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Detection and Classification of Short Transients and Interruption using Hilbert Transform

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Abstract- Widespread use of electronics from home appliances to the control of more sophisticated and costly industrial processes has raised the awareness of power quality. Power quality disturbance is generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipment. The study of power quality and ways to control is a major concerned for electric utilities, large industrial companies, businesses, and even home users. The study has intensified due to equipment have become increasingly sensitive to even minute changes in the power supply voltage, current, and frequency. In electrical energy power networks, disturbances can cause problems in electronic devices so their monitoring is very fundamental. In this paper, we address the problem of disturbance detection by using Hilbert transform which is employed as an effective tool for tracking the voltage waveforms in electrical distribution systems. In addition to this classification of disturbance is carried out by using cross correlation technique. Simulation results obtained shows the accuracy and flexibility of Hilbert transform in detecting the time instants during which the disturbance has occurred. This has been tested for oscillatory transients, interruption and multiple event interruption and sag.

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Detection and Classification of Short Transients and Interruption using Hilbert Transform

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Abstract- Widespread use of electronics from home appliances to the control of more sophisticated and costly industrial processes has raised the awareness of power quality. Power quality disturbance is generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipment. The study of power quality and ways to control is a major concerned for electric utilities, large industrial companies, businesses, and even home users. The study has intensified due to equipment have become increasingly sensitive to even minute changes in the power supply voltage, current, and frequency. In electrical energy power networks, disturbances can cause problems in electronic devices so their monitoring is very fundamental. In this paper, we address the problem of disturbance detection by using Hilbert transform which is employed as an effective tool for tracking the voltage waveforms in electrical distribution systems. In addition to this classification of disturbance is carried out by using cross correlation technique. Simulation results obtained shows the accuracy and flexibility of Hilbert transform in detecting the time instants during which the disturbance has occurred. This has been tested for oscillatory transients, interruption and multiple event interruption and sag.

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I. Introduction

The electrical power system is expected to deliver undistorted sinusoidal rated voltage and current continuously at rated frequency to the consumers. In recent years, grid users have detected an increasing number of drawbacks caused by electric power quality (PQ) variations. PQ problems have sharpened because of the increased number of loads sensitive to power quality. The problem is difficult to solve since the loads have become important causes of degradation of Power quality. Poor quality of electric power is normally caused by power line disturbances such as impulses, notches, glitches, momentary interruption wave faults, voltage sags, swell, harmonic distortion and flicker resulting in miss operation or failure of end user equipment. Many techniques can be employed for the detection of PQ disturbances, but the number of samples required was found to be large. Because of the above disadvantage, the algorithm becomes more complex and hence it cannot be applied to work in real-time. The disturbance detection algorithm should be able to detect disturbances as soon as possible, regardless of the nature of the voltage disturbance. At the same time, the disturbance estimation algorithm should have a good selection accuracy. In fact, fast detection algorithms may produce false trip operation of the mitigation equipment.

The main task of PQ analysis involves detection, identification, recognition and classification of various types of PQ disturbances. In this paper, we first generate the disturbances namely interruption, transient and sag + interruption. These are generated using IEEE standard equations with the necessary parameters. Decomposition of signal can be performed using empirical mode decomposition (EMD). Next phase is the detection of time instants at which the disturbance is occurring. This can be done by Hilbert Huang transform (HHT) i.e. EMD and Hilbert transform (HT). EMD gives intrinsic mode functions (IMF) for which HT is applied to get the amplitude plot and the amplitude plot gives time value. The final stage is classification and is done by cross correlation. Cross correlating amplitude plot with the standard sine wave will give the correlation coefficients (XCF). By comparing XCF with standard values, signal can be classified as an interruption, transient etc.

II. Literature Survey

Mario Ortiz et al., Proposed an advanced mathematical tool applicable to the recognition and classification of power system transients and disturbances. The Hilbert transform technique has been applied to analyze several short-term and steady events, like a short circuit, a capacitor-switching transient, or a line energisation used the instantaneous frequency to avoid overtraining errors. Simulation results demonstrated shows the performance, accuracy and flexibility of the HT techniques found superior [1]. Likhitha. R, et al., Proposed a mathematical model for a PQ signal generation which was developed and was validated against the real time PQ signal. PQ events such as sag, swell, transient, and harmonics were generated using the mathematical model. Real time signals consisting of PQ disturbances were generated and compared with the results of synthetic signals. Duration of occurrence of PQ disturbance was noted from real time results [2]. Tianshi Wang introduced a detection model to detect accurately interharmonics, based on HHT. The signals containing interharmonics

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were processed by EMD. It determined the instantaneous frequency and amplitude of each interharmonic, and the time of interharmonic mutations [3]. M.Caciotta et al., Provided a model for disturbance estimation by Hilbert transform which tracks the voltage waveforms in electrical disturbance systems. Tracking capability was detected by simulation and was tested for voltage dip, noise and frequency change [4]. Rajiv Kapoor et al., Proposed a method to detect and classify the power quality events based on demodulation concepts. The technique was well tested and detects transients, sag, and swell (for single PQ events) in real-time. Feedforward neural classifier has been employed for classification of PQ events from the knowledge base [5].M.Sushama et al., Proposed two prominent methods for detection and classification of sag and swell. The first one was based on the statistical analysis of adaptive decomposition signals and the second one is a new technique for detecting and characterizing disturbances in power systems based on wavelet transforms. The results obtained by the two methods are compared and tabulated [6].

III. Theory of EMD, HT and Cross Correlation

The EMD process will decompose a signal x(t) into IMFs which have the following properties:

- Each IMF must have exactly one zero between any two consecutive local extrema.
- Each IMF must have zero local mean.

An EMD algorithm decomposes adaptively the signal x(t) into intrinsic mode functions $c_i(t)$, i = 1, 2, …, n and into residue r(t):

$$x(t) = \sum c_i(t) + r(t); \text{ for } i=1 \text{ to } n \quad (1)$$

Where n means the number of IMF functions. Residue r (t) reflects the average trend of a signal x (t) or a constant value. The algorithm for searching of intrinsic mode functions is based on a procedure called "shifting" described in algorithm below.

a) Create upper envelope E_u (t) by local maxima and lower envelope $E_l(t)$ by local minima of data x (t).
b) Calculate the mean of upper and lower envelope i.e... $m_1(t)$
c) Subtract the mean from original data i.e.

$$h_1(t) = x(t) - m_1(t). \quad (2)$$

d) Verify that h_1 (t) satisfies the conditions for IMFs. Repeat steps a) to d) with h_1 (t), until it is an IMF.
e) Get first IMF (after k iterations) i.e.

$$c_1(t) = h_{1(k-1)}(t) - m_{1k}(t) \quad (3)$$

f) Calculate first residue, i.e. $r_1(t)=x(t)-c_1(t)$ (4)
g) Repeat whole algorithm with r_1 (t), r_2 (t) … until residue is monotonic function.
h) After n iterations x (t) is decomposed according to equation 1.

Combination of EMD and HT is called Hilbert Huang transform (HHT). The Hilbert transform is useful in calculating instantaneous attributes of a time series, especially the amplitude and frequency. The instantaneous amplitude is the amplitude of the complex Hilbert transform, the instantaneous frequency is the time rate of change of the instantaneous phase angle. The Hilbert Transform H(t) of a signal S(t) of the continuous variable t is defined as:

$$H(t) = \frac{1}{\Pi} \quad \mathrm{P}\int_{-\infty}^{\infty} \frac{S(\eta)}{\eta - t} d\eta \quad (5)$$

In a simple term, the Hilbert transform of a signal effectively produces an orthogonal signal that is phase shifted by 90 degrees from the original signal and independent of the frequency of the signal. Instantaneous frequency and amplitude of IMFs can be calculated as follows:

Instantaneous Amplitude

$$A(t)=\sqrt{S(t)^2+H(t)^2} \quad (6)$$

Instantaneous Phase

$$\phi(t)=\arctan\frac{H(t)}{S(t)} \quad (7)$$

Instantaneous frequency f(t) is found using:

$$\Phi'(t)=w(t)=2*pi*f*t \quad (8)$$

Where

$$w(t) = \frac{S(t)dH(t)\text{-}dS(t)H(t)}{\sqrt{S(t)^2+H(t)^2}} \quad (9)$$

Overall the HHT shows a great promise as a means to classify PQ events because of its flexibility and the ease with which the instantaneous magnitude and frequency information can be interpreted.

Cross-correlation, in simplest terms, is a measure of similarity between two waveforms. For two continuous functions f(t) and g(t), it is mathematically represented as:

$$[f*g](t) = \int_{-\infty}^{\infty} \bar{f}(\Gamma)g(t+\Gamma)d\Gamma \quad (10)$$

Where "*" stands for operation of cross-correlation and f(Γ) represents the conjugate of f(Γ). Cross correlation coefficients (XCF) are also capable of deciding whether a power event is multiple or single.

IV. Implementation

The first step is to generate the disturbances, using IEEE standard equations shown in Table 1. The plots for these disturbances are obtained using Matlab. By varying the parameters mentioned in the Table 1, required plots can be obtained. Generated disturbance (interruption) shown in Figure 1 is input to EMD process. EMD decomposes the signal into IMF each of which has instantaneous amplitude and frequency. EMD uses the shifting process for decomposing the signal. The true IMF is obtained through EMD algorithm repetition. Once true IMF is obtained, residue function is calculated, until residue is either monotonic or constant. If the residue obtained is either monotonic or constant, then EMD stops. The residual value provides average trend of the input signal. To detect the duration of the occurrence of disturbance in input signal, it is necessary to apply Hilbert transform on the 1st IMF obtained. The reason to choose 1st IMF is because it contains maximum information, energy of the input signal. Apply Hilbert transform for the 1st IMF to get amplitude plots. This Hilbert amplitude plot detects the point of disturbance. The peak indicates the beginning and end of disturbance occurrence and is shown in Figure 1. The above procedure is repeated for transients, multiple event interruption and sag and the plots for the same are presented in Figure 2 and 3.

In the classification phase, the output of the Hilbert plot of disturbance and a standard sine wave of frequency 50Hz is considered as input. Next, is to perform cross correlation between them according to the equation 10. This function provides us the correlation coefficients, XCF obtained is compared with values of single, multiple, interruption or for no event. If the value of XCF <=0. 1, then it is classified as an interruption. If XCF value lies in between 0.5 to 0.95 then signals is a single event, i.e. The signal has single disturbance. If XCF value lies in between 0.1 and 0.5 then the signal is classified as multiple event and the signal has multiple distortion. For all values of XCF >=0. 95, the signal is a pure sine without any disturbance, and hence it is classified as no event. The above condition is tabulated in Table 2. Once the signal is classified as single or a multiple event, it is necessary to find out the disturbances. There is a set of standard values for each disturbance shown in table 3. By comparing these with obtaining XCF, the signal can be easily classified according to the standard form. For all the values of XCF <=0.8, the signal is classified as transient.

Table 1 : Different types of power quality disturbances

Disturbance	Equation	Parameters
Pure Sine	$y(t)=\sin(w_d t)$	$w_d=2*pi*50$
Interruption	$y(t)=\sin(w_d t)*[1-\alpha(u(t-t_1)-u(t-t_2))]$	$0.9<=\alpha<=1$; $T<=t_2-t_1<=9T$; $T=1/50$
Sag	$y(t)=\sin(w_d t)*[1-\alpha(u(t-t_1)-u(t-t_2))]$	$0.1<=\alpha<=0.9$; $T<=t_2-t_1<=9T$; $T=1/50$
Transient	$y(t)=\sin(w_d t)+e^{((t_2-t_1)/\tau)*(u(t-t_1)-u(t-t_2))}*\sin(2*pi*f_n*t)$	$0.1<=\alpha<=0.8$; $0.5T<=t_2-t_1<=3T$; $T=1/50$; $300Hz<=f_n<=900Hz$; $5ms<=\tau<=40ms$

Table 2 : Type of PQ event with their XCF

Range of XCF	Type of PQ event
>=0.95	None
0.5 to 0.95	Single
0.1 to 0.5	Multiple
>=0.1	Interruption

Table 3 : PQ classification based on XCF

PQ event	XCF
Transient	<=0.8
Interruption	<=0.1

V. Result

Figure 1, 2, 3 shows the detection and classification results of disturbances corresponding to interruption, transients and multiple event. The GUI shows the plots of input signal (disturbances), 1st IMF, residue and the Hilbert plot for the 1st IMF. The correlation coefficient based on which the disturbances are classified are shown, and the results are tabulated in Table 4.

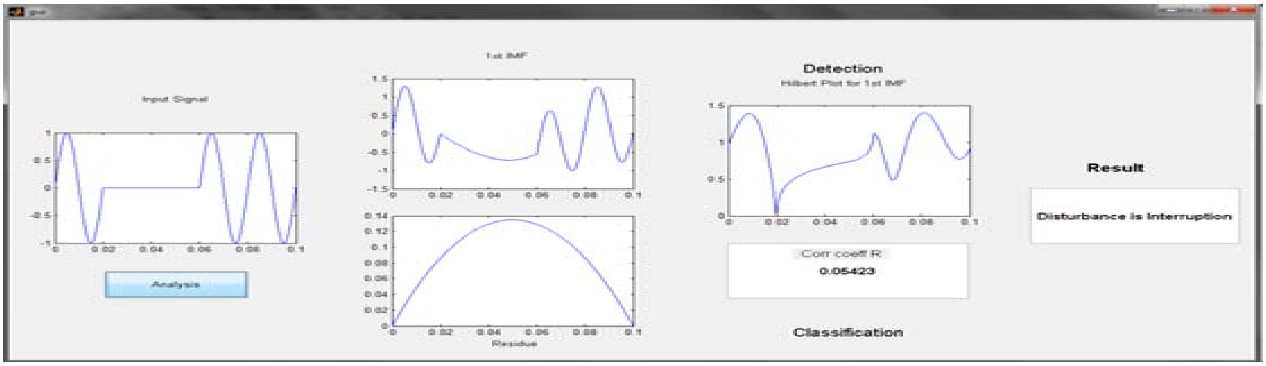

Figure 1 : Detection and classification of Interruption

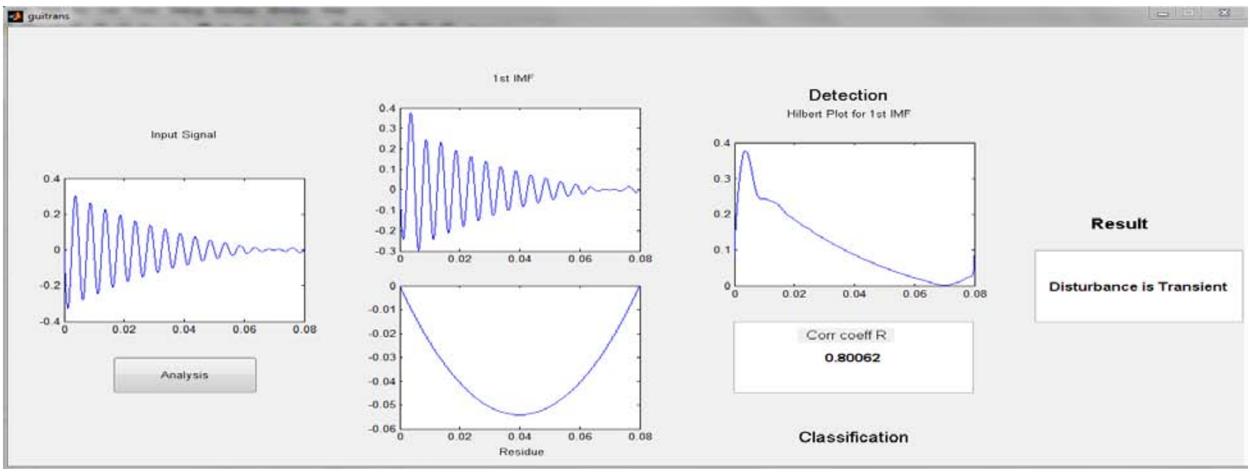

Figure 2 : Detection and classification of transients

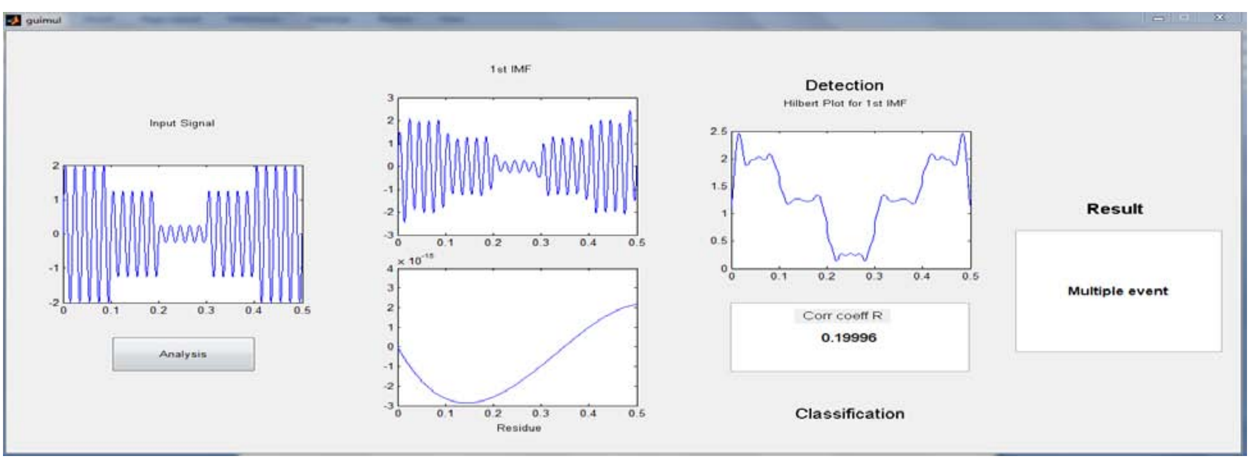

Figure 3 : Detection and classification of multiple event

Table 4 : Results of detection and classification

Disturbances	Detection interval	Correlation coefficients
Interruption	0.02 to 0.06	0.05
Transient	0.01 to 0.08	0.8006
Multiple event Interruption from 0.2 to 0.3 Sag from 0.1 to 0.4	0.2 to 0.3	0.19996

VI. Conclusion

This paper has presented the application of the Hilbert transform to the identification of electric power transients, interruption and multiple distortion by first filtering the signal into the IMF. The signal decomposition method EMD is used to extract signal components, and determine disturbance or quality phenomena components to identify patterns such as the instantaneous frequency of various types of disturbance with a simplified configuration of a power system. The use of instantaneous frequency is to avoid overtraining errors which improves the orthogonality of the results and therefore, the interpretation of them. Simulation result demonstrates that the performance, physical meaning, robustness, accuracy and flexibility of the Hilbert transform techniques are found to be superior.

References Références Referencias

1. Mario Ortiz, Sergio Valero and Antonio Gabaldón, "Transient Power and Quality Events Analyzed Using Hilbert Transforms", Journal of Energy and Power Engineering 6 (2012) 230-239, February 29, 2012.
2. Likhitha.R, A.Manjunath, E.Prathibha, "Development of Mathematical Models for Various PQ Signals and Its Validation for Power Quality Analysis", International Journal of Engineering Research and Development ISSN: 2278-067X, Volume 1, Issue 3 (June 2012), PP.37-44.
3. Tianshi Wang, "The Research on the Inter harmonics Detection Method Based on HHT", Communications in Information Science and Management Engineering, Apr. 2013, Vol. 3 Iss. 4, PP. 184-187.
4. M.Caciotta, S.Giarnetti, F.Leccese, Z.Leonowicz, "Detection of transients and interruptions using Hilbert transform", X1X IMEKO World congress, Fundamental and applied metrology, sept-6.11, 2009, Lisbon, Portugal.
5. Rajiv Kapoor, Manish Kumar Saini, Prerit Pramod3, "Detection of PQ Events Using Demodulation Concepts: A Case Study", International Journal of Nonlinear Science, ISSN 1749-3889 (print), 1749-3897 (online), Vol.13 (2012) No.1, pp.64-77.
6. M.Sushama, G. Tulasi Ram Das, "Detection and classification of voltage Swells using adaptive decomposition & wavelet Transforms", Journal of Theoretical and Applied Information Technology, 2005-2008.
7. Devendra Mittal, Om Prakash Mahela, Rohit Jain, "Detection and Analysis of power quality under faulty conditions in electrical systems", IJEET, ISSN 0976-6553, Volume 4, Issue 2, March-April (2013), pp. 25-36.
8. Subhamita Roy and Sudipta Nath, "Classification of Power Quality Disturbances using the Features of Signals", International Journal of Scientific and Research Publications, Volume 2, Issue 11, November 2012, ISSN 2250-3153.
9. Qin Wei, Quan Liu, Shou-Zhen Fan, Cheng-Wei Lu and Tzu-Yu Lin, "Analysis of EEG via Multivariate Empirical Mode Decomposition for Depth of Anaesthesia Based on Sample Entropy", www.mdpi.com/journal/entropy, ISSN 1099-4300, 30 August 2013.
10. Hahn Stefan L, "Hilbert transform in signal processing", Artech House, Inc., Boston, 1996.
11. S. Sathiakumar, "Power quality study using Matlab", lecturer in school of Electrical and Information Engineering, University of Sydney, NSW2206, Australia.

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