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Study of S-Transform For Spectral Energy Feature Space for Fault Location in Transmission Line

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Abstract:
Paper presents a new Technique for power quality analysis using a modified wavelet transform known as S-transform. In this paper fault location calculation of transmission lines using S-transform based spectral energy feature space and multi-layer perceptron is presented. The features obtained from ST are distinct, understandable, and immune to noise. S-transform can provide the time domain and frequency domain information at the same time, gives remarkable insight in to the protection issues of a transmission line. The energy distributions of the faulted current waveforms are used to compute the fault location using the pattern recognition approach. This paper proposes the fault detection and classification through S-transform energy by using synchronized measurement of the differential and average energy of current signals. The S-transform energy calculations are used for fault location using a neural network.

Keywords: spectral energy; transmission line protection; multi-layer perceptron is presented; neural network.

I. INTRODUCTION

Power quality is an issue that is becoming increasingly important to both utilities and electricity consumers at all of usage. The term power quality has been widely used by many industrial and commercial electricity end-users in the last decade and includes all aspects of events in the system that deviates from normal operation. The quality of electric power has become an increasing concern for electric utilities and their customers over the last decade. Poor quality is attributed due to the various power line disturbances like voltage sag, swell, impulsive and oscillatory transients, multiple notches, momentary interruptions, harmonics, voltage flicker etc. So Power system protection is a very important and sensitive issue to deal with. If the system goes to abnormal condition, it should be restored as quickly as possible to avoid severe damage in the power system network. Mostly it includes two parts, transmission line and transformer protection. For transmission line, the protection measure should be very fast acting and accurate. There are mainly two types of fault location method in transmission line, namely the impedance method and the traveling wave method. The traveling wave method is through measuring the time of the fault signal transient traveling wave to the measuring terminal so as to identify. the fault location, when a fault occurs. Distance protection algorithms are usually used to protect the transmission line [1]. The above scheme works on measurement of impedance at the fundamental frequency between the fault point and relaying point. This is done by phasor estimation both amplitude and phase of the faulted signals (voltage and current). The possibility of synchronized measurement of phasors has introduced interesting methods regarding differential protection of transmission lines [2]. The implementation of Global Positioning System (GPS) based Phasor Measurement Units (PMU) makes differential protection of transmission lines a practical idea. The concept of using synchrophasors for digital protection has already been done. Literature shows previous works on PMU based protection of transmission lines . Also, spectral energy based differential protection has been done using Discrete Wavelet Transform (DWT) The most important issues for the transmission line protection are fault detection, fault classification and fault location determination. This paper uses S-Transform for obtaining spectral energy of the signals measured and uses an online window based simulation to determine the immediate detection of the fault. The faulted phases are then identified and one of the faulted phase waveform is used for energy computation and finding the fault location using a multi-layer perceptron neural network. S-Transform, due to its inherent merits, acts as a superior substitute to other transforms applied to power system signals. The option of using S-Transform for digital protection and power quality estimations simultaneously makes it a subject of validation tests. Such approach could help in the holistic and more generic view of the power system issues. The simulation results validate the suitability of applying S-Transform for detection, classification and location of different kinds of faults.

II. OVERVIEW OF S-TRANSFORM

S-Transform is an extension to the idea of the Gabor transform and wavelet transform. It is based on a moving and scalable localizing Gaussian window. It is fully convertible both forward and inverse from time domain to frequency domain. Phase spectrum obtained using S-Transform is absolute in the sense that the origin of the time axis is taken as the fixed reference point. The S-Transform falls within the broad range of multi-resolution spectral analysis, where the standard deviation is an inverse function of the frequency, thus reducing the dimension of the transform. The Generalized S-Transform of a time varying signal h(t) is obtained as:

$$S(\tau, f) = \int_{-\infty}^{\infty} h(t).\, w(\tau - t, f).\, exp\,(-2\pi f t)\, dt \quad (1)$$

where the window function w(t, f) is chosen as

$$w\,(t,f) = \frac{1}{\sigma\,(f)\sqrt{2\pi}} exp(-t/2.\sigma(f^2)) \quad (2)$$

And $\sigma(f)$ is a function of frequency as

$$\sigma(f) = \frac{\alpha}{|f|} \quad (3)$$

The window is normalized as

$$\int_{-\infty}^{\infty} W_n(t,f)dt = 1 \quad (4)$$

Here α is normally set to a value 0.2 for best overall performance of S-Transform where the contours exhibit the least edge effects and for computing the highest frequency component of very short duration oscillatory transients α is made equal to 5. The S-Transform performs multiresolution analysis on the signal, because the width of its window varies inversely with frequency. This gives high time resolution at high frequencies and on the other hand, high frequency resolution at low frequencies. The discrete version of (1) is obtained as

$$S(j,n) = \sum_{m=0}^{N-1} H[m+n]G(m,n)\, e^{\frac{i2\pi mj}{N}} \quad (5)$$

Where

$$G(m,n) = e^{\frac{-2\pi^2 m^2 \alpha^2}{n^2}}$$

And H(m, n) is obtained by shifting the discrete Fourier transform (DFT) of h(k) by n; H(m) is g

$$H[m] = \frac{1}{N}\sum_{k=0}^{N-1} h(k)e^{\frac{-2\pi mk}{N}} \quad (6)$$

and j, m, n = 0, 1, 2, …… , N-1

The computational efficiency of FFT is used to calculate the S-Transform and the total number of operations is N (N+N logN). The output from the S-Transform is an N by M matrix called the S-matrix whose rows pertain to frequency and whose columns pertain to time. Each element of the S-matrix is complex valued. The S-matrix can be represented in a time frequency plane similar to that of the wavelet transform.

III. CASE STUDY AND METHODOLOGY

A system given in [5] is taken and studied for different fault conditions Synchronized measurements of current signals are made near to the source and the receiver. The procedure followed in the protection scheme is given below.

* The measured current values at source side and the receiver side are used to calculate the average and differential currents of each of the three phases.

$$Iavg = \frac{I_s(k) + I_r(k)}{2} \quad \text{(i.e. Average current)} \quad (7)$$

$$Idiff = I_s(k) - I_r(k) \quad \text{(i.e. differential current)} \quad (8)$$

Where Is(k)and Ir(k)are the instantaneous current samples at sending end and receiving end respectively.

* Cumulative summation (CuSum) is performed over differences in amplitudes of the current cycle and the previous cycle of each of the current signals. The CuSum operation for a discrete time signal x(k)can be represented as

$$Cusum\,(k) = Cusum\,(k-1) + (x(k) - x(k-N_s)) \quad (9)$$

Where k is the discrete time index and Ns is the samples per cycle. The surges in the waveform can be easily detected by the CuSum signals by

$$I_{diff}^{Cusum}(\mathbf{k}) > I_{avg}^{Cusum}(\mathbf{k}) + \varepsilon \quad (10)$$

Where ε is a small bias to prevent false detection. During normal operation of the given system, $I_{diff}^{Cusum}(\mathbf{k})$ is nearly zero. At the moment of fault, the current reverses its direction and flows towards the fault point in between the source and the receiver. This makes I_{diff}^{Cusum} signal to rise up very high. The value of k at which the surge is detected gives the time index at CuSum detection occurs.

* Upon the completion of a fundamental time period after the CuSum detection, the set of Iavg and Idiff are passed to the STransform to obtain the time-frequency localized complex matrix containing distribution of signal amplitudes. The Stransform operation on a full cycle of the sampled signal x(k) to obtain the complex S-matrix can be represented as

$$[S]_{M\times N} = ST\,([x_{k+1}, x_{(k+2)}, \dots, x_{(k+N+1)}, x_{(k+1)}]) \quad (11)$$

Here, N=Ns i.e. the number of samples per fundamental cycle.

* The maximum energy magnitudes of signal are used to corroborate the fault in a particular phase. Energy matrix E is given by

$$[E]_{M\times N} = \left|[S]_{M\times N}\right|^2 \quad (12)$$

$$[E]^{Max}]_{1\times N} = Max\,([E]_{M\times N}) \quad (13)$$

Where M is the number of frequency indices and N is the number of time indices. A phase is said to be faulted if the energy of the differential current is greater than the energy of the average signal. Hence the faulted phases are differentiated from the non-faulted ones.

* The energy matrix E of one of the faulted phase(s) is further used for feature extraction and fault location computation. The following eight features are considered as input to the multi-layer perceptron capable of fault location estimation.

$$F = \begin{bmatrix} \overline{\max}(E_{diff}), \overline{\max}(E_{avg}), \overline{kurtosis}(E_{diff}), \overline{kurtosis}(E_{avg}), \\ \overline{entropy}(E_{diff}), \overline{entropy}(E_{avg}), \overline{std}(E_{diff}), \overline{std}(E_{avg}), \\ \overline{skewness}(E_{diff}), \overline{skewness}(E_{avg}) \end{bmatrix} \quad (14)$$

The bar over the operation indicates that for a given multidimensional data, the operation is performed repeatedly to reduce the data to zero dimensions. For a given set of sampled value $Y = [y_1, \dots, y_N]$ The statistical parameters considered here can be represented as

$$kurtosis\,(y) = \frac{\overline{\overline{(Y-\overline{Y})^4}}}{((Y-\overline{Y})^2)^2} \quad (15)$$

$$entropy\,(X) = -\sum(Y_h\,.log_2(Y_h)) \quad (16)$$

$$std\,(Y) = \sqrt{\frac{\overline{\overline{(Y-\overline{Y})^2}}.N}{N-1}} \quad (17)$$

$$skewness(y) = \frac{\overline{\overline{(Y-\overline{Y})^3}}}{((Y-\overline{Y})^2)^{\frac{3}{2}}} \quad (18)$$

$$\overline{Y} = N^{-1}\sum_{i=1}^{N} y_i \quad (19)$$

Yh is the set containing the normalized non-zero histogram count of the values in set Y. The feature set thus obtained for different simulated conditions are used to train the multi-layer perceptron. The qualified artificial neural network obtained after training acts as an intelligent tool for fault location approximation**.**

IV. RESULT AND DISCUSSION

The study is done for different fault locations and for different fault types using Matlab (Simulink).. The kind of faults simulations are L-G, LLL and LLL-G faults. The fault distance is represented in per unit and the study considers fault distances varying from 1% of the line to 99% of the line with a step size of 0.01 p.u. The sampling frequency used is 3.2 KHz or 64 samples per fundamental cycle of 50 Hz. S-Transform flawlessly provides required energy information for feature extraction. Each phase is allocated its own CuSum based S-transform fault detection; but for the purpose of fault location, only one of the faulted phase(s) is used. A particular simulation is considered here for demonstration. The simulation is run for 0.5s and an A-G fault is engaged at 0.3s with a ground resistance of 10 ohms at a fault location of 25% of the line. The figures of signal variations and the energy contours are given below.

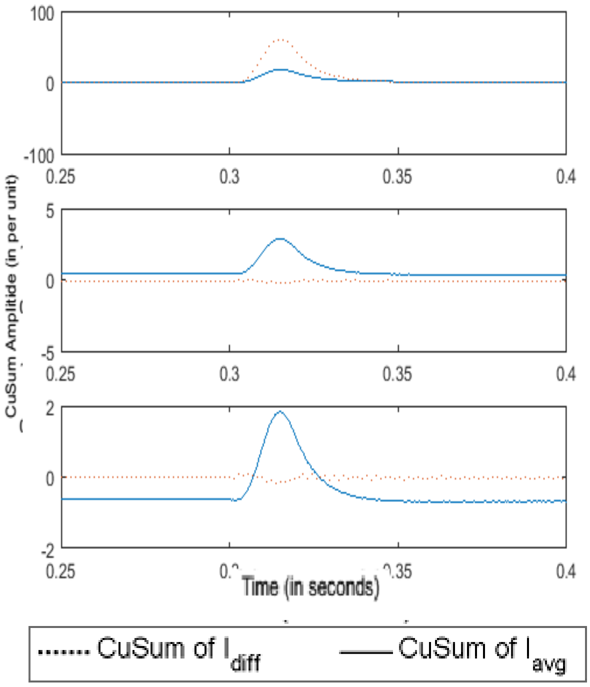

Figure.1. CuSum signals of Idiffand Iavgfor each phases (a) phase a CuSum signals (b) phase b CuSum signals (c) phase c CuSum signals.

Note that the CuSum detects surge of Idiff over Iavg only for phase a. The point of tripping is the point at which Ediff rises above Eavg. The energy content gets spread over the other frequencies liberally while fault occurs. These patterns can give more information other than the time and type of fault. The study of the energy patterns is extended to estimate the fault location using multi-layer perceptron based pattern recognition. Various fault types have been used to obtain the features. Hence the artificial neural network formed can obtain the fault location irrespective of the fault type. A particular case of 25% fault distance is taken and the errors in fault location estimation are given in Table 1. The multi-layer perceptron considered here has 20 hidden neurons with a sigmoidal activation function and an output layer with a linear activation. The number of inputs for a particular instance is 10 and has a single output. The network is trained using 70% of the cases and the rest are used for testing.

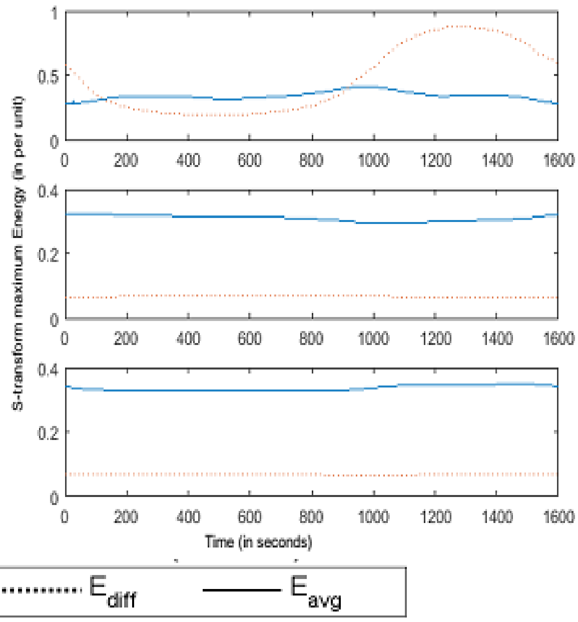

Figure.2. Energy signals of Idiff and Iavg for each phases (a) phase an energy signals (b) phase b energy signals (c) phase c energy signals. Note that the S-transform corroborates rise of Ediff over Eavg only for phase a.

Table.1. Absolute error of muti-layer perceptronfor different fault types in case of 25% fault distance

Fault Type	***Absolute Error (in pe unit)***
A-G	0.0018
ABC-G	0.0031
ABC	0.0031

The faults including all three phases are the most studied faults because of their severity. The proposed procedure has the least error for such kind of faults which increases its credibility in fault location. The results indicate the suitability of the S-transform in feature extraction and fault location approximation. The superior properties of the S-transform make it an ideal candidate for fault detection, classification and location computations.

V. CONCLUSION

The S-Transform was applied successfully to the system studied. The robustness of the transform was tested for various test cases of the same system using variation in fault types and fault locations. The capability of S-Transform to give comprehensive information about the signal features is used to perform feature extraction and fault location estimation using a multi-layer perceptron. The results validate the use of S-transform as a feature extraction tool.

VI. REFERENCES

[1]. J.A. Jiang, C.S. Chen and C.W.Liu, “A New Protection Scheme for Fault Detection, Direction Discrimination, Classification, and Location in Transmission Lines”, IEEE Transactions on Power Delivery, Vol. 18, No. 1, January 2003, pp. 34-42.

[2]. Nan Zhang, Mladen Kezunovic, “A real time fault analysis tool for monitoring operation of transmission line protective

relay", Electric Power Systems Research, Vol.77, 2007, pp. 361–370

[3]. C.S. Chen, C.W. Liu and J.A. Jiang, "A New Adaptive PMU Based Protection scheme for Transposed, Untransposed Parallel Transmission Lines", IEEE Transactions On Power Delivery, Vol. 17, No. 2, April 2002, pp.395-404.

[4]. Joe-Air Jiang, Jun-Zhe Yang, Ying-Hong Lin, Chih-Wen Liu,Jih-Chen Ma "An Adaptive PMU Based Fault Detection / Location Technique for Transmission Lines Part I: Theory and Algorithms", IEEE Transactions On Power Delivery, Vol. 15, No.2, April 2000, pp. 486-493

[5]. H.A. Darwish, A.M.I. Taalab, A.H. Osman, N.M. Mansour and O.P. Malik, "Spectral Energy Differential Approach for Transmission Line Protection", IEEE Power Systems Conference and Exposition, 2006, pp. 1931-1937