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Analysis of Power Quality Disturbances using Empirical Mode Decomposition and SVM Classifier

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***Abstract*— Power Quality disturbances like harmonics, voltage swells, transients, voltage swells are increasing every year with the increase in number of non-linear loads in the modern electronic devices. This may introduce many technical problems and hence detection and classification of disturbances become necessary. Empirical Mode Decomposition and Multivariate Empirical Mode Decomposition algorithms are used for detection of features and Support vector machine as a classifier. The features from the Simulink generated data and online gathered data are extracted and classified using the SVM classifier.**

***Index Terms*— Empirical Mode Decomposition, LIBSVM, Multivariate Empirical Mode Decomposition, Octave 3.8.1, Support Vector Machine.**

I. Introduction

The use of electricity in the field of science and technology is immense. It has created a revolution in the area of modern day electronic equipments. Due to the widespread use of electronic devices, which is comprised of power electronics like programmable logics, etc. resulted in a drastic change in electric loads nature. So, it is very much important to understand the quality of the power which is supplied with a power system Therefore, the power quality can be defined as the measure of ideal power systems and also it defines the extent of variation of signal characteristics like voltage, frequency, current in the normal system. Because of the increase in usage of non-linear loads and power electronic equipments, PQ has become an important issue and PQ noise like voltage dips, swell, flickers, harmonics, interrupts are often encountered in the industrial, domestic applications.

Because of PQ disturbances in the system, production of electric power with a high quality is the main problem of power engineering. Hence it is required to evaluate the problems using disturbance detection and classification algorithms.

The short duration voltage variations like voltage sag, swell, transients and steady state variations like harmonics are considered here. The features are extracted using Empirical Mode Decomposition (EMD) and Multivariate EMD algorithms and are classified using Support Vector Machine (SVM).

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II. Literature Survey

Power Quality data are represented in terms of time series of the amplitudes and these data are unstable and non-stationary. Hence information regarding both the time and frequency domain plays an important role. The detection and classification method based on Fourier linear combiner and a fuzzy based system is capable of classifying the variety of noise data but it requires large computation time and a small change in magnitude of phase angle results in error [1]. The method based on Self Organizing Learning Array System (SOLAR) uses wavelet transform to extract the features and SOLAR for classification. SOLAR has many advantages, but it requires a large number of training data set for classification purpose [2]. The method based on EMD and neural network classifies the data accurately, but the Probabilistic Neural Network (PNN) requires more memory to store the model [3]. Iterative EMD based method classifies the data by applying the EMD iteratively but the difficulty increases in separating the harmonics as the number of harmonics content increases [4]. The method based on wavelet transform, Fourier transform with back propagation Artificial Neural Network (ANN) predicts the fault current in the transmission line, but the method is complex and computational complexity is more [5]. Classification method based on S-transform and decision tree result in robust classification, but the small changes in data results in a large amount of errors [6]. The method based on Time-Time transforms and Neural Network gives a better result comparison between ANN and K-Nearest Neighbor classifier is done. But the closer values of mean and variance results in the erroneousness classification of each noise type [7]. Hence, to analyze the unstable, non-linear power quality disturbances in both time-frequency domains, a robust method called Empirical Mode Decomposition (EMD) to detect the features and Support Vector Machine (SVM) classifier is proposed. The emerging EMD technology is based on univariate data.

So, the extension of it called Multivariate EMD is presented. The comparison between two stoppage criteria of EMD is also presented.

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III. METHODOLOGY

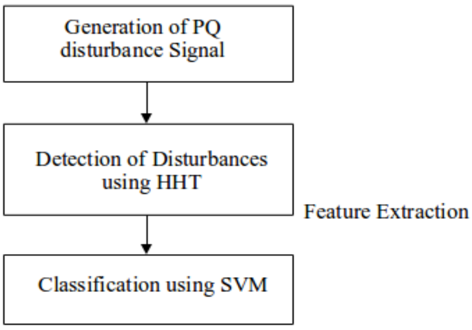

Figure 1. Classification Stages Based on Proposed Approach.

A. Generation of Power Quality Disturbances Using Simulink

1) Generation of Voltage Sag

Voltage sag is a reduction in voltage for a momentary period of time (0.5 cycle to a few seconds). The cause for sag can be changes in load, line to ground faults, etc. The three-phase source is the three-phase supply to the network. The distributed parameter line is the transmission line to which the three-phase earthing fault is introduced. The waveform is simulated for 0.35 seconds and the voltage sag is generated in the interval of 0.1 to 0.25 seconds [7-8], as shown in Fig 2.

2) Generation of Voltage Swell

Voltage swell occurs for a short period of time (0.5 seconds to a minute) during which there will be an increase in voltage level compared to nominal voltage. These are caused by faults in the systems. A voltage swell signal is generated by inserting the breaker circuit. Initially, the three-phase breaker circuit is set to closed state and it is made to open during the period of 0.1 to 0.25 seconds to generate swell [7-8]. The voltage swell waveform is simulated for 0.35 seconds as in Fig 3.

3) Generation of Voltage Harmonics

Harmonics are voltage or current signals having frequencies that are integer multiple of the fundamental frequency. Harmonics are caused due to the presence of nonlinear loads. The three-phase bridge controllable rectifier circuit is used for generation of harmonics in the circuit. Due to the mismatch in the impedance between the source and the load, harmonics are produced. The waveform is simulated for 0.35 seconds of duration [7-8], as shown in Fig 4.

4) Generation of Transients

Transients are sudden change in the power level and it occurs in milliseconds to microsecond time. Transient voltages are due to lightning, faults in network switching operations. And the voltage transient waveform is generated as shown in Fig 5.

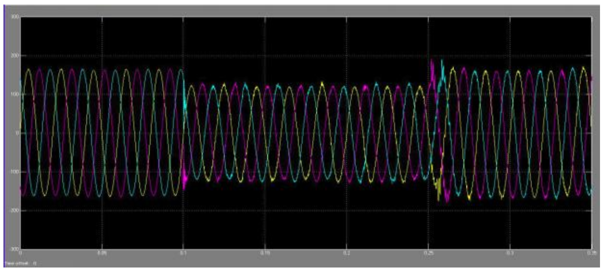

Figure 2. Voltage Sag Waveform.

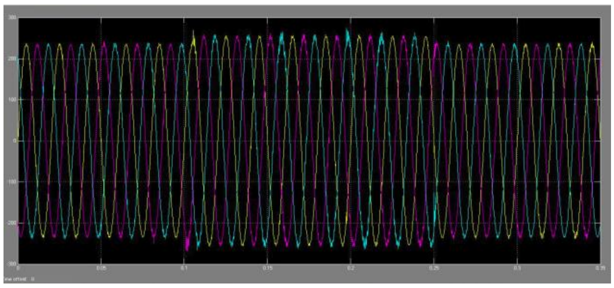

Figure 3. Voltage Swell Waveform.

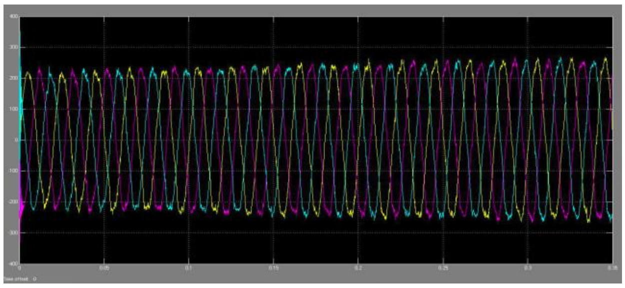

Figure 4. Voltage Harmonics.

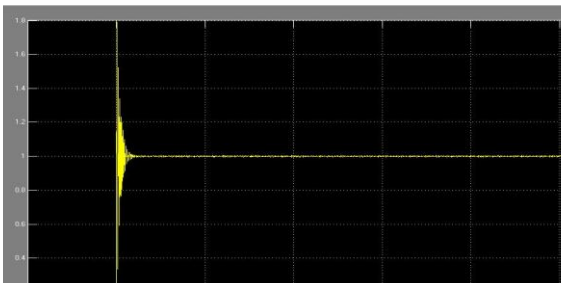

Figure 5. Voltage Transients.

B. Feature detection using Empirical Mode Decomposition

1) Empirical Mode decomposition Algorithm

1. Consider x(t) be a univariate signal. The EMD algorithm starts with defining the local minimal points and local

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maximal points.

2. Cubic spline interpolation is used to join the local extrema points to get upper envelope u(t) and lower envelope l(t).
3. Find the mean of upper and lower envelope.

$$m(t) = (u(t) + l(t))/2 \quad (5)$$

4. Determine the difference between input signal and mean, m(t).

$$d(t) = x(t) – m(t) \quad (6)$$

5. If d(t) is a zero mean process and if the extrema and zero crossing value differs by one then call it as first IMF. Otherwise, substitute x (t) by d (t) in step (a) and repeat the process.
6. Compute the residue

$$r(t) = r(t) – c(t) \quad (7)$$

If r(t) is a monotonic function, then call it as residue, otherwise goto step (a) and repeat the process. The above repeated process is called as “sifting” process. Two types of stopping criteria are used to stop the sifting process.

A standard Deviation based approach based on previous and present IMF is calculated. This process is based on single parameter and theoretical analysis and practical formulation is difficult using this method.

To avoid the problem of over-sifting, Rilling's criterion is used. The boundary conditions and extracting the extreme values are better than the previous method and hence the spreading of extreme values are reduced thus avoiding over-decomposition of signals.

It is based on two thresholds (θ1, θ2) and a tolerance (α) value. The sifting process is iterated for a duration less than 'θ1' seconds for a predefined fraction of (1-α) of the duration and evaluation function less than' θ2' .The value of 'α' can be set to 0.05. The Hilbert transform is applied to the extracted features of said EMD. The statistical features like mean, standard deviation, maximum, minimum values, correlation between first IMF and data are extracted from first Instantaneous Frequency (IF) and first Instantaneous Amplitude (IA).The Instantaneous frequency is the derivative of instantaneous phase. Hilbert transform of first IMF gives the first Instantaneous Amplitude value.

2) *Multivariate Empirical Mode Decomposition (MEMD)*

The Empirical Mode Decomposition algorithm works for univariate data. The extension of EMD called MEMD is presented for multi-variable data. Hence, the three-phase voltage signal can be decomposed based on MEMD.

C. Support Vector Machine (SVM) Classification

From the surveyed classifiers, it is found that Radial Basis Function (RBF) based SVM is found to be best classifier and extracted statistical features are trained and tested using Octave interface LIBSVM software.

It is observed that, the use of Radial Basis Function kernel is best for nonlinear, unstable data like power quality disturbance signal.

IV. Experiments And Results

The performance comparison between EMD based on standard deviation and Rilling's criterion is evaluated using correlation coefficient values.

TABLE 1. COMPARISON OF PEARSON PRODUCT-MOMENT CORRELATION COEFFICIENT BETWEEN EMD STOPPAGE CRITERIA.

SI. No	Correlation Coefficient Values		
	Power Quality Disturbances	***First Stoppage Criteria***	***Second Stoppage Criteria***
1.	Voltage Sag	0.0203	0.0176
2.	Voltage Swell	0.5863	0.6254
3.	Harmonics	0.0181	0.0127
4.	Transients	0.9235	0.9390

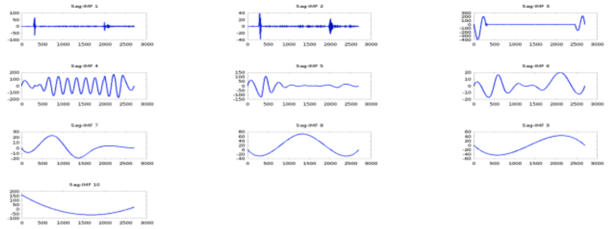

Figure 6. Decomposition of Sag signal using first stoppage criterion.

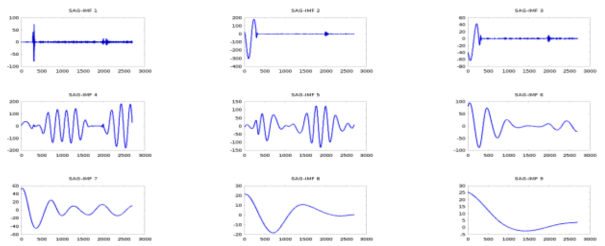

Figure 7. Decomposition of Sag signal using second stoppage criterion.

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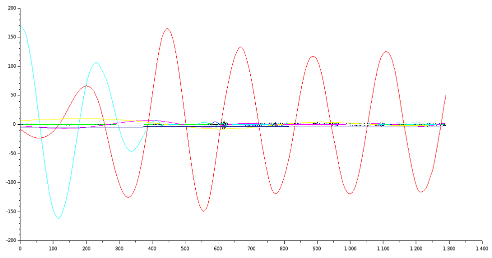

Figure 8. Decomposition of Sag signal using MEMD.

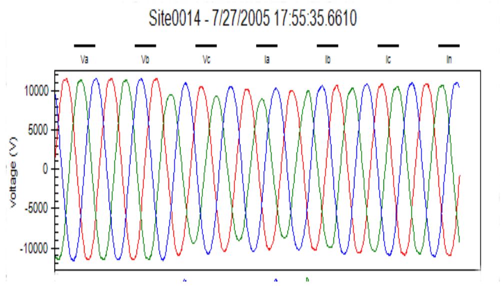

Figure 9. Online data of various events gathered.

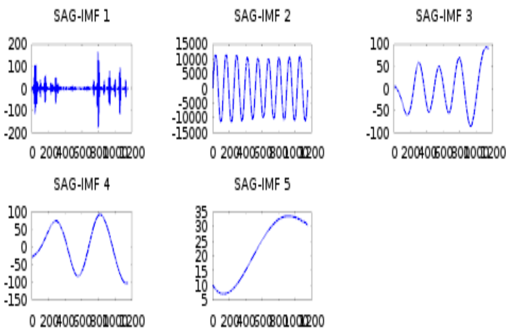

Figure 10. Decomposition of online data.

SVM classification using RBF on simulated data and online gathered data is done and higher percentage accuracy of 80 is observed.

V. Merits

1. The basic problem of EMD, over-sifting is overcome by using Rilling's criteria.
2. The SVM classifier works well for nonlinear data like power quality disturbances.
3. Analysis of real-time data shows the fault location by using first IMF.
4. Computation time of the algorithm reduces compared to that of a traditional EMD algorithm.
5. MEMD works on three-phase data hence all the thee-phase can be analyzed at a time.

VI. Applications

The main application of the proposed algorithm is to monitor the power quality disturbances in commercial, industrial, domestic applications.

VII. Conclusion

The power quality disturbances such as harmonic, transients, voltage sag, voltage swell are generated using the Simulator. The features are extracted using the Empirical Mode Decomposition algorithm. The two stoppage criteria are compared based on the correlation coefficients. Rilling's criterion is found to be having higher efficiency and over-sifting of signals can be avoided. The Multivariate EMD is applied for three-phase data and features are extracted. Along with the generated data, online data features are trained and tested using SVM classifier with RBF kernel

VIII. References

[1] P. K. Dash, S. Mishra, M. M. A. Salama, and A. C. Liew, "Classification of Power System Disturbances Using a Fuzzy Expert System and a Fourier Linear Combiner," *IEEE Transactions On Power Delivery*,Vol.15, April 2000.

[2] Haibo He and Janusz A. Starzyk, "A Self-Organizing Learning Array System for Power Quality Classification Based on Wavelet Transform," *IEEE Transactions On Power Delivery*, Vol. 21, No. 1, January 2006.

[3] M Manjula, A V R S Sarma, "Assessment of Power Quality Events by Empirical Mode Decomposition based Neural Network," *IEEE Transactions on Power Delivery*, Oct. 2009, 2159-2165.

[4] C. F. Drummond and D. Sutanto, "Classification of Power Quality Disturbances using the Iterative Hilbert Huang Transform," *IEEE Conference on Harmonics and Quality of Power (ICHQP)*, 2010.

[5] Neenu Raphael, Ancy Sara Varghese, "Mathematical Transforms Clubbed With Artificial Intelligence for Power Quality Disturbance Classification," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 2, Issue1, 2013.

[6] A. Rodriguez, Merino, E. Aguado, J, Lopez, J.J, "A decision Tree and S-Transform Based Approach for Power Quality Disturbances Classification", *IEEE Conference on Power Engineering, Energy and Electrical Drives (POWERENG)*, May 2013.

[7] Ankita Dandwate , Dr. Prof. K. B. Khanchandani "Generation of Mathematical Models for various PQ signals using MATLAB," *International Journal of Engineering Research and Applications (IJERA)*, ISSN: 2248-9622.

[8] Namrata B. Pawar, Dhondiram M. Kakre, "Generation of different types of Voltage Sag using Matlab/Simulink," *International Journal of Engineering and Innovative Technology (IJEIT)*, Volume. 3, Issue 9, March 2014.

[9] Donghoh Kim and Hee-Seok Oh, "EMD: A Package for Empirical Mode Decomposition and Hilbert Spectrum," *Contributed Research Articles Rjournal.*

[10] Chih-Chung Chang and Chih-Jen Lin, "LIBSVM : a library for Support Vector Machines," *ACM Transactions on Intelligent Systems and Technology*, Issue 3, 2011.

[11] Gabriel Rilling, Patrick Flandrin and Paulo Gon calv'es, On Empirical Mode Decomposition and Its Algorithms.

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