International Journal of Electronic and Electrical Engineering.
ISSN 0974-2174 Volume 6, Number 1 (2013), pp. 43-54

http://www.irphouse.com

Location and Classification of Faults in High Voltage Underground Cable Using Wavelet Transform

D. Prabhavathi[1], K. Prakasam[2], Dr. M. Surya Kalavathi[3] and Dr. B. Raveendranath Reddy[4]

[1]Siddartha Institute of Engineering and technology, Ibrahimpatnam, Hyderabad, Andhra Pradesh, India.
[2]Siddartha Institute of Engineering and technology, Ibrahimpatnam, Hyderabad, Andhra Pradesh, India.
[3]Jawaharlal Nehru Technological University, Kukatpally, Hyderabad, Andhra Pradesh, India.
[4]Jawaharlal Nehru Technological University, Kukatpally, Hyderabad, Andhra Pradesh, India.

Abstract

Protecting transmission lines is one important task to safeguard electric power systems. The transient fault signal on transmission lines need to be detected, classified and located accurately and cleared as fast as possible. This research present an application of a discrete wavelet transforms (DWT) for fault diagnosis in underground cable system. Fault simulations are carried out using ATP/EMTP program, with a frequency-dependent transmission line model. Post-fault current signals are used in the analysis. The TS90 is the most advanced TDR fault locator based on Digital technology that provides distance to fault on cables. The mother wavelet daubechies4 (db4) is employed to decompose, high frequency component from the current fault signals. The time of positive sequence in first scale for detecting fault was used an input for travelling wave in order to identifying fault location. The comparisons of the coefficients DWT have been performed in order to classify fault types. The coefficients detail (phase A, B, C and zero sequence of post fault current signals) of DWT at the first peak time that positive sequence current can detect fault, are performed as comparison indicator. The results are shown that the wavelet transform is a powerful tool and gives satisfactory results. SIMply the best for locating underground cable faults Errors in fault location obtained from proposed technique are 0.4 km. In addition, the proposed algorithm can indicate fault types with the accuracy higher than 90%.Fault location on distribution systems has become an important issue due to the negative impact of a no continue and reliable service on distributor. There are many techniques and strategies proposed for this problem, however, it isn't clear which one is the best. In that use transient state analysis to locate short-circuit faults with low fault resistance in radial systems. The main conclusion is that, due to the commitment with the precision of the techniques, a combination of some strategies is needed for a real system implementation.

Keywords: Fault location, SIM, db4,Cable thumping,TS 90, transients analysis, wavelet transform.

Introduction

The TS90 and TS100 Metallic TDR Cable Fault locators in association with Tempo Textron Europe are the most advanced units on the market for locating faults in metallic cables on account of ease of use and unparallel accuracy that assist Telecom and Facility maintenance teams save tremendous time and effort in locating cable faults. Figure 1. Shows display fault locations on different cables and Power quality issues have taken more relevance thanks to the proliferation of electronic devices and the need of a reliable service. This is mainly due to the fees that the utility must to overcome if the continuity of the service is affected [1]. As consequence, a negative impact on the revenue might be seen [2, 3].

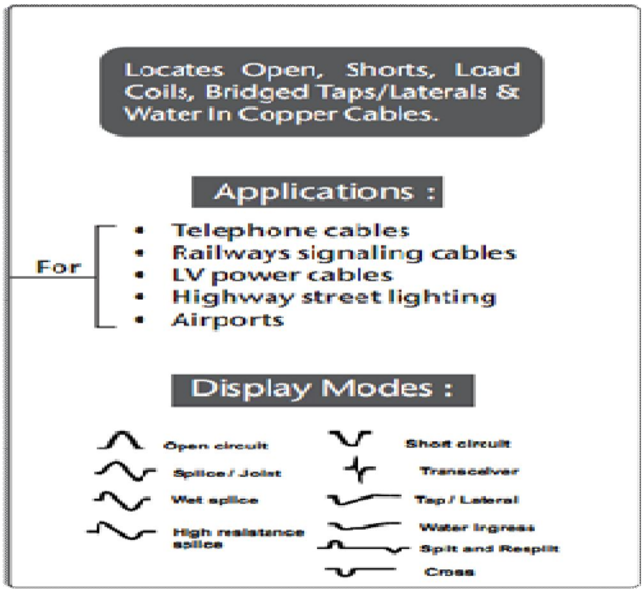

Figure 1:display modes of fault locations on different cables.

However, fault location on the power distribution systems still remains has a problem partially solved. This is mainly because of multiple feeders and laterals presence, unbalanced and distributed loads, changes on the conductor type and medium (overhead line or underground cable), issues on load modeling and the fault resistance effect [4, 5]. In this second part, fault locators which use advanced analysis techniques such as soft computing techniques and Wavelet Transform are presented. Follow that is treated the transient state techniques. Then, on the fourth section, some of the fault locators critical points are discussed. Finally, the conclusions of the paper are presented. Named after Ingrid Daubechies, the Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function (called the father wavelet) which generates an orthogonal multiresolution analysis.

Underground Cable Testing & Fault Location

The rising demand for electrical energy increases the importance and priorities of uninterrupted services to customers. Thus, faults in power distribution networks have to be quickly detected, located and repaired. Third Wave Services Pvt. Ltd. offers 24 x 7 timely service for underground cables of up to 33 KV working voltage all over India from its nearest located branch. Our wide range of quality products including underground cable finder, electric cable detector, cable fault locators, power cable fault locator, and pipe & cable detector accomplishes the needs of all kinds of industries.Our state of art, full featured electric cable fault location system tests, pre-locates, and pin-points the precise position of the cable fault within minimum time especially in a long distance range through the powerful Arc reflection method used for pre-location of high resistance faults. Low resistance faults can be located with only the TDR and without having to use high voltage methods.We have got excellence in power cable testing, electrical cable testing, high voltage testing of cables, and to detect LT cable fault, underground cable fault location, underground cable faults, cable fault testing, and cable fault finding. Burning is resorted to only in extreme circumstances. 1000 joules of surge energy provide the necessary power for accurately pin pointing cable faults with the acoustic method. HV Test is conducted on cable to cross check the health of cable.

Discrete Wavelet Transforms-Algorithms and Applications

As DWT provides both octave-scale frequency and spatial timing of the analyzed signal, it is constantly used to solve and treat more and more advanced problems. Discrete Wavelet Transforms: Algorithms and Applications reviews the recent progress in discrete wavelet transform algorithms and applications. It covers a wide range of methods (e.g. lifting, shift invariance, multi-scale analysis) for constructing DWTs. Describes the progress in hardware implementations of the DWT algorithms.Wavelet transform (TW) is a tool that has found great acceptance for signal analysis [6,7]. In [8] is presented a complete implementation of the TW to classify and locate faults. Clasification is required since this is an input of the localizer. The sampling rate using this locator is between 60 and 200 Hz because it takes up the third level of detail of the wave [9]. The tests were performed with different fault resistance on a system of 19 nodes and only failed to identify the fault on the last leg of the distribution system when the fault resistance was 200 [5,6]. This is true if the components of 12.5 kHz to 25 kHz.Finally, a combination of TW with a technique similar to LAMDA is implemented in [12,13]. This method uses 20 samples per cycle, giving a sampling frequency of 1.2 kHz [14].Figure 2(b)An example of the 2D discrete wavelet transform that is used in JPEG2000. The original image is high-pass filtered, yielding the three large images, each describing local changes in brightness (details) in the original image. It is then low-pass filtered and downscaled, yielding an approximation image; this image is high-pass filtered to produce the three smaller detail images, and low-pass filtered to produce the final approximation image in the upper-left.

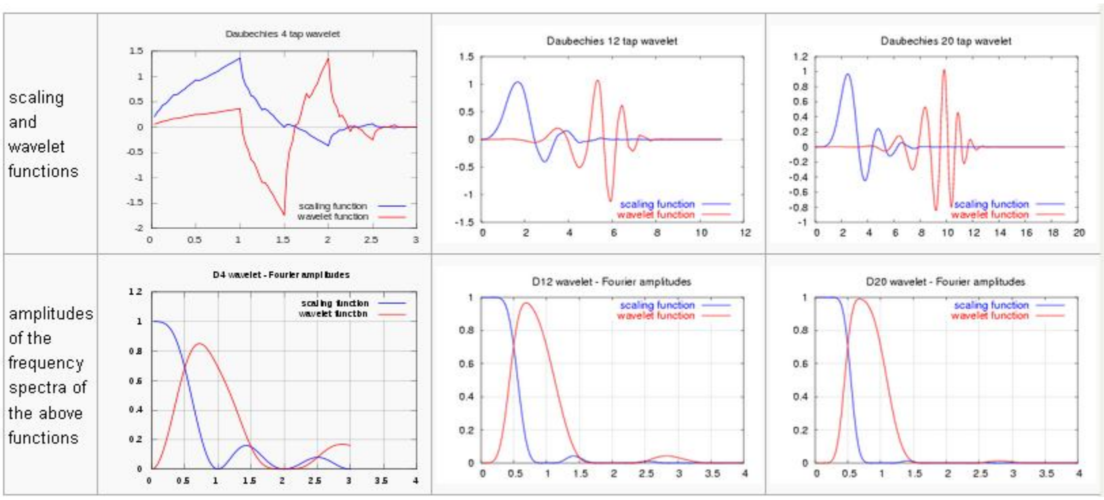

Figure: (a)

Also addresses image processing algorithms such as multiresolution approach for edge detection, low bit rate image compression, low complexity implementation of CQF wavelets and compression of multi-component images. And focuses watermaking DWT algorithms. Finally, describes shift invariant DWTs, DC lossless property, DWT based analysis and estimation of colored noise and an application of the wavelet Galerkin method. Therefore, a Discrete Wavelet Transform (DWT) based MCM system was developed as an alternative to DFT based MCM scheme.

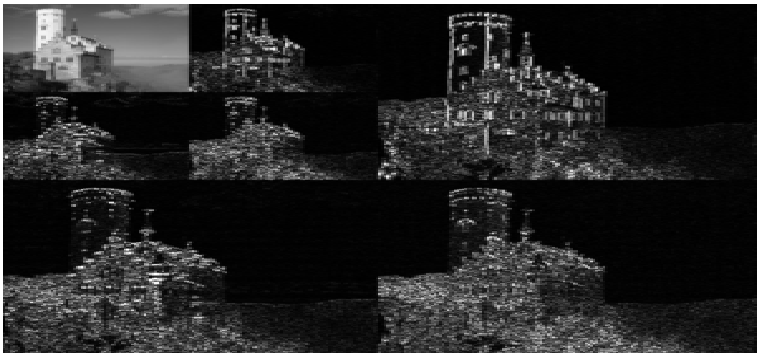

Figure (b)

Figure 2(a). Note that the spectra shown here are not the frequency response of the high and low pass filters, but rather the amplitudes of the continuous Fourier transforms of the scaling (blue) and wavelet (red) functions. **Figure** (b) 2D Descrete wavelet transform .

The 2A−1 possible solutions the one is chosen whose scaling filter has extremal phase. The wavelet transform is also easy to put into practice using the fast wavelet transform. Daubechies wavelets are widely used in solving a broad range of problems, e.g. self-similarity properties of a signal or fractal problems, signal discontinuities, etc.The Daubechies wavelets are not defined in terms of the resulting scaling and wavelet functions; in fact, they are not possible to write down in closed form. The graphs below are generated using the cascade algorithm, a numeric technique consisting of simply inverse-transforming [1 0 0 0 0 ...] an appropriate number of times.

Wavelet Filter Banks &Multirate Signal Processing Systems

Wavelets and filter banks play an important role in signal decompositioninto various subbands, signal analysis, modeling and reconstruction. Some areas of DSP,such as audio and video compression, signal denoising, digital audio processing and adaptivefiltering are based on wavelets and multirate DSP systems. Digital communication is a relatively new area for multirate DSP applications. The wavelets are implemented by utilizing multirate filter banks. The discovery of Quadrature Mirror Filter banks (QMF) led to the idea of Perfect Reconstruction (PR), and thus to subband decomposition. Mallatcame up with the idea of implementing wavelets by filter banks for subband coding and multiresolution decomposition . DWT gives time-scale representation of a digital signal using digital filtering techniques. The DWT analyzes the signal at different frequency bands with different resolutions by decomposing the signal into approximation and detail coefficients. The decomposition of the signal into different frequency bands is obtained simply by successive highpass and lowpass filtering of the time domain signal.

Analysis and synthesis filter banks

Analysis filter banks decomposes input signal into frequency subbands. A two channel analysis filter bank, as shown in Figure 3, splits the input signal $X(z)$ into a high frequency component $U0(z)$ and a low frequency component $U1(z)$. The input signal $X(z)$ is passed through a low pass filter $H0(z)$ and a high pass filter $H1(z)$, yielding the $U0(z)$ and $U1(z)$ respectively.

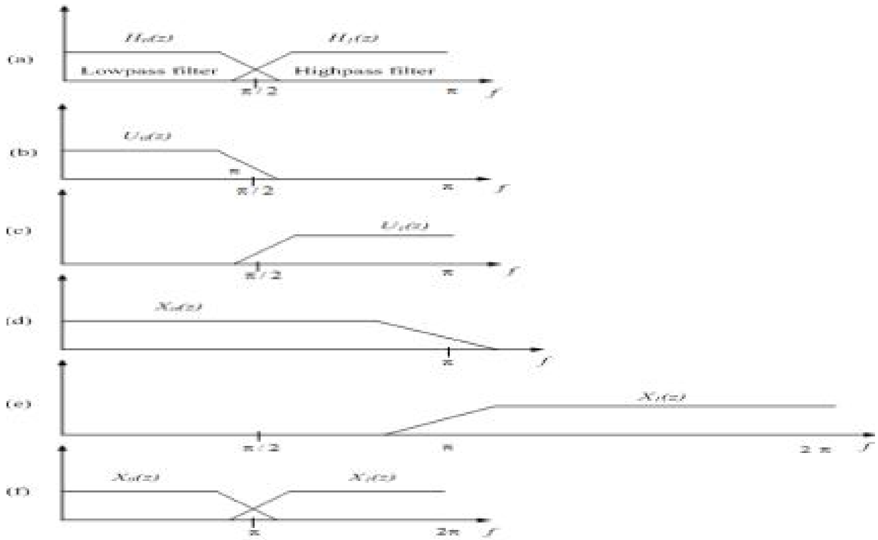

Figure: (a)

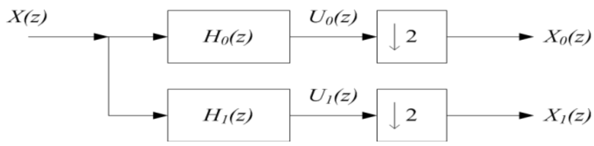

Figure (4)

Figure 4.Signal spectra in two-channel analysis filter bank. (a) Lowpass & highpass filtertransfer functions. (b) lowpass filtered signal spectrum U0(z).(c) highpass filtered signal spectrum U1(z) . (d) downsampled signal X0(z) spectrum. (e) downsampled signal X(z) spectrum (f) output signal spectra.

Consequently, with the sampling frequency, $Fs=2\pi$, the available bandwidth from 0 to π , is divided into two halves, $0\leq f\leq Fs4$ for the lower frequency signal $U0(z)$ and $Fs4\leq f\leq Fs2$ for the high frequency signal $U1(z)$. Therefore, the filtered signals $U0(z)$ and $U1(z)$ have half the bandwidth of the input signal after being convolved with the low pass filter and high pass filter respectively.The filtered and downsampled signal spectra are shown in Figure 4&5. Gives 2 channel filter synthesis bank.[X0(z)X1(z),]=12[H0(z12)H0(−z12)H0(z12)H0(−z12)][X(z12)X(−z12)] he two signal spectra overlap. The downsampling will produce aliased components of the signals, that are functions of $X(-z1/2)$ in Eq. 1,since the filtered signals are not bandlimited to π . Two-channel synthesis filter bank is the dual of analysis filter bank, as shown in Figure . 3 $G0(z)$ and $G1(z)$ denote the lowpass and highpass filters, which recombine [15] the upsampled signals $U0(z)$ and $U1(z)$ into $X(z)$, the reconstructed version of the input signal. The aliased images are removed by the filter $G0(z)$ in the frequency range $FS4\leq f\leq FS2$, while the filter $G1(z)$ eliminates the images in the upsampled signal $U1(z)$ in the frequency range $0\leq f\leq FS4$. Therefore, the signal $X(z)$, output from the synthesis filter bank is X(z)=[G0(z)G1(z)][X0(z2)X1(z2)]

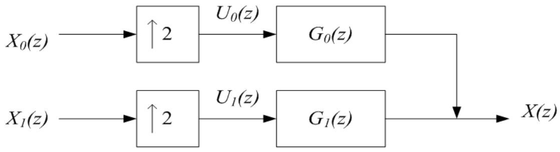

Figure 5: Two-channel Synthesis filter bank.

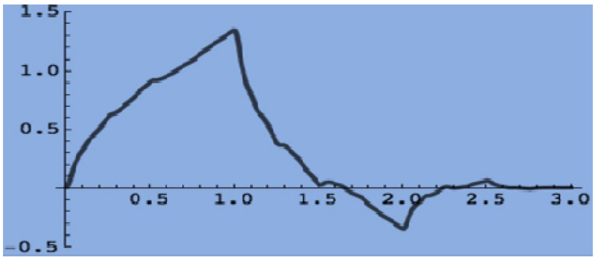

Figure 6: Scaling function.

Both the scaling sequence (Low-Pass Filter) and the wavelet sequence (Band-Pass Filter) (see orthogonal wavelet for details of this construction) will here be normalized to have sum equal 2 and sum of squares equal 2. This function is defined on the interval [0, 3]; it has no analytic formula.[7,8] It is the solution $\varphi(t)$of a difference equation, called variously "the dilation equation", "the refinement equation", and the multi-resolution analysis (MRA) equation": $\varphi(t) = \sum_n h(n)\ \sqrt{2}\ \varphi(2\ t - n)$ and in this case, the scaling coefficients h are:It is called D4 because it was invented by Ingred Daubechies and it has 4 nonzero h's. As I said, it is called a "scaling function" in contrast to "a wavelet". In some applications, they are normalised to have sum√2, so that both sequences and all shifts of them by an even number of coefficients are orthonormal to each other.Using the general representation for a scaling sequence of an orthogonal discrete wavelet transform with approximation order A, $a(Z) = 2^{1-A}(1+Z)^A\ p(Z)$ with N=2A, p having real coefficients, p(1)=1 and degree(p)=A-1,one can write the orthogonality condition as $a(Z)\ a(Z^{-1}) + a(-Z)\ a(-Z^{-1}) = 4$,or qually as $(2-X)^A P(X) + X^A P(2-X) = 2^A$(*),with the Laurent-polynomial $X := 1/2 \cdot (2 - Z - Z^{-1})$generating all symmetric sequences and

$X(-Z) - 2 - X(Z)$. Further, P(X) stands for the symmetric Laurent-polynomial $P(X(Z)) = p(Z)p(Z^{-1})$. Since $X(e^{iw}) = 1 - cos(w)$and $p(e^{iw})p(e^{-iw}) = |p(e^{iw})|^2$, P takes nonnegative values on the segment [0,2].Equation (*) has one minimal solution for each A, which can be obtained by division in the ring of truncated power series in X, $P_A(X) - \sum_{k=0}^{A-1} \binom{A+k-1}{A-1} 2^{-k} X^k$.Obviously, this has positive values on (0,2)The homogeneous equation for (*) is antisymmetric about X=1 and has thus the general solution $X^A(X-1)R((X-1)^2)$, with R some polynomial with real coefficients,the sum$P(X) = P_A(X) + X^A(X-1)R((X-1)^2)$shall be nonnegative on the interval [0,2] translates into a set of linear restrictions on the coefficients of R. The values of P on the interval [0,2] are bounded by some quantity 4^{A-r}, maximizing r results in a linear program with infinitely many inequality conditions.To solve $P(X(Z)) = p(Z)p(Z^{-1})$for p one uses a technique called spectral factorization resp. Fejér-Riesz-algorithm. The polynomial P(X) splits into linear factors $P(X) = (X-\mu_1)\ldots(X-\mu_N)$, N=A+1+2deg(R). Each linear factor represents a Laurent-polynomial $(X(Z) - \mu) = -\frac{1}{2}Z + 1 - \mu - \frac{1}{2}Z^{-1}$that can be factored into two linear factors. One can assign either one of the two linear factors to p(Z), thus one obtains 2N possible solutions. For extremal phase one chooses the one that has all complex roots of p(Z) inside or on the unit circle and is thus real.

TS 90

The TS90 is designed for ease-of-use – you'll spend less time operating the TDR, and more time repairing faults. Simply select the cable type to be tested and the TS90 does the rest. Impedance, Vp, gain, pulse width, and vertical position are automatically selected and adjusted as you scan the cable. Just move the cursor to the fault to pinpoint its location.On the performance side, the TS90 employs optimized pulsing and sampling, coupled with advanced filtering [9,10] and signal processing techniques, to insure the maximum measurement range.

Sim the Best for Locating Underground Cable Faults

SIM

The SIM technique combines low-voltage TDR and a thumper in an integrated system that makes the trace easier to interpret, with a clear indication of the fault location on a handheld display. The process starts by running a TDR test on a healthy core, which is stored in the SIM system memory. The thumper is then triggered to send a single high-voltage pulse and, while the arc is forming at the fault, the TDR sends a further low- voltage pulse. The arc acts as a very low impedance point that causes the pulse to reflect in exactly the same way it would from a short-circuit. The handheld display combines the two traces and the fault location is shown as a large negative dip, with its distance easily read off on the x-axis.

SIM enables a fault to be located to within a few metres, even over cable runs of several kilometres.

Transient State Analysis

This kind of techniques exploits the relationship between system parameters and the frequency of the transients and speeds of traveling waves induced in response to changing network con Figure uration involving a change in how energy is distributed in the system. For this reason, the main problem of these methods is to identify faults with small angles of insertion [13]. Below are two classes of such techniques.

Wavelet Transform Method

There can be observed an apparent superiority of SVM-based technique compared to using the LAMDA methodology and finite mixtures. However, this superiority can be attributed to changes in the descriptors and areas that must tolerate the techniques already named. Then, the proper selection of descriptors and areas plays an important role in the fault locator performance.Another factor to consider with techniques that take advantage of system information, and might be ignored, is the relevance of the data taken as a reference once the locator have been implemented. That is because the misrepresentation can decrease the efficiency of the locator. Finally, as a location for TW is concerned, two aspects are of vital importance: the first is the need to properly choose the mother wavelet to use, so that characterize most of the transient frequency and reach more precise conclusions. In [14], the author speaks of the need to even build the mother wavelet to maximize the available information. The second point is the need to assess the practical and financial feasibility of implementing a Wavelet fault locator before deciding to implement it. This is for the costs of measuring equipment and computational complexity that is needed to carry out this type of analysis.

Conclusion

The multirate digital signal processing techniques, including wavelets and filter banks are part of new emerging technologies, which are finding applications in the field of digital communications. DWT based Multicarrier modulation techniques have opened new avenues for researchers, to avoid the spectral leakage and spectral inefficiency associated with Fourier Transform based MCM techniques.It can be seen that the number of measurement points can play an important role in the choice of locator technology. In particular, the development of techniques that exploit the information and communication technologies applied to monitoring and automation of operation of distribution systems play an important role in the success of such strategies. In transient analysis techniques, it appears that still is not possible to maximize the computational tools to analyze this phenomenon. Finally, it should be clear that not always the most complex and expensive solution is the best. Simple techniques of localization, based on a preliminary analysis of the distribution network and a mixed technique of analysis should be implemented. The multirate digital signal processing techniques, including wavelets and filter banks are part of new emerging technologies, which are finding applications in the field of digital communications.

DWT based Multicarrier modulation techniques have opened new avenues for researchers, to avoid the spectral leakage and spectral inefficiency associated with Fourier Transform based MCM techniques.

References

[1] Bascom, E.C. and D.W. Von Dollen, 1994, “Computerized underground cable fault location expertise”, in IEEE Power Engineering Society Transmission and Distribution Conference, 376-382.

[2] Chaari, O., M. Meunier, F. Brouaye, 1996. “Wavelets: A New Tool for the Resonant Grounded Power Distribution System Relaying”, IEEE Trans on Power Delivery, 11(3): 1301-1308.

[3] Choi, M.S., D.S. Lee and X. Yang, 2005. “A line to ground fault location algorithm for underground cable system”, KIEE International Transactions on Power Engineering, 54: 267-273.

[4] D. Shakya and S. N. Singh, "SVM based fault location and classification using fuzzy classifier for PQ monitoring," Proc. IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy 2008.

[5] Germán Andrés-Morales España and Alvaro Gómez- Ruíz, Estudio e implementación de una herramienta basada en máqinas de soporte vectorial aplicada a la localización de fallas en sistemas de distribución

[6] Germán Morales-España, Hermann Raúl Vargas, and Juan José Mora-Flórez, "Influencia de la Variación en la Carga y del UIS Ingenierías, Universidad Industrial de Santander, vol. 6, pp. 47-57, 2007

[7] L. Sousa Martins, J.F. Martins, V. Fernao Pires, and C.M. Alegria, "A neural space vector fault location for parallel double-circuit distribution lines," Electrical Power and Energy Systems, vol. 27, pp. 225-231, 2005.

[8] E.A. Mohamed and N.D. Rao, "Artificial neural network based fault diagnostic system for electric power distribution feeders," Electric Power Systems Research, vol. 35, pp. 1-10, 1995.

[9] J. J. Mora-Flórez, G. Carrillo, and L. Perez, "Fault Location in Power Distribution Systems using ANFIS Nets and Current Patterns," Proc. IEEE/PES Transmission \& Distribution Conference and Exposition: Latin America TDC '06 [10] CREG, Resolución 097.: Comisión de Regulación de Energía y Gas, Septiembre, 2008.

[10] B. Terzic, "Distribution Companies of the Future," Power Engineering Review, IEEE, vol. 22, pp. c2-c2, 2002.

[11] F.H. Magnago and A. Abur, "A new fault location technique for radial distribution systems based on high frequency signals," Power Engineering Society Summer Meeting, 1999. IEEE, vol. 1, pp. 426-431 vol.1, 1999.

[12] IEEE Guide for Determining Fault Location on AC Transmission and Distribution Lines.: Power System Relaying Committee, IEEE Power Engineering Society, C37.114, 2004.
[13] [14] M.M. Saha, E. Rosolowski, and J. Izykowski, "ATP-EMTP Investigation for Fault Location in Medium Voltage Networks," International Conference on Power Systems Trasients, 2005.

Authors Profile

[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 iniversity in the year 2003.She has specialised in Power Systems, High Voltage Engineering.She is currently working as Assoc.Prof ,dept of EEE Siddhartha Institute of Engineering and Technolgy, Ibrahimpatnam, Hyderabad Her research interests include Simulation studies on faults identification in UG cable of LT and HT. She has 12 years of experience. Mail id gvitgem@gmail.com,

[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 specialised in Power Systems, High Voltage Engineering 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 Assoc.Prof and HOD of Dept of EEE, Siddhartha Institute of Engineering and Technolgy, Ibrahimpatnam, Hyderabad, Mail id D.Prabhavathi10@gmail.com,

[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 the Professor (EEE) in JNTUH College of Engineering, Kukatpally, Hyderabad. Published 16 Research Papers and presently guiding 5 Ph.D. Scholars. She has specialised 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 in institutes. Mail id munagala12@yahoo.co.in,

[4] Bhumanapally. Ravindhranath 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, Hyderabad . Mail id bumanapalli_brreddy@yahoo.co.in