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Wavelet based detection and location of faults in 400kv, 50km Underground Power Cables

D.Prabhavathi[1], K.Prakasam[2], Dr.M.Suryakalavathi[3], Dr.B.Ravindranath Reddy[4]

[1]Department of Electrical and Electronics Engineering, Sri Sivani College of Engineering,Srikakulam,A.P.INDIA
[2]Department of Electrical and Electronics Engineering, Sri Sivani College of Engineering,Srikakulam,A.P,INDIA
[3]Department of Electrical and Electronics Engineering, JNTUH, Hyderabad, INDIA.
[4]Department of Electrical and Electronics Engineering, JNTUH, Hyderabad, INDIA.

ABSTRACT

In this paper, a method for detection and location of fault in a power line is presented. This method can be applied for both transmission and distribution power lines of underground cables. The proposed method is capable to determine type of fault the fault location upon its occurrence, based on the data available from the measuring equipment. The algorithm presented uses the fault steady-state data (voltages and currents) and the system parameters, to calculate the fault location. The influence of the fault resistance that depends on the design characteristics of the power line is disregarded. The proposed method has been modeled in mat lab simulink of version 7.8.

KEYWORDS: *Cables, distribution, Fault location, Fault diagnosis, steady state, transmission, underground, wavelet,*

I. INTRODUCTION

Detection and Location of faults in power transmission lines is one of the main concerns for all the electric utilities as the accurate detection and fault location can help to restore the power supply in the shortest possible time. Fault location methods for transmission lines are broadly classified as impedance based method which uses the steady state fundamental components of voltage and current values [1–3], travelling wave (TW) based method which uses incident and reflected TWs observed at the measuring end(s) of the line [4, 5], and knowledge based method which uses artificial neural network and/or pattern recognition techniques [6,7]. All the above methods use the measured data either from one end of the transmission line or from all ends. Fault analysis methods are an important tool used by protection engineers to estimate power system currents and voltages during disturbances. It provides information for protection system setting, coordination and efficiency analysis studies. Today, three approaches are used in the industry for such analysis: classical symmetrical components, phase variable approach and complete time-domain simulations [19]. Classical fault analysis of unbalanced power systems is based on symmetrical components approach [20, 21]. However, in un transposed feeders with single-phase or double- phase laterals, the symmetrical component methods do not consider accurately these specific characteristics [22]. Hence, symmetrical components based techniques may not provide accurate results for power distribution systems, which are normally characterized by those asymmetries. With industrial computer facilities improvement, the fault analysis phase variable approach has been proposed to substitute the symmetrical components methods on distribution systems [23]. In the phase variable approach, system voltages and currents are related through impedance and admittance matrices based on phase frame representation, considering the typical distribution systems asymmetries. However, fault analysis is still fault resistance dependant [24]. Due to fault resistance stochastic nature, typical fault analysis studies consider the fault paths as an ideal short-circuit. To overcome this limitation, recent studies suggest the usage of fault resistance estimation algorithms [25–27]. These works provide a fault resistance estimate using symmetrical components or modal analysis techniques, restricting the application on balanced systems with equally transposed lines. The usage of artificial intelligence has also been recently proposed in order to overcome the fault resistance effects in classical power system protection [28] and fault location [29] applications.

II. WAVELET TRANSFORMS

A wavelet is a waveform of effectively limited duration that has an average value of zero. The driving force behind wavelet transforms (WTs) is to overcome the disadvantages embedded in short time Fourier transform (STFT), which provides constant resolution for all frequencies since it uses the same window for the analysis of the inspected signal x (t). On the contrary, WTs use multi-resolution, that is, they use different window functions to analyze different frequency bands of the signal x (t). Different window functions ψ(s,b,t);which are also called son wavelets, can be generated by dilation or compression of a mother wavelet ψ(t) , at different time frame. A scale is the inverse of its corresponding frequency. WTs can be categorized as discrete WTs or continuous WTs. For vibration-based fault diagnosis, usually continuous WTs are employed. A continuous type of wavelet transform (CWT) that is applied to the signal x (t) can be defined as,

$$w(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t)\psi\left(\frac{t-b}{a}\right)dt \qquad (2.1)$$

Where

- a is the dilation factor,
- b is the translation factor and
- $\psi(t)$ is the mother wavelet.
- $1/\sqrt{a}$ is an energy normalization term that makes wavelets of different scale has the same amount of energy.

A continuous wavelet transform (CWT) is used to divide a continuous-time function into wavelets. Unlike Fourier transform, the continuous wavelet transform possesses the ability to construct a time-frequency representation of a signal that offers very good time and frequency localization. In mathematics, the continuous wavelet transform of a continuous, square-integrable function $x(t)$at a scale $a > 0$and translational value $b \in \mathbb{R}$is expressed by the following integral

$$X_w(a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} x(t)\psi^*\left(\frac{t-b}{a}\right) dt \qquad (2.2)$$

where $\psi(t)$is a continuous function in both the time domain and the frequency domain called the mother wavelet and $*$ represents operation of complex conjugate. The main purpose of the mother wavelet is to provide a source function to generate the daughter wavelets which are simply the translated and scaled versions of the mother wavelet. To recover the original signal $x(t)$, inverse continuous wavelet transform can be exploited.

$$x(t) = \int_0^{\infty} \int_{-\infty}^{\infty} \frac{1}{a^2} X_w(a,b) \frac{1}{\sqrt{|a|}} \tilde{\psi}\left(\frac{t-b}{a}\right) db\ da \qquad (2.3)$$

$\tilde{\psi}(t)$is the dual function of $\psi(t)$. And the dual function should satisfy

$$\int_0^{\infty} \int_{-\infty}^{\infty} \frac{1}{|a^3|} \psi\left(\frac{t_1-b}{a}\right) \tilde{\psi}\left(\frac{t-b}{a}\right) db\ da = \delta(t-t_1). \qquad (2.4)$$

Sometimes, $\tilde{\psi}(t) = C_{\psi}^{-1}\psi(t)$, where

$$C_{\psi} = \frac{1}{2}\int_{-\infty}^{+\infty} \frac{\left|\hat{\psi}(\zeta)\right|^2}{|\zeta|} d\zeta \qquad (2.5)$$

is called the admissibility constant and $\hat{\psi}$is the Fourier transform of ψ. For a successful inverse transform, the admissibility constant has to satisfy the admissibility condition:

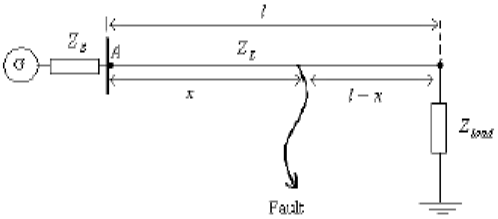
$$0 < C_{\psi} < +\infty.$$

It is possible to show that the admissibility condition implies that $\hat{\psi}(0) = 0$, so that a wavelet must integrate to zero.

III. PROPOSED SYSTEM

A 400KV, 100MVA, 50km, 50Hz power cable is considered and is designed using Mat lab simulink with Simpower systems block sets. Since the length of the line is small**,** the leakage current can be neglected and the shunt part of the line can be neglected and with the series impedance an accurate detection can be obtained.

To induce a fault in the power line, a point in the line has to be connected to ground through a small resistance (fault resistance), fig1 and Fig.2 represents a single-ended power line with a fault at distance x from point A.



Fig, 1 One - end power cable of 50Km long

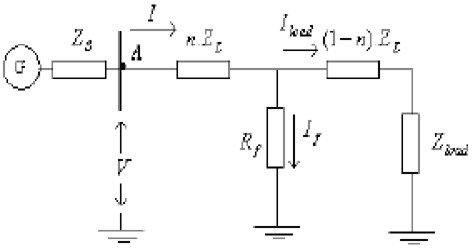


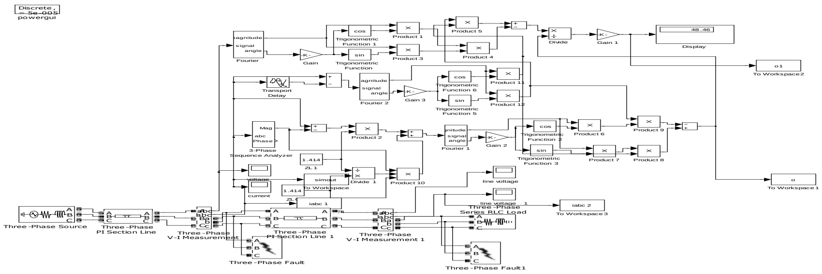
Fig.2 Representation of a single-ended power line with a fault at distance x from point A.

Z = The source impedance. ,Z $_L$ = The line impedance
load Z =The load impedance. : load Z ,l = The line length.
X=The length from the fault location equipment (point A) to the fault.
V= The measured voltage. I = Measured current R_f = The fault resistance
I_f = Fault current, I = Load current
n = the per unit length from the measuring equipment (point A) to the fault: n = x/l

The mat lab simulink modeling is obtained from the mathematical modeling of the power cable and is shown in fig.4.1.The various fault are carried and the detection and location of faults were analysed.

IV. SIMULATION STUDIES OF PROPOSED SYSTEM

This section presents the simulation results to evaluate the developed fault location algorithm. The developed fault location algorithm is implemented in Mat lab. The model has been created with a toolbox of Matlab/Simulink® called SimPowerSystems®. It is a collection of blocks that allow the modeling of different elements that usually are present on power systems. It uses the Simulink as simulation engine. The studied power system is a 400KV, 50 Hz, 50 km underground cable transmission line system. The simulation of the algorithm is focused on a single phase-to- ground fault, a type of fault that occupies about 90% of all of the transmission line faults. The results of the simulations are the voltage and current waveforms of the three phases at the header of the line, the same information that can be obtained from real faults. The voltage and current phasors are found taking the fundamental frequency by using the fast Fourier transform. With the phasors and the model of the network, now the algorithms can be computed. The Simulink model used to simulate the algorithm used is shown in the Figure. 4.1. Continuous wavelet transform is applied to extract the accurate detection and location of the faults.



4.1. MATLAB Simulink model of 400KV, 50Km Three phase UG cable

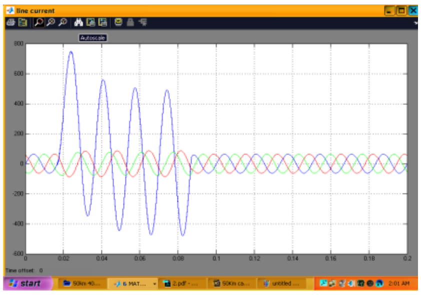


Fig.4.2.Single line to ground fault current (AG fault)

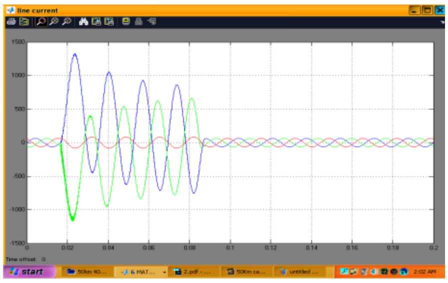


Fig.4.3.Double line to ground fault current (ABG fault)

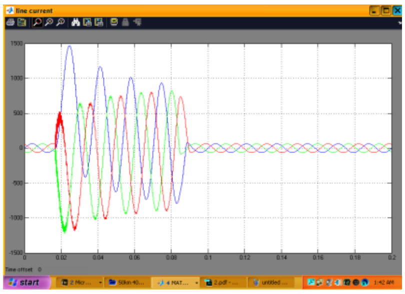


Fig.4.4.Three Phase to ground fault current (ABCG fault)

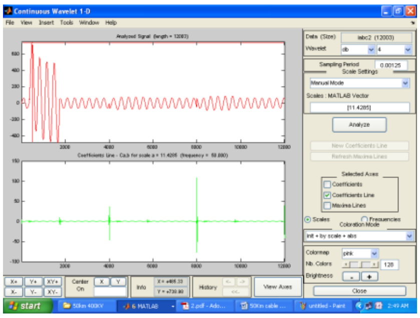


Fig 4.5.Single line to earth fault (AG) at 50km by wavelet transforms

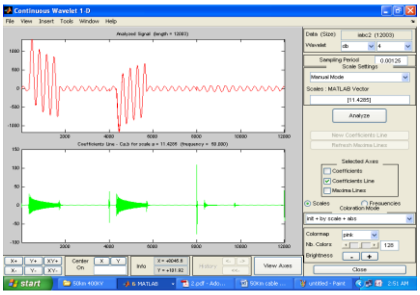


Fig 4.6.Double line to earth fault (ABG) at 50km by wavelet transforms

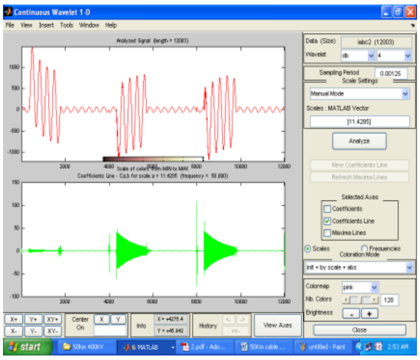


Fig 4.7.Tripple line to earth fault (ABCG) at 50km by wavelet transforms

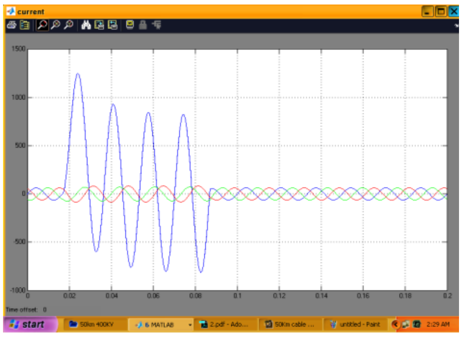


Fig.4.8.Single line to ground fault current (AG fault) at 25km

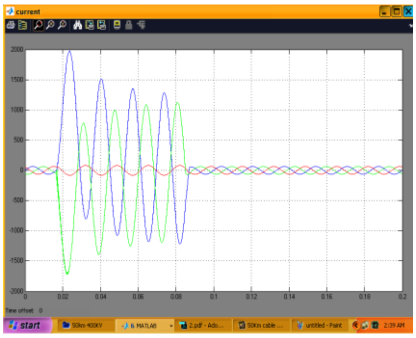


Fig.4.9.Double line to ground fault current (ABG fault) at 25km

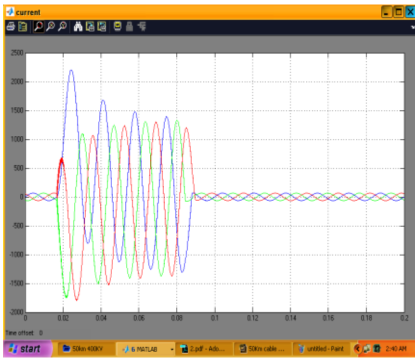


Fig.4.10.Tripple line to ground fault current (ABCG fault) at 25km

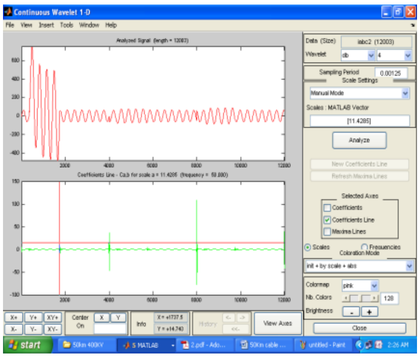


Fig 4.11.Single line to earth fault (AG) at 25km by wavelet transforms

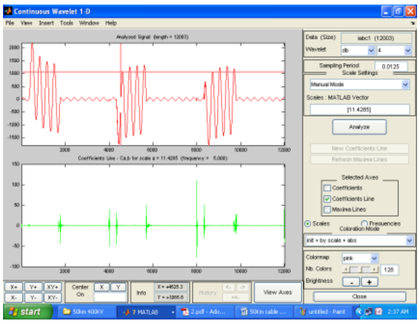


Fig 4.11.Double line to earth fault (ABG) at 25km by wavelet transforms

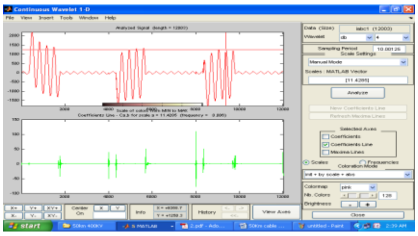


Fig 4.11.STripple line to earth fault (ABCG) at 25km by wavelet transforms

Table-1

LG Fault		
Actual Distance(km)	Measured Distance(km)	% Error
25	24.58	1.68
50	51.45	-2.9

Table-2

LLG Fault		
Actual Distance(km)	Measured Distance(km)	% Error
25	25.1	-0.4
50	49.58	0.8

Table-3

LLLG Fault		
Actual Distance(km)	Measured Distance(km)	% Error
25	25.87	-3.4
50	53.18	-6.36

The estimation accuracy is evaluated by the percentage error calculated as per the following equation

$$\frac{\text{Actual fault location} - \text{estimated fault location}}{\text{Total lenghth of the line}} X100$$

Where the location of the fault is defined as the distance between the bus at which the measuring equipment are installed, and the fault point. As can be seen, the fault location estimates are satisfactory. The location fault is estimated in wavelet transform between the two peaks of the waveform.

V. CONCLUSIONS

This paper presents detection and location of fault in 400KV underground .The proposed algorithm uses the steady-state data (voltages and currents), available by the measuring equipment, to calculate the fault location. The influence of the fault resistance is disregarded. The proposed method can be used to built a stand-alone fault locating equipment and as a part of a protective device as an impedance relay. Simulation studies have shown that the proposed algorithm can yield quite accurate estimates of the fault detection and location. The resultant of all types of faults are shown in figures 4.2 to 4.7 for fault at 50km and from figures 4.8 to 4.11 for faults at 25km.The resultant values of all faults are tabulated in table I, table II and table III. From this it can be observed that the wavelet transform gives better results in detection and location of faults. The maximum error in this analysis is -6.36%

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Biographies and Photographs

1)D.Prabhavathi Born in 1976 august 27, her B.Tech degree from KSRM college of Engineering, kadapa , SV university, and M.Tech degree from SV University in the year 2004.She has specialized in Power Systems operation and control. She is currently working as Assoc.Prof, dept of E.E.E *Sri Sivani College of Engineering*, Srikakaulam, Andhrapradesh,INDIA. Her research interests include Simulation studies on faults identification in UG cable of LT and HT. She has 13 years of experience.

2) K.Prakasam, Born in 1973 April 20, his B.Tech degree from KSRM College of Engineering SV university in 1997 and M.Tech degree from SV university in the year 2004. He has specialized in Power Systems operation and Control Systems. His research interests include Simulation studies on Transients of different power system equipment. He has 16 years of experience. He is presently working as Prof .Prof and HOD of Dept of EEE, *Sri Sivani College of Engineering*, Srikakaulam,Andhrapradesh,INDIA

3) Dr. M. Surya Kalavathi, Born on 8th July 1966, Obtained her B.Tech degree from S.V. U. in 1988 and M.Tech from S.V.U. in the year 1992.Obtained her doctoral degree from JNTU, Hyderabad and Post Doctoral from CMU, USA. She is presently working as Professor (EEE) in JNTUH College of Engineering, Kukatpally, Hyderabad. Published 16 Research Papers and presently guiding many Ph.D. Scholars. She has specialized in Power Systems, High Voltage Engineering and Control Systems. Her research interests include Simulation studies on Transients of different power system equipment. She has 18 years of experience. She has invited for various lectures.

4) Bhumanapally.Ravindhranh Reddy, Born on 3rd September, 1969. Got his B.Tech in Electrical & Electronics Engineering from the J.N.T.U. College of Engg., Anantapur in the year 1991. Completed his M.Tech in Energy Systems in IPGSR of J.N.T.University Hyderabad in the year 1997.Obtained his doctoral degree from JNTU, INDIA