IJRD International Journal of Research & Development Organisation
ISSN-4567-7860
Journal Of Electrical And Electronics Engineering

An Efficient Fault Location Technique on a Compensated Transmission line Using Synchronized Voltage Measurement

Vinay Kumar Soni
IEEE Student Member,
Department of Electronics Engineering,
RITEE, Raipur, vinaysoni91@rediffmail.com

Dipesh Kumar Sharma
Associate Professor,
Raipur Institute of technology, Raipur,
Chhattisgarh, India

Abstract — The power continuity and quality is affected by the faults occurring in the transmission line between the generator and receiver of the grid supply systems. The detection of fault location is a vital step towards the removal of fault generated in the line. Several fault location techniques are given by the researchers of power sectors. Most techniques of fault location are based on the current measurement at both ends of the line but due to poor accuracy of the current transformers such techniques were required to be replaced by the advanced techniques adopting GPS, optical fibers and PMUs (phasor measurement units). This paper gives an advanced technique for fault location based on synchronous voltage measurement. A compensated transmission line is considered for the analysis and results are given which will prove this technique to be promising for the long length of line. As for the lines having long length the errors approximating 10% due to the poor accuracy of current transformers will lead in a large labor effort in repairing the fault to the fault team, this technique is very much useful for long line lengths as the errors are very small. In this paper circuit is modeled in EMTP-ATP and simulated using MATLAB-SIMULINK and the results are given.

***Key words* - Fault location, EMTP, Fault analysis, Synchronized phasor measurement, Series Compensation.**

I. INTRODUCTION

The power industries are focusing their efforts for a good power demands providing continuously to the consumers of power sector. The supply is highly affected due to several faults occurring in the transmission lines. Fault is any abnormal current in the transmission lines. Several faults occurring in a transmission line may be Line-to-Line fault, Line-to–Ground Fault, Double line-to-Ground fault etc. As an example, a short circuit is a fault in which current bypasses the normal load similarly open-circuit fault occurs if the circuit is interrupted by some failures. In the three-phase systems, a fault may involve one or more phases and ground, or it may occur only between phases. In case of a "ground fault" or "earth fault", charge flows into the earth [1]. For removal of faults occurred in any transmission lines it is essential to locate the fault in that line. Several fault location techniques are provided by the researchers of power engineering, most techniques involve measurement of current at both terminals but the disadvantage of this technique is poor efficiency of current transformers. For smaller line length lines such measurement techniques may be applicable but the lines having length few kilometers the errors in location about 10% may be very high and such methods will be not applicable for efficient location of faults and rapid repair of the fault(s) occurred. If the accuracy in locating the faults is high then it will be easier task for inspection, maintenance, and repair of the line. Fast restoration in the power services will reduce the outage time, crew repair expense and the customer complaints. These factors are very essential for the researchers of competitive power industry because the power industry is demanding a fault free good quality power for the consumers.

The researchers have done considerable work in this area of fault diagnosis particular to radial distribution systems. Traditional outage handling methods were based on the customer trouble calls. Here the geographic location of the caller and the connectivity of the distribution network have to be overlapped exactly for the exact location of fault. Also, there might not be any calls during night-time, which poses a problem for the operator in locating the fault [2]. Such problems are required to be overcome through new location techniques.

When developing the very accurate fault location schemes it is very important to have information from both terminals. At present fault location methods using two end data are more feasible due to the application of advanced communication technologies like Global Positioning System (GPS), Phasor Measurement Unit (PMU), Fiber Optics and high-speed Ethernet.

Currently, in the traction network systems, the generally used fault distance measurement method is the impedance method, which can eliminate the influence of the fault transient resistance. However, the obtained fault distance from this method is only accurate under the condition of single-side power supply and without the locomotive load [3].

Fault location on series-compensated lines (SCLs) is considered to be one of the most important tasks for the manufacturers, operators and maintenance engineers since these lines are usually spreading over a few

hundreds of kilometers and are vital links between the energy production and consumption centers [4].
S. M. Brahma and A. A. Girgis [5] also gave the synchronous voltage measurement technique for failt locations. Several other researchers [6]-[14] also provide different fault location techniques.

II. MEASUREMENT OF SYNCHRONOUS PHASOR FOR FAULT LOCATION ON A TRANSMISSION LINE

As the current measurement techniques are not efficient due to low current transformer's accuracy this method uses the measurement of synchronous phasor to detect the location of fault occurred. Application of Phasor Measurement Units will improve the accuracy in the location of faults and it will reduce the errors significantly. The basic transmission line considered is given in figure below:

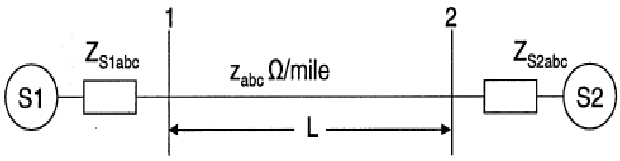

Fig. 1. Transmission line having length "L".

In the concept for measuring the fault location is that a finite length line is considered and at a distance (location), here 'k', a fault is inserted in that line. Now the location of fault is measured using the formulas of this method which uses the bus impedance matrix, bus admittance matrix, and change in voltage and current values in different phases etc. which is compared with actual fault location and the percentage error is calculated.

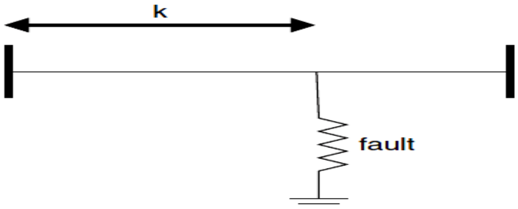

Fig. 2. Concept used for fault location.

The transmission line with a fault is shown in figure 3 below, (here S1 is the generation end and S2 is the load end):

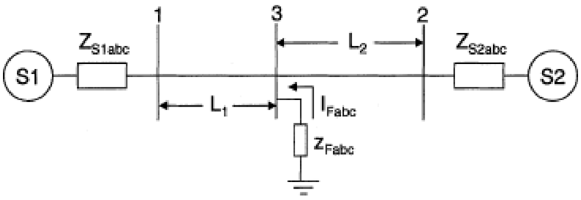

Fig. 3. A faulted Transmission line.

This transmission line is modeled in ATP and simulated for the fault location. The ATP model is given in figure 4:

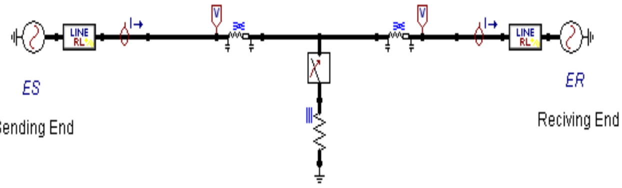

Fig.4. ATP model of the transmission line.

S. M. Brahma and A. A. Girgis [5] utilized voltages from both line terminals which ensured complete immunity to the saturation of current transformers (CTs). They used the Bus Impedance Matrix and gave the fault locations using the following formula:

$$z_{abc} = \begin{bmatrix} z_{aa} & z_{ab} & z_{ac} \\ z_{ba} & z_{bb} & z_{bc} \\ z_{ca} & z_{cb} & z_{cc} \end{bmatrix} \quad \text{---------------(1)}$$

Here Z_{abc} is bus impedance matrix. It's inverse is given as (bus admittance matrix):

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \quad \text{-----------------(2)}$$

The location of fault is given by:

$$L_1 = \frac{|\Delta V_1(1) - \Delta V_2(1) + LQ(1)|}{P(1) + Q(1)} \quad \text{----------------(3)}$$

Where P and Q are the vectors of dimensions 3 X 1 and are given by

$$P = z_{abc}\left(\frac{y_{abc}}{L} - Y_{11}\right)\Delta V_1 \quad \text{------------------(4)}$$

$$Q = z_{abc}\left(\frac{y_{abc}}{L} - Y_{22}\right)\Delta V_2 \quad \text{------------------(5)}$$

Where 'L' is the total line length and ΔV is the change in the three phase voltages [4].

III. SERIES COMPENSATED TRANSMISSION LINE FAULT LOCATION USING SYNCHRONIZED PHASOR MEASUREMENTS

In this section a new algorithm for fault location for series compensated transmission lines with Fixed Series Capacitor (FSC) is given. Series compensated line has limitation with metal oxide varistor (MOV) operation, prefault system condition, high resistance fault and

IJRD International Journal of Research & Development Organisation
ISSN-4567-7860
Journal Of Electrical And Electronics Engineering

shunt capacitance. So MOV is also used with the capacitors. The transmission line using MOV is given in the following figure 5 and figure 6 represents the ATP model [15] of a compensated transmission line which is adopted for the study in this paper for the fault location technique:

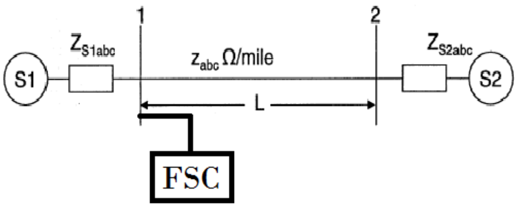

Fig.5. Series Compensated line considered for analysis.

In above figure the block FSC is added at the terminal 1 of the transmission line.
The ATP model of a compensated transmission is shown below in figure 6. The capacitors are used for the compensation. The bus impedance matrix for this compensated line will be given as:

$$z_{abc} = \begin{bmatrix} z_{aa} & z_{ab} & z_{ac} \\ z_{ba} & z_{bb} & z_{bc} \\ z_{ca} & z_{cb} & z_{cc} \end{bmatrix} - j \begin{bmatrix} Xcaa & Xcab & Xcac \\ Xcba & Xcbb & Xcbc \\ Xcca & Xccb & Xccc \end{bmatrix}$$

----------------(6)

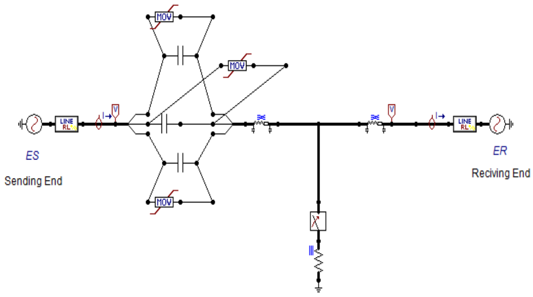

Fig.6. ATP model of the compensated transmission line.

IV. SIMULATION RESULTS

A 500-kV, 200-mi-long line is taken for simulation [5]. Both the uncompensated and the compensated transmission lines are modeled and simulated for the fault level and locations. The following figures represent the occurrence of the faults in the considered transmission line. It is clear from the figures that the compensated transmission line will improve the power quality as compared to the uncompensated line.

In the figure 7, for an uncompensated line, the fault occurred with a considerable decrease in the voltage level, here the voltage decreases below 400 kV and figure 8 shows the voltage level of a compensated line, in which the voltage level is above 400kV. So it is cleared that due to the compensation the quality or level of voltage is improved when a fault occurs in a transmission line. The transient time is about 0.05 seconds from the sending end (generating end) at which the fault occurred in the line.

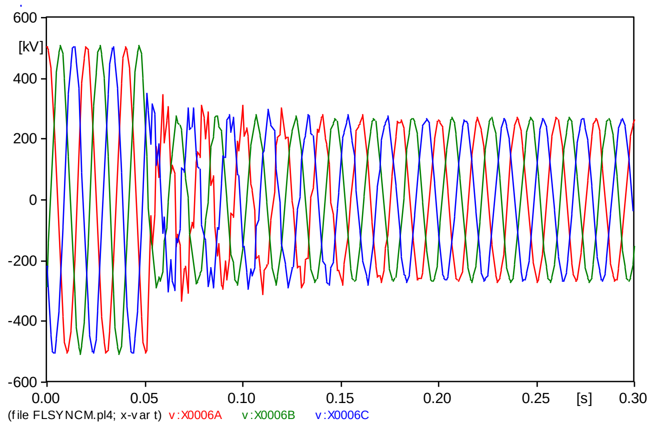

Fig.7. Fault occurred in the uncompensated transmission line.

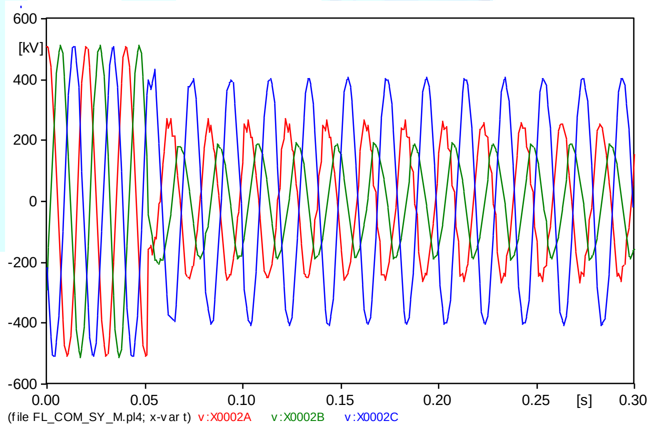

Fig.8. Fault occurred in the compensated transmission line.

The percentage error is calculated as follows:

$$\% \text{ Error} = \frac{\text{Actual Location} - \text{Fault Location}}{\text{Total Line Length}} \times 100$$

Here different fault resistances are used to get different fault location results for study. The results obtained for an uncompensated line are given in table 1 following as:

Fault Type	Distance (miles)	Fault Resistance	**Simulation results**		
			% Error ph A	% Error ph B	% Error ph C
LLL	10	10	0.41	0.85	2.17
	10	50	1.03	0.53	1.30
	100	10	0.17	0.24	0.02

	100	50	0.03	0.04	0.39
	180	10	5.57	4.86	6.84
	180	50	6.06	6.17	6.78

Table 1: Performance of fault location method using data obtained from EMTP analysis without neglecting line capacitance (for an uncompensated line).

The results of a compensated line aregiven below in table 2 as (negative errors are due to fact that fault locations calculated are more than the actual fault locations):

Fault Type	Distance (miles)	Fault Resistance	Simulation results		
			% Error ph A	% Error ph B	% Error ph C
LLL	10	1	2.31	-1.01	-3.47
	10	10	-2.33	-1.24	-3.84
	100	1	-0.19	0.39	0.29
	100	10	-0.08	0.39	0.17
	180	1	-4.97	-4.85	-4.76
	180	10	-4.47	-5.09	-4.89

Table 2: Performance of fault location method using data obtained from EMTP analysis without neglecting line capacitance (for a compensated line).

V. CONCLUSION

From the above results shown it is obvious that the location of faults through the technique will be very promising for the lines having length longer for the distribution. The uncompensated line gives the maximum error as 6.84% and this is 5.09% for the compensated transmission line. Due to the rapidly growing demand in the industry of power production and the competitive quality requirements of fault free power to the end users the fault location technique discussed here in this paper will be very helpful to the maintenance team also in the reduction of power outages time during the fault. The GPS technology will provide the transient error free results for the fault locations.

VI. REFERENCES

[1]. http://en.wikipedia.org/wiki/Electrical_faults.

[2]. M. Mirzaei, M.Z. A Ab Kadir, E. Moazami, H. Hizam, Review of Fault Location Methods for Distribution Power System, Australian Journal of Basic and Applied Sciences , 3(3): 2670-2676, 2009.

[3]. Yimin Zhou, Guoqing Xu and Yanfeng Chen, Fault Location in Power Electrical Traction Line System, Energies 2012, 5, 5002-5018; doi:10.3390/en5125002.

[4]. Ali H. Al-Mohammed and M. A. Abido, Member, IEEE, A Fully Adaptive PMU-Based Fault Location Algorithm for Series-Compensated Lines, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 29, NO. 5, SEPTEMBER 2014,2129-2137.

[5]. Sukumar M. Brahma, Member, IEEE, and Adly A. Girgis, Fellow, IEEE, Fault Location on a Transmission Line Using Synchronized Voltage Measurements, IEEE transactions On Power Delivery, Vol. 19, No. 4, October 2004.

[6]. M. Djuric, Z. Radojevic, and V. Terzija, “Distance protection and fault location utilizing only phase current phasors,” IEEE Trans. Power Delivery, vol. 13, pp. 1020–1026, Oct. 1998.

[7]. M. Tawfik and M. Morcos, “ANN-based techniques for estimating fault location on transmission lines using Prony method,” IEEE Trans. Power Delivery, vol. 16, pp. 219–224, Apr. 2001.

[8]. S. Tamronglak, S. Horowitz, A. Phadke, and J. Thorp, “Anatomy of power system blackouts: Preventive relaying strategies,” IEEE Trans. Power Delivery, vol. 11, pp. 708–715, Apr. 1996.

[9]. Phadke, A.G.; Thorp, J.S., "Expose hidden failures to prevent cascading outages [in power systems]," Computer Applications in Power, IEEE , vol.9, no.3, pp.20,23, Jul 1996.

[10]. M. Kezunovic and B. Perunicic, “Automated transmission line fault analysis using synchronized sampling at two ends,” IEEE Trans. Power Systems, vol.11, no. 1, pp. 441–447, Feb. 1996.

[11]. D. Novosel, D. G. Hart, E. Udren, and J. Garitty, “Unsynchronized two terminal fault location estimation,” IEEE Trans. Power Del., vol. 11, no. 1, pp. 130–138, Jan. 1996.

[12]. M. S. Sachdev and R. Agarwal, “A technique for estimating line fault locations from digital distance relay measurements,” IEEE Trans. Power Del., vol. 3, no. 1, pp. 121–129, Jan. 1988.

[13]. V. Cook, “Fundamental aspects of fault location algorithms used in distance protection,” Proc. Inst. Elect. Eng. C, vol. 133, no. 6, pp. 359–368, Sept. 1986.

[14]. M. M. Saha, J. Izykowski, and E. Rosolowski, “A method of fault location based on measurements from impedance relays at the line ends,” in Proc. Inst. Elect. Eng., 8th Int. Conf. Developments Power System Protection, Amsterdam, The Netherlands, 2004, pp. 176–179.

[15]. Alternative Transients Program (ATP) - Rule Book, CanAm EMTP User Group, Portland, OR, Sep. 1992, [online]. Available: www.emtp.org.