



DETECTION OF OSCILLATORY TRANSIENTS USING MORPHOLOGICAL TRANSFORM

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ABSTRACT

This paper presents the Mathematical Morphology Transform (MMT) signal processing technique for the detection of oscillatory transients due to capacitance switching in a power distribution system. The oscillatory transient is simulated and processed to the MMT technique, generating Structural Element (SE) from which it obtained the value of energy and standard deviation for the samples of power system transient and is classified. The classified output showed that the MMT had more compatibility in identifying the power quality disturbances.

Keywords: power quality, oscillatory transients, mathematical morphology transform, structural element, parseval's theorem.

1. INTRODUCTION

The power quality disturbances can be classified into steady state variations and events. The steady state variations are small deviations from the desired voltage and current values. Voltage fluctuations, harmonic distortion and unbalancing voltage and current are some of the steady state variations. A significant sudden change of wave shape or deviation of voltage or current from the desired value is termed as power quality event. The common power quality events are voltage sag, voltage swell, interruptions and transients.

The need of extracting power system voltage and current waveforms from the raw data using simulation models is to analyze them through signal processing techniques [1]. Signal processing is therefore called upon for identification, classification and characterization; also the techniques used vary depending on the characteristics of the phenomenon. Alternating voltage magnitude is often measured using Root Mean Square (RMS) method. A rough estimate of non-periodic or time varying voltage variations which include voltage dips, swells and interruptions are characterized and classified using RMS [2].

In literature, there are several signal processing techniques like Fourier Transform, Short-Time Fourier Transform (STFT), S-Transform, wavelet transform and wavelet packet transform are used for examining the power quality events such as swell, sag and transients. Fourier Transform and STFT can be used only in a fixed window width which is inadequate for the analysis of the transient non-stationary signals [3]. In modern spectrum and harmonic analysis, Discrete Fourier Transform (DFT) is used to monitor and assess the recorded data. DFT is not successful in transient signal tracking, because it must perform only in a fixed length window. The magnitude and phase angle of various frequency components of stationary voltage or current waveform are obtained by using DFT method. Rectangular sampling windows of 10 cycle's width in 50Hz power system are used and the grouping of output bins of DFT analysis is done to compute the voltage and current waveform harmonic distortion. However, DFT analysis only provides

information in the frequency domain with a resolution that depends on the width of the time window. It does not give any time information about the signal provided [4]. In reference, various electric power quality disturbances are analyzed using wavelet transform in time-scale domain [5]. A complex wavelet network is used for power quality disturbances [6]. In the paper, authors utilized various mother wavelet functions to identify the voltage sag [7]. In another method, wavelet packet transform is used for power quality disturbances [8].

When more explicit information is needed such as evaluating the disturbance propagation, time frequency decomposition method is necessary. The wavelet transform approach can be used for analyzing the power system transients. Wavelets are short duration oscillatory waveforms with zero mean that soon decay to zero amplitude, especially suited to analysis of non-stationary signals. Unlike DFT analysis, the wavelets simultaneously evaluate a signal in both time and frequency domains with different resolutions [9]. Wavelets are used in transient analysis when it is not important to know the exact frequency of a disturbance, but the time information is important [10]. Discrete wavelet transform, the digital representation of the continuous wavelet transform, can be implemented by using a multi-stage filter bank with wavelet function and it's dual as Low-Pass filter (LP) and High-Pass filter (HP) respectively. This decomposition tree is down sampled by two at the output of the filters which scales the wavelet by two for the next stage [11].

As an extension of the wavelet transform and Fourier transform, the S-transform is introduced by Stockwell et al. and it has good time frequency analysing ability [12]. The S-transform has distinctive advantages compared with the wavelet transform and Fourier transform. The time frequency spectral localization technique of S-transform is invertible and this technique combines the elements of the wavelet transforms and STFT. The width of analysis window of S-transform decreases with frequency, thereby rendering its resolution frequency dependent. In recent days, a non-linear signal processing technique called MM technique has been used in various power system problems such as islanding



techniques [13], high impedance fault and power quality disturbances [14]. Various MM filters such as Closing Opening Difference Operation (CODO), Median, Multi-resolution Morphological gradient (MMG), and Open-Closing Maximal and Close-Opening Minimal (OCCO), are available [15].

In this paper, OCCO type filter has been used for analyzing the power system disturbances and the oscillatory transient is analyzed using mathematical morphology transform with flat SE and OCCO filter and then the energy and standard deviations are calculated using Parseval's theorem.

2. METHODOLOGY OF THE PROPOSED WORK

Figure-1. Shows the methodology of the proposed system organized in the following steps.

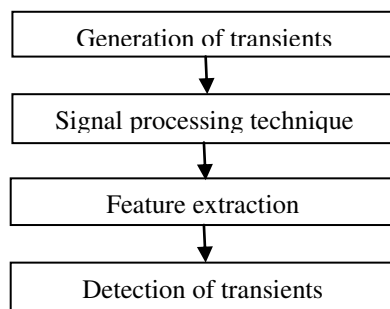


Figure-1. Methodology of the proposed work.

- Generation of oscillatory transients from power system model using MATLAB/SIMULINK software.
- Data obtained from the event are processed to MM transform signal processing technique.
- Feature extraction is done on the processed events of MM transform. MM transform produces energy matrix from the OCCO processed waveform. The energy values for all instances of time and the corresponding STD values are obtained using Parseval's theorem.
- Detection of power quality disturbances are based on obtained energy values from processed signals.

3. INTRODUCTION TO MATHEMATICAL MORPHOLOGY TRANSFORM

Morphology is the method of applying an edge operation on the images. Any signal can be converted to image as Mathematical morphology can be applied to images only. All the operations of Mathematical morphology are based on the interaction between the image and structural element. The SE is a set of points which is used to slide over the entire signal which is another set of points. In SE slide over, signal is like a moving window and detects its interaction with the neighbourhood of every point of the signal.

The basic operations of mathematical morphology are dilation and erosion from which all other operators such as opening, closing, hit or miss, top-hat are derived. The erosion and dilation operations are developed from the definitions of Minkowski's addition and subtraction. The closing operation fills narrow valleys and gaps in a contour. From the four basic mathematical morphology operators namely erosion, dilation, opening, and closing, many morphological filters like CODO, OCCO, Generalized Multi-resolution Morphological Gradient (GMMG), MMG, Series MMG, Close-Opening-Open-Closing morphological gradient (OOCG) are developed [14].

SE is the fundamental component for any Mathematical Morphology transformation in which signals are broken into sub signals with different physical significance in order to take out the features from the parent signal and to reduce the noise from the parent signal. SE may have any one of the following different geometrical shapes like linear, sphere, disc, ball, beeline, curve, triangle, polygon and inclined line. The selection of SE is based on practice, trial-error method, the size of the signal, its sampling rate, and the type of frequency spectrum of interference. Normalization of voltage and current waveforms is necessary in order to make an SE more generalized so that it can be used for different voltage and current levels. After normalization, the height of structuring element is assigned with a very small arbitrary value. Optimization of height is not needed as the output for various heights is same. However, for different SE, the selection of height is also to be considered. The length of SE has to be adjusted according to the sampling rate of the signal. An increase in sampling rate increases the length of SE and a decrease in sampling rate decreases the length of SE. However, it does not follow a linear fashion. Any change in the length of SE affects the size of filter window and therefore there is a change in the delay in the output, i.e., an increase in length of SE increases the filter window size which in turn increases the delay in the output. For OCCO operation the delay in output is given by $(l-1) \Delta T$ where l is the length of SE and ΔT is the sampling interval.

4. APPLICATION OF PARSEVAL'S THEOREM FOR DATA COLLECTION

According to Parseval's theorem, the energy of signal $v(t)$ is same for signal domain and transformed domain [16].

$$E_{signal} = \frac{1}{T} \int_0^T |v(t)|^2 dt = \sum_n \left| v(t) \right|^2 \quad (1)$$

where T and N are the time period and length of the signal $i(t)$. The Fourier transform of the signal is $v(t)^2$. Using equation (1), the energy is computed from MM output; then corresponding STD is calculated for power system transients. Power system transient signal samples provide relevant feature for identifying the type of transients using energy and STD values. Once the signal is extracted it is



processed to MM transform to obtain relevant features for identifying the change in the waveform output.

5. SIMULATION RESULTS AND DISCUSSIONS

5.1 Power system model for oscillatory transients

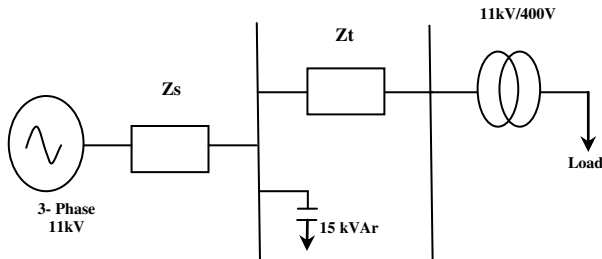


Figure-2a. Equivalent circuit for generation of transients.

The equivalent circuit for the generation of oscillatory transients is given in Figure-2a. The occurrence of transients is captured after energization of capacitor at the secondary of the transformer using simulink model. The simulink model is constructed with a three phase source of 3MVA, 11kV, 50Hz capacity connected to a load of 15kW resistive and 15kVAR inductive load through bus bars and a transformer of 11kV/400V rating. The oscillatory transients are observed in the voltage waveform when a capacitor bank of 15 kVAR is energized at the bus bar. Oscillatory phase voltages due to transients are obtained by voltage moment of the load side.

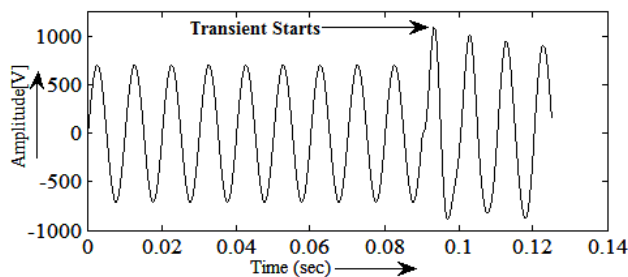


Figure-2b. Voltage waveform with transient.

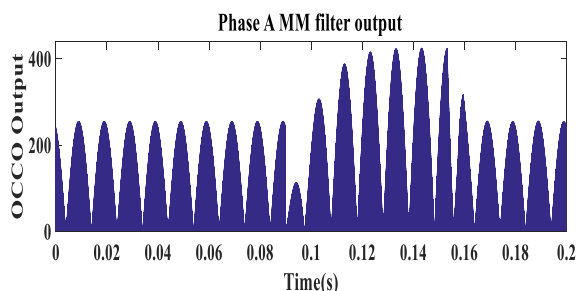


Figure-2c OCCO output for MM transform

Figure-2. Detection of transients using MM transform.

Figure-2b shows the generation of transient signal. Figure-2c shows the OCCO processed MM

transform output for transients which occur at 0.09sec. Table-1 gives the computed energy values of switching transients. Using these values transients can be easily discriminated from other events like harmonic, sag and swell. The occurrence of oscillatory transients is detected by setting a proper threshold value for the average values of energy and STD disturbances.

Table-1. Energy values under normal condition and during oscillatory transient period.

Phase	Normal condition		Oscillatory transient	
	Energy	Standard deviation	Energy	Standard deviation
a	1059660	34.6788	1623130	42.1317
b	794745	28.4969	7756543	103.0687
c	684574	25.9463	6092204	90.8754

8. CONCLUSIONS

This paper presented the study of oscillatory transients using MM transform based signal processing technique. The energy and standard deviation were evaluated for the given waveform for specified time duration under normal condition and during oscillatory transient condition. For example, the duration of transient was uniformly made to occur at the same time duration 0.09sec to 0.15sec. The results obtained from MM transform had uniform variation over that period of time. The occurrence of oscillatory transients are easily detected by comparing its energy and standard deviation values with that of normal condition by using a simple rule based system. The proposed MM transform was found to be more robust, as it was having uniform variation of energy values for a particular power system disturbance, faster convergence of results and very less computation time.

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