I_S in (6) and equating (5) to the newly derived (6) with the characteristic impedance $Z_{C,R}$ and the propagation constant γ_R for the power cable section respectively, the fault location index D_1 can be obtained as follows:

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$$\mathbf{D_1} = \frac{\ln\left(\frac{N_R}{M_R}\right)}{2\Gamma_R L_R} \quad (12)$$

Where $\Gamma_R = \sqrt{Z_R Y_R}$, in which Z_R and Y_R are respectively the positive sequence impedance and admittance of the underground power cable L_R .M_R and N_R are given by

$$\mathbf{M}_R = 1/2(\mathbf{V}_{P,S} + Z_{C,R}\,\mathbf{I}_{P,S}) * e^{-\Gamma_R L_R} - 1/2(V_R + Z_{C,R}\,I_R) \quad (13)$$

$$\mathbf{N}_R = 1/2(V_R - Z_{C,R}\,I_R) - 1/2(\mathbf{V}_{P,S} - Z_{C,R}\,\mathbf{I}_{P,S}) * e^{\Gamma_R L_R} \quad (14)$$

Where,

$Z_{C,R} = \sqrt{Z_R / Y_R}$.

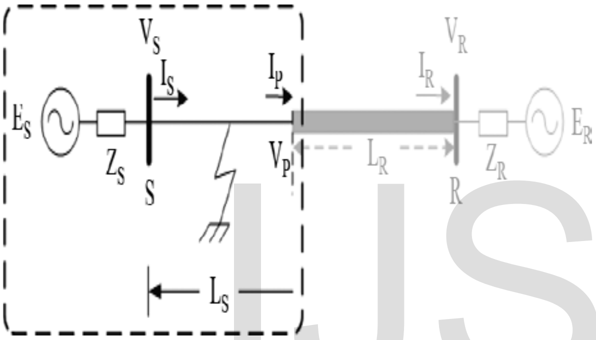

Fig.3 A Fault on Overhead Line Section

Step 2: Assume a fault on the left side of tap point P. We assume that the fault occurs on the overhead line L_S, as shown in Fig. 3. Given the healthy section of the cable L_R, we can similarly derive the voltage and current phasors P at in terms of the receiving end data (V_R, I_R)

$$V_{P,R} = 1/2 * e^{\Gamma_R L_R} (V_R + Z_{C,R}\,I_R) + 1/2 * e^{-\Gamma_R L_R} (V_R - Z_{C,R}\,I_R) \quad (15)$$

$$I_{P,R} = 1/ Z_{C,R}\,[1/2 * e^{\Gamma_R L_R} (V_R + Z_{C,R}\,I_R) - 1/2 * e^{-\Gamma_R L_R} (V_R - Z_{C,R}\,I_R)] \quad (16)$$

Now we derive the fault location index, D_2 using voltage and current phasors at tap point *P* and bus S and the line length L_S . Substituting $V_{P,R}$, $I_{P,R}$ expressed in (15), (16) into V_R , I_R in (5) and equating (6) to the newly derived (5) with the characteristic impedance, $Z_{C,S}$ and the propagation constant, Γ_S for the overhead line section, respectively, the fault location index D_2 can be obtained as follows:

$$\mathbf{D_2} = \frac{\ln\left(\frac{N_S}{M_S}\right)}{2\Gamma_S L_S} \quad (17)$$

Where,

$$\mathbf{M}_S = 1/2(V_S + Z_{C,S}\,I_S) * e^{-\Gamma_S L_S} - 1/2(\mathbf{V}_{P,R} + Z_{C,S}\,\mathbf{I}_{P,R}) \quad (18)$$

$$\mathbf{N}_S = 1/2(\mathbf{V}_{P,R} - Z_{C,S}\,\mathbf{I}_{P,R}) - 1/2(V_S - Z_{C,S}\,I_S) * e^{\Gamma_S L_S} \quad (19)$$

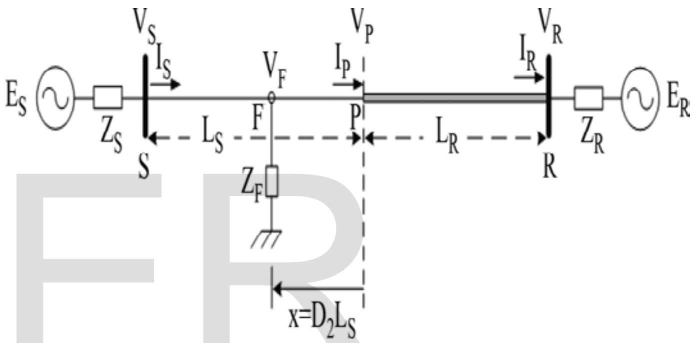

Fig. 4. A fault occurs at a distance $x = D_2\,L_S$ away from tap point P.

3.2.2 Two-Terminal N-Section (N>=2) Compound Lines

In practice, the structure of compound transmission line systems is usually more complicated than the two-section case mentioned above. Now we move to more general multisection compound transmission line cases. Consider an N-section (N>=2) compound line depicted in Fig. 5.

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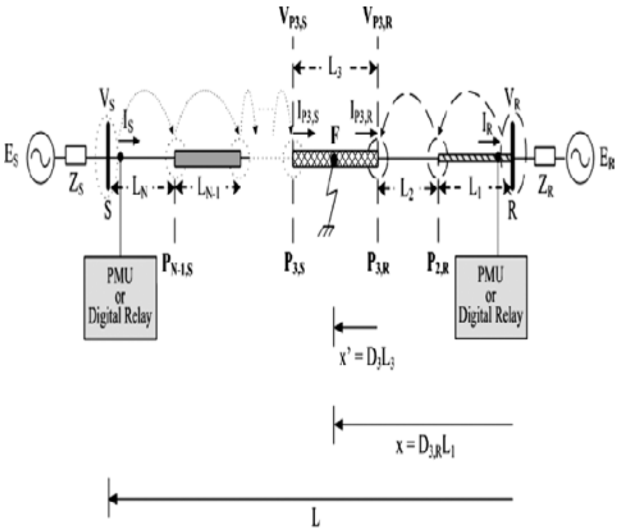

Fig. 5. One line diagram of an N-section compound transmission line.

PMUs or digital relays are installed at sending bus *S* and receiving bus *R*. Therefore, we can obtain the synchronized voltage and current phasors at both terminals of the considered system. The length of every section is denoted as $L_{1.....,}$ L_{N-1}, and L_N. Every line section may be composed by either an overhead line or an underground power cable. Two consecutive line sections may be either overhead lines, both underground cables, or an overhead line with an underground cable. For example, L_1 and L_2 in Fig. 8 are both overhead lines, but their line impedances are very different. The proposed fault location scheme for general two-terminal N-section compound transmission lines can be composed of two portions.

The N Fault Location Indices Derivation:

In order to illustrate the proposed fault location technique in a convenient manner, suppose first that a fault occurs at the point F, which is *x* km away from the receiving end R and on the L_3 section of a transmission line shown in Fig. 5. The line length L_1 is defined as reference length of the derived fault location indices. The fault location scheme for the fault on the L_3 section is divided into three procedures, as described below:

Procedure 1: Derive voltage/current phasors at point $P_{3,R}$

The voltage and current at any point on the L_1 or L_2 can be derived by applying boundary conditions of bus *R* into (3) and (4) in terms of the line parameters of the L_1 or L_2. As a result, the voltage and current phasors at tap point $P_{3,R}$ can be derived using successive algebraic substitution steps from the data sets (V_R, I_R) at receiving end . This is expressed in matrix form as follows:

$$\begin{bmatrix} V_{P3,R} \\ I_{P3,R} \end{bmatrix} = T_{R2}.T_{R1}.\begin{bmatrix} V_R \\ I_R \end{bmatrix} \qquad (20)$$

Where T_{R1} and T_{R2} are defined as the phasor transformation matrices of bus *R* and the subscripts 1 and 2 denote the use of the line parameters of the L_1 and L_2 sections, respectively. The general form of the matrix T_R is given as the following:

$$T_{Rm} = \frac{1}{2}\begin{bmatrix} e^{\Gamma_{Lm}Lm} + e^{-\Gamma_{Lm}Lm} & Z_{C,Lm}.(e^{\Gamma_{Lm}Lm} - e^{-\Gamma_{Lm}Lm}) \\ \dfrac{e^{\Gamma_{Lm}Lm} - e^{-\Gamma_{Lm}Lm}}{Z_{C,Lm}} & e^{\Gamma_{Lm}Lm} + e^{-\Gamma_{Lm}Lm} \end{bmatrix}$$

$$= \begin{bmatrix} \cosh(\Gamma_{Lm}L_m) & Z_{C,Lm}.\sinh(\Gamma_{Lm}L_m) \\ \dfrac{\sinh(\Gamma_{Lm}L_m)}{Z_{C,Lm}} & \cosh(\Gamma_{Lm}L_m) \end{bmatrix} \qquad (21)$$

Where $Z_{C,Lm}$ and Γ_{Lm} are the positive sequence characteristic impedance and propagation constant for the L_m section, respectively.

Procedure 2: Derive voltage/current phasors at point $P_{3,S}$

Since the $L_{N,...}$ L_5 and L_4 are all healthy sections, we can likewise derive the voltage and current phasors ($V_{P3,S}$, $I_{P3,S}$)at tap point $P_{3,S}$ in Fig. 6 via a series of substitutions from the data sets ($V_{S,}$ I_S) at sending end using the following relations:

$$\begin{bmatrix} V_{P3,S} \\ I_{P3,S} \end{bmatrix} = T_{S4}.T_{S5}.T_{S6}..........T_{S(N-1)}.T_{SN}.\begin{bmatrix} V_S \\ I_S \end{bmatrix} \qquad (22)$$

where T_{S4},$T_{S5,....,}$ T_{SN} and are defined as the phasor transformation matrices of bus *S*. The general form of the matrix T_S is shown below:

$$T_{Sm} = \frac{1}{2}\begin{bmatrix} e^{\Gamma_{Lm}Lm} + e^{-\Gamma_{Lm}Lm} & -Z_{C,Lm}.(e^{\Gamma_{Lm}Lm} - e^{-\Gamma_{Lm}Lm}) \\ -\dfrac{e^{\Gamma_{Lm}Lm} + e^{-\Gamma_{Lm}Lm}}{Z_{C,Lm}} & e^{\Gamma_{Lm}Lm} + e^{-\Gamma_{Lm}Lm} \end{bmatrix}$$

Procedure 3: fault location indices computation

The application of the two-terminal fault location technique to solve for fault location $x' = D_3 L_3$ away from the receiving end $P_{3,R}$ using two-terminal data sets ($V_{P3,R}$, $I_{P3,R}$) and ($V_{P3,S}$, $I_{P3,S}$)expressed in (22) and (24) is shown as follows:

$$D_3 = \frac{\ln\left(\frac{N_3}{M_3}\right)}{2\Gamma_{L3} L_3}$$

Where

M_3 = 1/2 ($V_{P3,S}$ + $Z_{C,L3}$ $I_{P3,S}$) $e^{-\Gamma_{L3,L_3}}$ - 1/2($V_{P3,R}$+$Z_{C,L3}$ $I_{P3,R}$)

(25)

N_3 = 1/2 ($V_{P3,R}$ - $Z_{C,L3}$ $I_{P3,R}$) $e^{-\Gamma_{L3,L_3}}$ - 1/2($V_{P3,S}$-$Z_{C,L3}$ $I_{P3,S}$) $e^{\Gamma_{L3,L_3}}$

(26)

Furthermore, we can normalize D_3 to obtain $D_{3,R}$ using the line length L_1 as reference length, such that the fault location x = $D_{3,R}L_1$ away from bus in the form

$$D_{3,R} = \frac{\ln\left(\frac{N_3}{M_3}\right)}{2\Gamma_{L,3} L_1} + \alpha_3 \qquad (27)$$

Where,

$$\alpha 3 = \frac{(L1+L2)}{L1} \qquad (28)$$

Using the principle of mathematical induction, the general form of fault location indices D_K for all line sections can be obtained, where K= 1….N are as follows:

$$D_K = \frac{\ln\left(\frac{N_K}{M_K}\right)}{2\Gamma_{L,K} L_K} \qquad (29)$$

And the general normalized fault location indices $D_{K,R}$ are written as the following:

$$D_{K,R} = \frac{\ln\left(\frac{N_K}{M_K}\right)}{2\Gamma_{L,K} L_1} + \alpha_K \qquad (30)$$

Where, (24)

M_K =

$$\frac{1}{2}(V_{PK,S} + Z_{C,LK} I_{PK,S})e^{-\Gamma_{LK}LK} - \frac{1}{2}(V_{PK,R} + Z_{C,LK} I_{PK,R}) \qquad (31)$$

N_k =

$$\frac{1}{2}(V_{PK,R} + Z_{C,LK} I_{PK,R}) - \frac{1}{2}(V_{PK,S} + Z_{C,LK} I_{PK,S})e^{\Gamma_{LK}LK} \qquad (32)$$

$$\alpha_K = \frac{(\sum_{n=1}^{K-1} L_n)}{L_1} \qquad (33)$$

where the data sets ($V_{PK,R}$, $I_{PK,R}$) and expressed in (33) and (34) can be derived in terms of the data sets (V_R , I_R) and by rewriting (22) and (24) into general forms, as shown in the following:

$$\begin{bmatrix} V_{PK,R} \\ I_{PK,R} \end{bmatrix} = \left(\prod_{m=1}^{K-1} T_{R(K-m)}\right)\begin{bmatrix} V_R \\ I_R \end{bmatrix} \qquad (34)$$

$$\begin{bmatrix} V_{PK,S} \\ I_{PK,S} \end{bmatrix} = \left(\prod_{m=1}^{K-1} T_{Sm}\right)\begin{bmatrix} V_S \\ I_S \end{bmatrix} \qquad (35)$$

3.3 The Proposed Fault Section/ Fault Location Identification:

So far, we have derived *N* fault location indices, D_k and *N* normalized fault location indices, $D_{k,R}$ Now the problem is which fault location index set (D_k,$D_{k,R}$) is the correct set for accurately locating a fault. Theoretically, only one correct index set corresponds to a single fault. We propose an efficient searching algorithm for this purpose. The flowchart of the algorithm had shown in Fig. 8 illustrates the operations of fault section/location identification strategies for two-terminal multisection compound transmission lines. The details of the algorithm are explained in the following three steps:

Step 1) As mentioned above, bus R and the line length L_1 are selected as the receiving end and reference length. Base on the assumption that a midway fault occurs at y km away from bus R in section K, so $y = D_{K,R} L_1$.

Step 2) Generate the N Fault Location Index Set

The data sets ($V_{PK,R}$, $I_{PK,R}$) and ($V_{PK,S}$, $I_{PK,S}$)can be derived by (36) and (37). Equations (31) and (32) are then applied to obtain the fault location index D_K and $D_{k,R}$, where is from 1 to N.

Step 3) Searching for correct fault location index set

Similar to the results of two-section compound lines shown in Table I, we further propose three strategies for the efficient search for the correct fault location index set.

Strategy 1: If any D_K is an indefinite value, then an external fault or no fault occurs.

Strategy 2: From K=1 to N-1 , if the obtained D_K falls within the interval [0,1] , according to the two-terminal fault location theorem [13]–[3] then the D_K is recognized as the correct fault location index and the correct fault distance *y* is $D_{K,R}$ L_1 away from the receiving end *R*.

Strategy 3: Given K=N, since L_N is the last line section of the proposed fault-locating procedures, it obviously indicates the fact that D_N is identified as the correct fault location index and the correct fault distance *y* is $D_{N,R}$ L_1 away from the receiving end *R*.

CONCLUSION

A new fault location technique for double circuit transmission lines is presented here. Extensive simulation studies show that the performance of the proposed algorithm is very excellent and the average error of fault location is well less than 1% under various system operation and fault conditions considered.

The simulation results also demonstrate the feasibility and effectiveness of the proposed fault location technique for multiterminal transmission lines with arbitrary configurations. The proposed fault location technique is an accurate method and its performance is almost unaffected by system operation conditions and fault events.

Applications

- The developed simulated proposed system is applicable for smart grid applications.
- It's a new protection technique for transmission grids using phasor synchronized measuring technique in a wide area system.

Future Scope

This method presents a new protection technique for transmission grids using phasor synchronized measuring technique in a wide area system. The protection scheme has successfully identified the faulted line all over the interconnect system. The relay described in this paper represents a new state-of-art in the field of interconnected grid protection for many reasons. One relay is used instead of many stand alone relays with different complexity coordination. The relay has the feature of unit protection in identifying the faulted zone. One and only one trip decision is issued from the protection center. In the near future and with a very fast communication links the relay can be considered as a main relay on the interconnected grids. An innovative fault location technique for two-terminal multisection compound transmission lines is presented , by only the derived indices of compound lines, the faulted section or fault position can be identified correctly.

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