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Entropy Based Feature Extraction for Power Quality Disturbances

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Abstract: Power line disturbances are mainly caused due to voltage sag, voltage swell, outage and harmonics. These disturbances must be recognized and classified. This paper presents wavelet based decomposition of the disturbances using norm entropy and pattern recognition by probabilistic neural network. In this paper total of 175 power quality disturbance signals are considered for designing the neural network model.

Key Words: Power quality, wavelet packet decomposition, entropy, probabilistic neural network.

I. INTRODUCTION

The term power quality is generally used to express the quality of the voltage. It is sometimes used as synonymous with supply reliability to indicate the existence of an adequate power supply. The poor power quality causes many problems for affected loads such as instabilities, malfunctions, short life time etc. This poor quality of electric power is normally caused by power line disturbances such as sag, swell interruptions, harmonics, sag & harmonics and swell & harmonics. Toimprove the power quality it is required to identify & classify the different power quality disturbances so that appropriate mitigating actions can be taken. The wide use of non-linear loads and other electronic equipment in the power distribution network has made the analysis a major problem. Distribution systems are vulnerable to problems such as voltage wave distortion, local faults, poor power factor etc. The demand for clean power has been increasing in the past several years.

The reason is mainly due to increased use of microelectronic processors in various types of equipment, such as computer terminals, programmable logic controller, diagnostic systems etc. Most of devices are quite susceptible to disturbances of the incoming alternating voltage waveforms. Wavelet analysis is becoming a common tool for analysing localized variations of power within a time series. Gencer et al.[1] proposed that several studies have been done to show the identification and classifications of power quality problems using wavelet transform. Poisson et al.[2] andSantaso et al.[3] proposed that wavelet transform is a signal processing tool used in power quality analysis. Gargoom et al.[4] proposed that the wavelet transform(WT), like the Short Time Fourier Transform (STFT), provides an understandable transient signal representation corresponding to a time frequency plane. If such disturbances are not mitigated theycan lead to failures or malfunctions of various sensitive loadsinpower system and may be costly. Therefore, there is a growing need to develop power quality (PQ) monitoring techniques that can classify the potential sources of disturbances. Ouyang et al. [5] has shown using mathematical morphology that power quality control systems can detect disturbances very soon. However, the signal under investigation isoften corrupted by noises and the performance of the mathematical morphology would be greatly degraded.

Gaouda et al.[6] showed the main advantage of multiresolution analysis comes from its ability to separate power quality problems that overlap in both time and frequency. Dwivedi et al [7] proposed a low complexity robust de-noising and detection scheme in the wavelet domain for automatic detection and time localization of power quality events. Meher et al. [8] proposed the design of a tool to quantify power quality parameters using wavelet and fuzzy set theory. Safty et al. [9] showed how wavelet entropy in association with fuzzy inference system is used for disturbance classification. The wavelet entropy principle has been used in different applications in power system.Reaz et al.[10] showed how artificial neural network can be used to solve power system protection problems, particularly those where traditional approaches have difficulty in achieving the desiredspeed, accuracy, and selectivity. Chung et al.[11] proposed that a hidden Markov model is adopted to correctly determine the disturbance existence by extracting hidden relationships between the wavelet packet coefficients at different levels. Pérez et al. [12] proposed a new method for online real-time detection and classification of voltage events in power systems.

The efficiency in the detection and analysis of voltage events using Kalman filtering depends on the model of the system used. Glil et.al [13] proposed a data mining approach to generate a set of inference rules by adopting power quality disturbance database. Mishra et al. [14] proposed a probabilistic neural network based on S-transform for the classification of different types of power quality disturbances. As it required less number of features the memory requirement and computational time has been reduced. Oleskovicz et al. [15] proposed a hybrid system that can automatically detect, locate and classify the disturbances affecting power quality in an electrical power system. The disturbances characterized are events from an actual power distribution system simulated by the ATP (Alternative Transients Program) software.

II. EATURE EXTRACTION OF POWER QUALITY DISTURBANCES

A wavelet is a waveform of effectively limited duration that has an average value of zero. Wavelets use variable window sizes thus lead to an optimal time-frequency

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resolution in all the frequency ranges. The wavelet transform is computed separately for different segments of time signal. Entropy is a measure of irregularities of states such as imbalance and uncertainity. Since the power quality (PQ) disturbances have the imbalance e.g. the different frequency component and the different energy distribution, the norm entropy is used to extract the significant features from different PQ disturbance signals as a measurement of these irregularities.

The Daubechies db_4 wavelet as mother wavelet has been chosen for signal decomposition up to the 12^{th} level.

III. RESULTS OF FEATURE EXTRACTION TECHNIQUE

Seven types of disturbance signals are considered in this paper and the pure sinusoidal waveform have been considered as the reference. All the disturbance signals are normalized with respect to pure sine wave. All the signals are of the frequency 50 Hz, amplitude as 1 p.u. and time period is calculated on the basis of 256 points/cycle. Fig.1 shows the graph of norm entropy vs. decomposition levels for different amplitudes of sag. Amplitudes of sag had been varied from sag 0.9 p.u. up to sag 0.1 p.u. Fig.2 shows the graph of norm entropy vs. decomposition levels for different amplitudes of swell. Amplitudes of swell had been varied from swell 1.1 p.u. up to swell 1.9 p.u.Fig.3 shows the graph of norm entropy vs. decomposition levels for different cycles of outage. Outages have been varied in terms of cycles i.e. from outage 1 cycle up to outage 8 cycles. Fig.4 shows the graph of norm entropy vs. decomposition levels for harmonics. The harmonic signal consists of fundamental frequency.3^{rd} harmonics, 5^{th} harmonics,7^{th} harmonics and 9^{th} harmonics.Fig.5 shows the graph of norm entropy vs. decomposition levels for sag and harmonics. The variation of the amplitude of the signal is varied from sag 20%,sag 30%,sag 50% and sag 90%. Fig.6 shows the graph of norm entropy vs. decomposition levels for swell and harmonics. The variation of the amplitude of the signal is varied from swell 20%,swell 30%,swell 50% and swell 90%. In case of sag, swell and outage the level d_8 shows the peak as can be observed from Fig.1, Fig.2 and Fig.3 and in case of harmonics, sag with harmonics and swell with harmonics the level d_6 shows the peak as can be observed from Fig 5, Fig 6 and Fig 7.

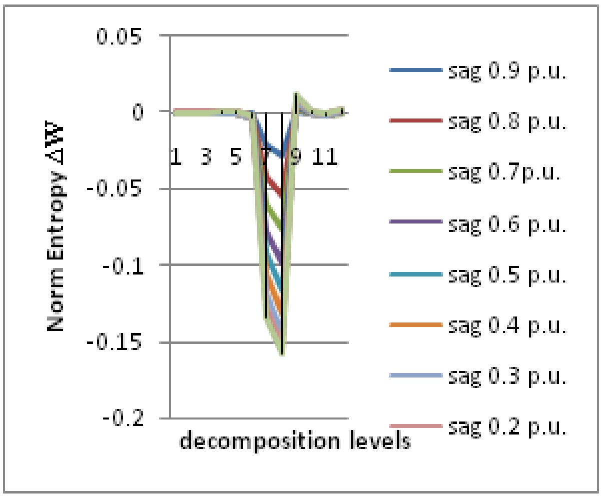

Figure.1. Variation in norm entropy for sag.

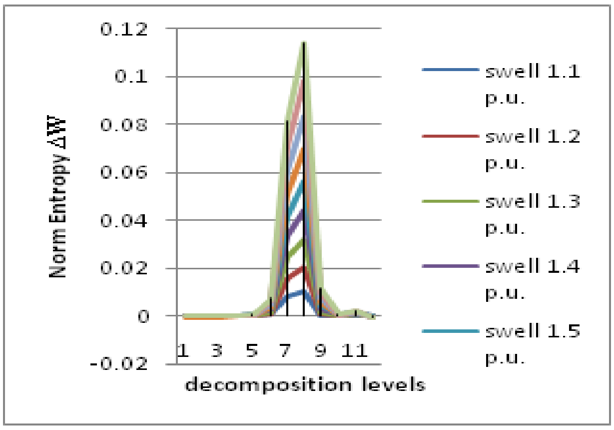

Figure.2. Variation in norm entropy values for swell.

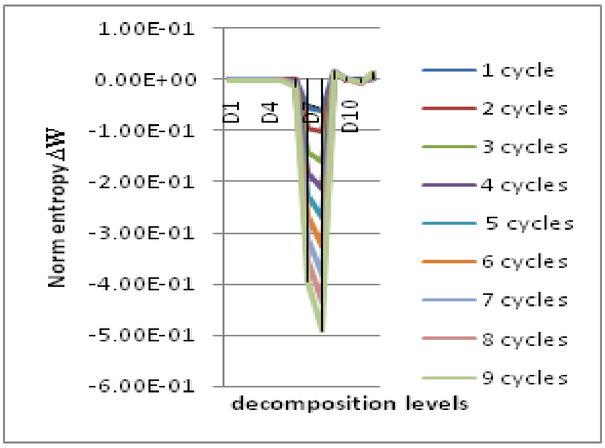

Figure.3.Variation in norm entropy for interruption.

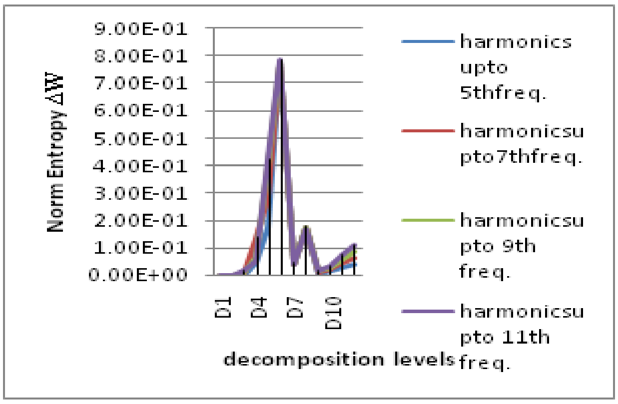

Figure.4. Variation in norm entropy for harmonics.

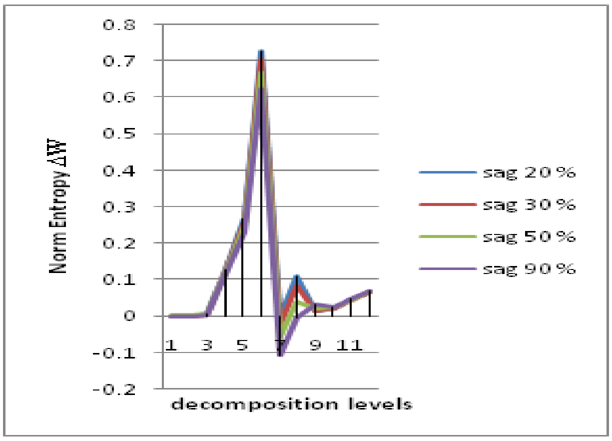

Figure.5. Variation in norm entropy for sag & harmonics

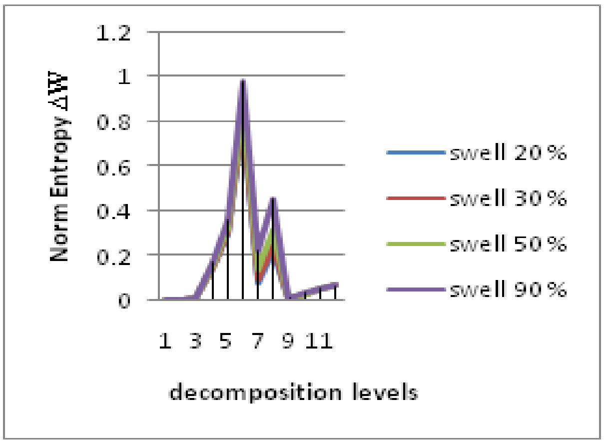

Figure.6. Variation in norm entropy for swell & harmonics

IV. SIMULATION AND ANALYSIS

Probabilistic neural networks are also known as belief networks, bayesian networks, and knowledge maps. The advantages of PNN model are:

a. Training is much faster and accurate.

b. Reduction of data size and memory space without losing the properties of the features.

Seven types of signals have been taken namely pure sine wave, voltage sag, voltage swell, outage, harmonics, sag with harmonics and swell with harmonics. Based on the feature extraction with wavelet entropy, the training and testing data are constructed. Considering db_4 as mother wavelet up to the 12th level detail and approximate coefficients are obtained. The total size of training data is 13× 175, where 13 is the number of levels of each case and 175 comes from 25 cases per class multiplied by 7 classes of signals. This is the input vector to the classifier. Similarly the total size of testing data is 13× 70, where 70 come from 10 cases per class multiplied by 7 classes of signals.

Table 1 shows the classification result of PNN algorithm based on norm entropy feature extraction. In case of pure sinusoidal signal all the 10 signals matched with the target output so the accuracy is 100%. For case of voltage sag. sag&harmonics and swell & harmonics all the 10 signals matched with the target output so the accuracy is 100%. For case of voltage swell

Table1: Classification result of PNN algorithm based on norm entropy feature extraction

True class	**Pure**	**Sag**	**Swell**	**Interruption**	**Harmonics**	**Sag& harmonics**	**Swell & Harmonics**	**Accuracy**
Pure	10	0	0	0	0	0	0	100%
Sag	0	10	0	0	0	0	0	100%
Swell	0	1	9	0	0	0	0	90%
Interruption	0	3	0	7	0	0	0	70%
Harmonics	2	0	0	0	8	0	0	80%
Sag & Harmonics	0	0	0	0	0	10	0	100%
Swell & Harmonics	0	0	0	0	0	0	10	100%

V. CONCLUSION

In this paper all the power quality disturbance signals are decomposed with the help of wavelet norm entropy and pattern recognition is done with probabilistic neural network (PNN).The PNN model had been trained for 175 signals and tested for 70 signals. The accuracy of the neural network model is found to be 91%.

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