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Travelling Wave based Fault Location for Teed Transmission Network using S-transform Technique

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Abstract: ***A Travelling predicated fault locator approach is implemented in this paper for the teed transmission network. The work is similar to the fault location for teed circuits for unsynchronized measurements in [12]. Advantage of S-transform is more effective then wavelet transform. The stock well transforms (S-Transform) technique is utilized for the extraction of high-frequency fault transients in order to confine the peregrinate time of the transients along the monitored lines between the fault points and relays. The fault location is resolute by taking time distinction between the advent of the rearward and forward travelling waves. The algorithm gives precise results for the three-terminal lines under different fault conditions. The performance of the algorithm is tested in a MATLAB environment.***

Keywords: Transmission lines; teed circuits; fault location; travelling waves; S-transform

1. Introduction

In power systems, protection of the electrical equipment from faulted sections plays a significant role. Accuracy in finding fault location is an important task. Remedial and precautionary maintenance and continuity of power transfer are greatly influenced by an accurate determination of fault location. An overview[1] the most important types of fault locators are: impedance and traveling wave locators. Because of considerable errors in reactance and impedance methods for finding fault location, other possibilities are explored. Unlike the impedance measurement methods which can locate short-circuit faults in normal AC power lines only, traveling wave technique can be used to measure distance to fault in all kinds of power lines, including AC transmission lines, lines with T branches, the line containing cable sections and overhead line. Numerous strategies have been proposed for fault location using two terminals lines.

An approach for fault location on transmission lines monitored in two terminals was presented in reference [2]. Reference [3] gives the detailed information related to the factors affecting the practical application of the single-ended fault location. Identification of fault location using S-transform [4] for two terminal networks has clear advantages compared to wavelet transform. Usually the one terminal technique for fault location is simple and easy to implement. However, these techniques are always based on certain assumptions. Furthermore, when multi-terminals network topologies are considered, the one-terminal based techniques are hardly to achieve accurate results. The multi-terminals based techniques [5] are considered, accuracy fault locations can be easily calculated via the multi-terminals measurements. Thus, the fault location errors induced from the assumptions in one-terminal based techniques. Reference [6] presents a fault location method in which a multi terminal line is reduced to a two terminal line containing the faulted section. This approach uses synchronized phasors at all ends. A circuit analysis based procedure using synchronized voltage measurement is proposed by Brahma [7].This fault location method is claimed to be insensitive to the CT errors. A fault location method for multi-terminal lines that combines both impedance and travelling based algorithm is proposed by [8]. The use of wavelet transform for analysing the power system fault transients in order to determine the fault location for two terminal transmission lines is described in [9]. Reference [10] describes fault section identification and fault location algorithm for three terminal lines using wavelet transform of the fault initiated transients.

In this paper, a traveling wave predicated fault location technique is proposed for the teed circuits utilizing unsynchronized quantifications. The work is similar to the fault location for teed circuits for unsynchronized measurements in [12]. Advantage of S-transform is effective compared with wavelet transform. S-transform technique is used for the analysis of the voltage signals to obtain the time information of the rearward and forward travelling waves. The proposed algorithm is tested by simulating three-terminal circuits under different fault conditions such as sundry fault inception angles, fault distance, and fault resistance.

Section-II of this paper describes the Fault location algorithms utilizing travelling waves for a two-terminal network. Section -III presents a proposed method for the

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Fault location in teed circuits. Section-IV presents the simulation results and Section-V presents conclusion.

2. Proposed Methodology

The Fault location for two terminal networks is carried out by utilizing travelling wave theory with synchronized quantifications as given in [9]. Traveling wave theory is utilized in capturing the peregrinate time of forward and rearward transients along the monitored lines between the fault point and the relay. Time resolution for the high frequency components of the fault transients, is provided by the S-transform.

2.1. S- Transform

S transform proposed in 1996 by geophysicists R.G. Stock well is an extra time window Fourier transforms frequency reversible analysis method, which is the extension of continuous wavelet transform using Morlet wavelet as basic wavelet [4]. The spectrum contains both amplitude and phase information. To utilize the phase information of continuous wavelet transform (CWT), it is necessary to modify the phase of the mother wavelet. The CWT $W(\tau,d)$ of a function h(t) is given as

$$W(\tau,d) = \int_{-\infty}^{\infty} h(t) w(t-\tau,d) dt \qquad (1)$$

Where, w(t,d) - scaled replica of the fundamental mother wavelet.

The S– transform is obtained by multiplying the CWT with a phase factor, as given below

$$S(\tau,f) = e^{i2\pi ft} W(\tau,d) \qquad (2)$$

where the mother wavelet for this particular case is given as

$$w(t,f) = \frac{|f|}{\sqrt{2\pi}} e^{-\frac{r^2 f^2}{2}} e^{-i2\pi ft} \qquad (3)$$

In equation (2) dilation factor *d* is inverse of frequency *f*. Thus, final form of the continuous S–transform is obtained as

$$S(\tau,f) = \frac{|f|}{\sqrt{2\pi}} \int_{-\infty}^{\infty} h(t)\, e^{-\frac{(t-\tau)^2 f^2}{2}} e^{-i2\pi ft}\, dt \qquad (4)$$

and width of the Gaussian window is

$$\sigma(f) = T = {}^{1}/_{|f|} \qquad (5)$$

In this work, S-transform is used for extraction of high frequency components. Wavelet need multi scaling divisions to get high frequency but in case of s-transform does not required.

2.2. Travelling waves

Fault or switching initiated transients are composed of travelling waves. While these waves are travelling along the lines reflections occur due to the discontinuities such as the fault point, receiving or sending end terminals of a line. These transients perpetuate to bounce back and forth between the fault point and the terminals until a post-fault steady state is reached.

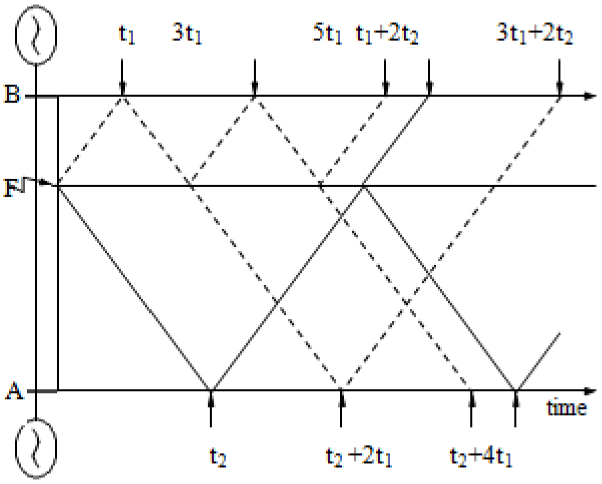

Figure 1: Lattice diagram for two terminal network

The transmutation in terminal bus transients can only be understood by utilizing the famous Lattice Diagram method. The Lattice diagram shows multiple reflections and refractions initiated by the fault. The arrival times of the backward and forward travelling waves are indicated. Assume that the fault is x miles away from bus A. Then the arrival time of the forward travelling wave at bus B, $t_B = l - x/v$, and the arrival time of the backward travelling wave at bus A, $t_A = x/v$. This information is utilized to locate the fault. The fault location formula for two ended system is

$$x = \frac{l - v*(tB - tA)}{2} \qquad (8)$$

Where x is the faulted distance, l is the total line length and v is the travelling wave velocity.

The above fault location procedure is extended to teed (three terminal) circuits. Due to the superimposed reflections of the fault signal from the T-node and the fault point, fault location in teed circuits presents unique challenges. Consider the following three terminal network using synchronized measurements as shown in figure.2.

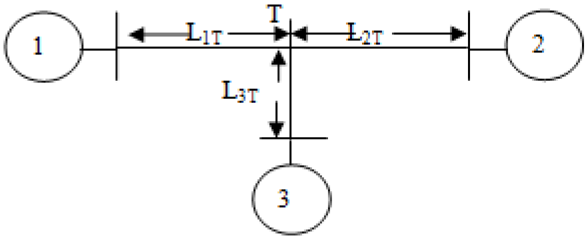

Figure 2: Teed Transmission networks

2.3. Proposed algorithm

The proposed algorithm involves five major steps. They are explained below.

2.3.1. Fault detection

In Fault Location scheme, fault detection is the first step to be done accurately for reliability of supply. Reference [11] has proposed a incipient fault detection method based on current slopes. The method claim accurate fault detection at any critical event condition. In this work, this method is utilized here to detect the fault prior to fault location procedure in three terminal lines.

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2.3.2.Fault type identification (grounded or un-grounded)

The fault type is classified based on extraction of STC^2 frequency components for ground mode signal measured at all terminals. The procedure is followed similarly in [8], such that STC^2 coefficients values are very low during ungrounded faults whereas high for ground involved faults. To evade this condition, a threshold is assigned in order to discriminate the both type of faults.

2.3.3 Fault Section Identification

The faulted section is identified by comparing the maximum magnitudes of the STC^{2}s of the aerial mode voltages for un-grounded faults and ground mode voltages for grounded faults at each terminal as shown in the flow chart. In flow chart A_i is called the maximum of mode3 for ungrounded faults and mode1 for grounded faults. By using these values we can calculate fault section index (FSI) at terminals Mathematically,

$$FSI_i = \frac{Ai}{\max(Ai)} \qquad (12)$$

Where i=1, 2, 3 terminals.

2.3.4 Fault location procedure for teed circuits

Fault location for teed circuits using travelling wave theory is clearly mentioned above. Firstly, measured post voltage signals of one cycle data is used for location. This data is converted to modal transformation using Clark's model is given in eq.16.

$$T = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 2 & -1 & -1 \\ 0 & \sqrt{3} & -\sqrt{3} \end{bmatrix} \qquad (16)$$

The modal transformation gives three modes that are mode l, is regularly consider as the ground mode, and its magnitude is high only throughout faults having a path to ground. Hence, this component cannot be used for location purpose. Next, mode 2, mode3 also known as the aerial mode, however is present for any kind of fault. Accordingly, the fault location quandary is formulated predicated essentially on the aerial mode. The aerial mode voltage STC2 obtained at the sending cessations of the faulted line segment and one of the un-faulted line segments are utilized in this algorithm. The fault location formula is given below

$$x_i = \frac{(L(j)+L(i))-(v*(t(j)-t(i)))}{2} \qquad (17)$$

Where i=1, 2, 3 terminals, x_i is the fault distance in ith section, L_j & L_i is the total line length of the faulted and un-faulted section and t_j & t_i is the arrival times of the backward and forward travelling waves of un-faulted section and faulted line section. v is the travelling wave velocity. The entire algorithm is presented in flow chart in figure 4.

3. Simulation Results

The three terminal networks shown in Fig.6 is considered for simulation utilizing MATLAB/SIMULINK. The scheme is evaluated utilizing 220 kV, 50 Hz transmission system whose line parameters are R0 = 0.01888Ω/km, R1=0.02 Ω/km, L0 = 3.5 mH/km, L1 = 0.94 mH/km, C0=0.0083 µF/km & C1 = 0.012 µF/km. A sampling frequency of 150 kHz is opted to capture the high frequency content of voltage and current signals. Adoption of such high sampling frequency eschews the utilization of anti-aliasing filter thus abbreviating some delay. At this sampling frequency, each cycle of data window contains 3000 samples

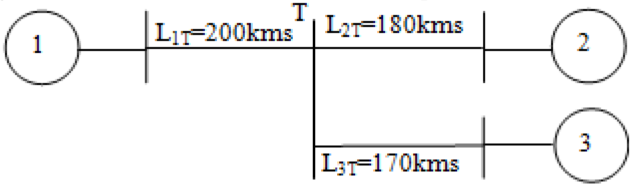

Figure 3: Three terminal networks

The network is simulated for sundry fault situations. Exhaustive simulations are carried out for variants of faults occurring in different sections at sundry locations within the circuit. For each type of fault at a particular location, the fault inception angle is widely varied from 00 to 1800 is evaluate the performance of the proposed scheme. Influence of fault resistance is withal evaluated by considering a fault resistance variation of 0 to50 ohms.

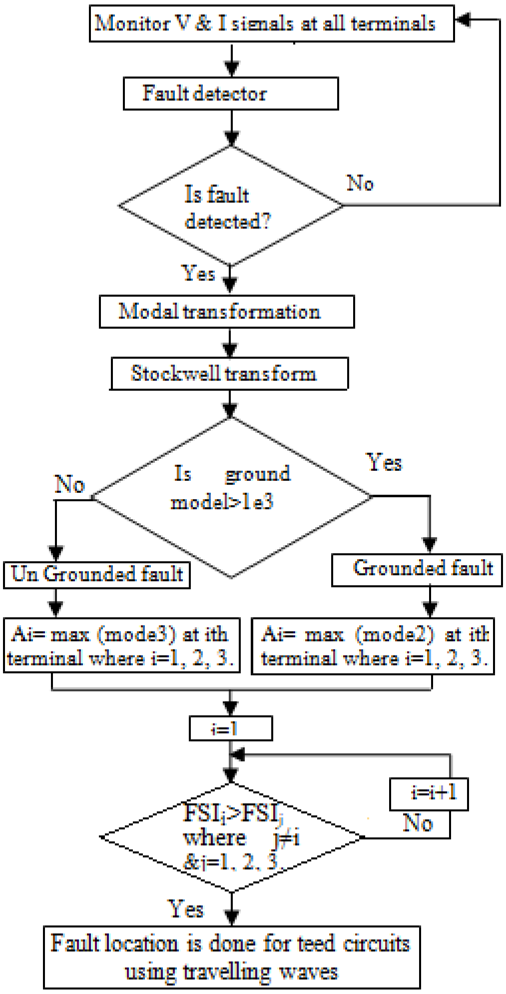

Figure 4: Flow chart for three terminal networks

3.1. Detection

Fault simulations are carried out for different faults, inception angles and fault resistance. In all cases, faults are detected quickly and accurately by using current slope based method. The fault detector used detected the faults in a short span of time. After fault detection, the three end signals are synchronized accurately. Figure 5 shows the current signal with fault incepted at 0.0425 sec and the variation of the fault detection index. It can be seen that with the inception

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of fault, the index grows to large value which can be used to detect the fault. The method detects the fault with in 10ms after fault incepted.

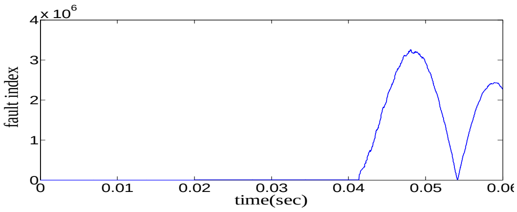

Figure 5: Fault current and Fault detection index

3.2. Fault type grounded or ungrounded

The following subplot in figure-6 indicates the type of the fault during ungrounded and ground involved faults. The threshold assigned to discriminate the type is 10^3 value. If the maximum of STC^2 of ground mode signal is less than assigned value then fault is ungrounded otherwise grounded fault

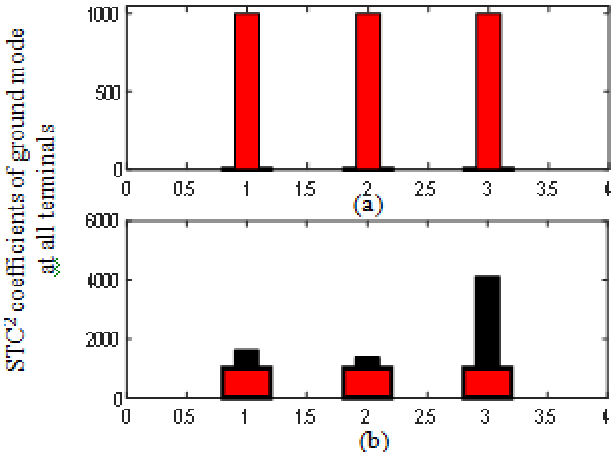

Figure 6: Result for fault type identification (a) Ungrounded fault & (b) Grounded fault

3.3. Fault Section identification results

By comparing the FSI values at all the terminals as shown in the bar charts, section identification is done.

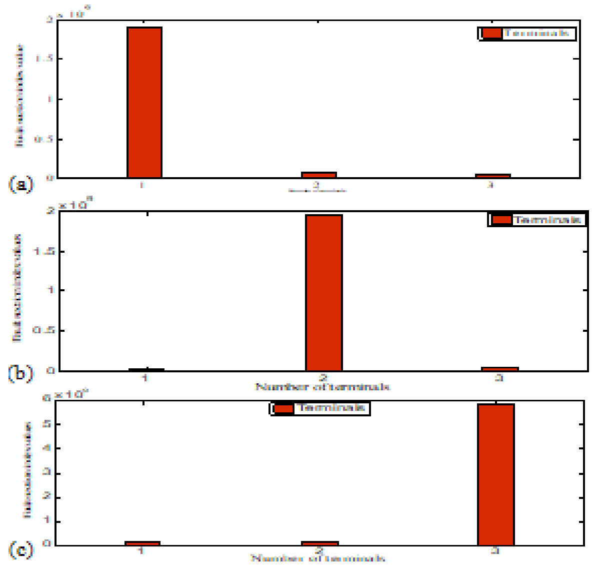

Figure 7: FSI values at all terminals for AB fault (a) Terminal 1, (b) Terminal 2 & (c) Terminal 3

The maximum FSI value gives the faulted section and the FSI values at remaining terminals will be less value. So as explained in the flow chart for the faulted section.

3.4. Fault location results

Fault location is calculated based on two ended algorithm proposed in [10]. Consider the double line to ground fault at 50kms from section 3-T.

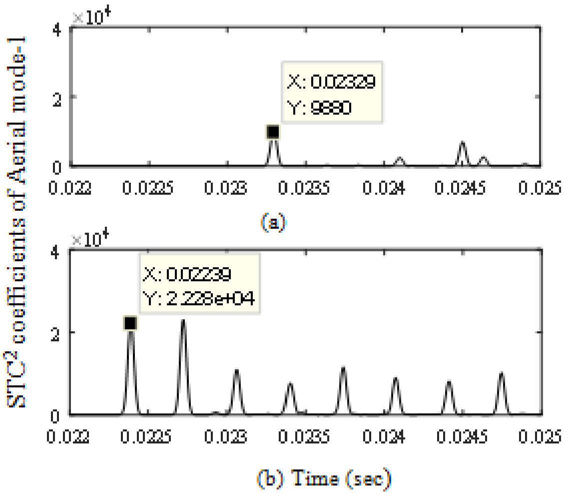

Figure 8: STC^2 values of mode2 (aerial mode) for ACG fault (a) terminal-1, (b) terminal -3

Propagation velocity is taken as $v=2.9775*10^5$. By measuring the time delay between backward and forward travelling waves of unfaulted section and faulted line section of the STC^2. Therefore t_1=0.0233sec and t_2= 0.0224sec. The estimated fault distance is to be calculated using eq. (20)

$$X_{(1)} = \frac{((L(2)+L(1))-(v*(t1-t2))}{2}$$

$$= \frac{((200+170)-(297750*(0.0233-0.0224)))}{2} = 50.02 \text{ kms}$$

The fault location for various faults, fault resistances and inception angles is shown in table 2.

Table 1: Fault Location Results

Section	*Type of fault*	*Fault resistance*	*Inception angle*	*Actual distance in kms*	*Estimated distance in kms*
A-T	ABG	0.01	10	20	20.12
	AG	5.0	30	80	80.05
B-T	ABCG	1.0	120	80	79.98
	BC	0.01	30	40	41.42
	CG	5.0	150	120	120.66
C-T	AG	0.01	150	20	19.81
	ABC	10.0	30	160	160.84

4. Conclusions

Fault location procedure for teed circuits using S-transform is presented in this paper. The proposed method utilizes synchronized signals from all ends for processing. The work is similar to the fault location for teed circuits for unsynchronized measurements in [12]. Advantage of S-transform is more effective then wavelet transform. The method gives accurate results for all types of fault conditions. Simulation results in MATLAB environment indicate the efficacy of the algorithm.

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5. Acknowledgment

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References

[1] Krzysztof, G., Kowalik, R.,&Rasolomampionona, D, "Regular paper traveling wave fault location in power transmission systems: an overview. *J. electrical Systems*, *7*(3), 287-296, 2011.
[2] Lopes, F. V., Fernandes Jr, D., &Neves, W. L. A, "Fault location on transmission lines based on travelling waves.",Proceeding in International Conference on Power Systems Transients (IPST2011) in Delft, the Netherlands June 14-17, 2011.
[3] Gemelli, G., Palone, F., Rebolini, M., &Falorni, F, "Factors Affecting the Single-Ended Travelling Wave-Based Fault Location in HV Lines", in 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), pp. 1-6, June 2018.
[4] Liqun, S., &Wensong, Z, "Study of Fault Locations in Transmission Line Using S Transform", in proceeding 2016 International Symposium on Computer, Consumer and Control (IS3C), 4-6 July 2016.
[5] M.Abe, T.Emura, N.Otsuzuki, and M. Takeuchi, "Develoopement of a new fault location system for multi-terminal single transmission lines," IEEE Trans. Power del., vol.10, no.1, pp. 159-1687,Jan.1995.
[6] Kapoor, G, "Evaluation of fault location in three-phase transmission lines based on discrete wavelet transform", ICTACT Journal on Microelectronics, Vol. 06, no,1, pp. 897-901, April 2020,
[7] S.M. Brahma, "Fault Location Scheme for a Multi-Terminal Transmission Line Using Synchronized Voltage Measurements", IEEE Trans. on Power Del., Vol. 20, No. 2, pp. 1325–1331, April 2005.
[8] NguEngEng and KrishnathevarRamar," A combined impedance and traveling wave based fault location method for multi-terminal transmission lines.", Electrical Power and Energy Systems 33 (2011) , 1767–1775 ,7 October 2011.
[9] F.H.Magnago and A.Abur," Fault location using Wavelets," IEEE transaction on power delivery, Vol. 13, no. 4, pp. 1475-1480, oct. 1998.
[10] CansinY.Evrenosoglu and Ali Abur, ''Travelling Wave Based Fault Location for Teed Circuits'', IEEE Transactions on Power Delivery, Vol.,20, No.2,pp 1115-1121,April 2005
[11] Bh.R.K. Varma, Karri Nagaraju, P.S.V. Sivateja Varma, "A Current-Slope based Fault Detector for Digital Relays', proc in IEEE INDIA 's Annual conference, INDICON 2011.
[12] K. Andanapalli, and B. R. K. Varma, "Travelling wave based fault location for teed circuits using unsynchronised measurements," 2013 International Conference on Power, Energy and Control (ICPEC), Sri Rangalatchum Dindigul, pp. 227-232,Dec. 2013.

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