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CLASSIFICATION OF POWER QUALITY DISTURBANCES USING WAVELET TRANSFORM AND S-TRANSFORM BASED ARTIFICIAL NEURAL NETWORK

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ABSTRACT*:* This paper presents features that characterize power quality disturbances from recorded voltage and current signals using wavelet transformation and S-transform analysis. The disturbance of interest includes sag, swell, transient and harmonics. A 25kv distribution network has been simulated using matlab software. The feature extraction has been done using wavelet transformation and S-transform, the coefficients are collected and given to the neural network for the best classification. The S-transform based classification shows better performance in detecting, localizing and classifying compared to the wavelet transform based Back Propagation Algorithm.

Keywords: Artificial neural network, power quality,S-transform,Wavelettransform.

I. INTRODUCTION

Power quality issues have been a source of major concern in recent years due to extensive use of power electronic devises and non-linear loads in electrical power system and consequently sensitive detection and accurate classification of power disturbances. To monitor various power quality problems[5], different techniques are available like Fourier transform[1], short-time Fourier transform, and wavelet transformation. Short-time Fourier transform (STFT) is most often used. This transform has been successfully used for stationary signals where properties of signals do not evolve in time. For non stationary signals, the STFT does not track the signal dynamics properly due to the limitation of a fixed window width. Thus, STFT cannot be used successfully transient signals of both high and low- frequency components. Wavelet analysis [2] is based on the decomposition of a signal according to time-scale rather than frequency. This uses multi-resolution analysis technique. Wavelet transform[4] represents the signal in time frequency format but the frequency information will be lost at particular point of time. S-transform [6] technique which is obtained by the multiplication of phase correction factor to the continuous wavelet transformation which is introduced in this paper for time frequency localization of signals [9]. This technique is also used for the feature extraction which will be given as input to the artificial neural network [3].

The paper proposes a 25kv distribution network from which the four power quality problems voltage sag, voltage swell, transient and harmonics are detected. The samples taken are hundred for each power quality disturbance and the feature extraction has done with wavelet transform and s-transform programming approach. The detail coefficients obtained from s-transform and wavelet transform are given to the classifier. In which back propagation algorithm and probabilistic neural networks have been used. So the proposed S-transform based probabilistic neural network classifier effectively classifies the power quality problems compared to previous Fourier transform, short time Fourier transform and wavelet transform.

II. WAVELET TRANSFORMATION MULTI-RESOLUTION ANALYSIS

In multi resolution analysis (MRA) [7], wavelet functions and scaling functions are used as building blocks to decompose and construct the signal at different resolution levels. The wavelet function will generate the detail version of the decomposed signal which constitutes the high pass digital filter and the scaling function will generate the approximated version of the decomposed signal which constitutes low pass digital filter.

Let c_0 (n) be a discrete –time signal recorded from a physical measuring device. This signal is to be decomposed into a detailed and smoothed representation. From the MRA technique, the decomposed signals at scale 1 are c_1(n) and

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$d_1(n)$,where $c_1(n)$ is the smoothed version of the original signal (or approximation), and $d_1(n)$ is the detailed representation of the original signal $c_0(n)$ in the form of wavelet transform coefficients.

$$c_1(n) = \sum_k h(k-2n)c_0(k) \quad \text{------------------------------ (1)}$$

$$d_1(n) = \sum_k g(k-2n)c_0(k) \quad \text{------------------- (2)}$$

Where h (n) and g (n) are the associated filter coefficients that decompose $c_0(n)$ in to c_1 (n) and $d_1(n)$ respectively. That means in first stage decomposition the original signal is divided into two halves of frequency bandwidth. The next higher scale decomposition is now based on the signal $c_1(n)$. The decomposed signal at scale 2 is given by

$$c_2(n) = \sum_k h(k-2n)c_1(k) \quad \text{---------------------------- (3)}$$

$$d_2(n) = \sum_k g(k-2n)c_1(k) \quad \text{-----------------------------(4)}$$

Higher scale decompositions are performed in the same way as described above. Thus the procedure is repeated until the signal is decomposed to a pre-defined certain level. The set of signals thus attained represent the same original signal, but all corresponding to different frequency bands.

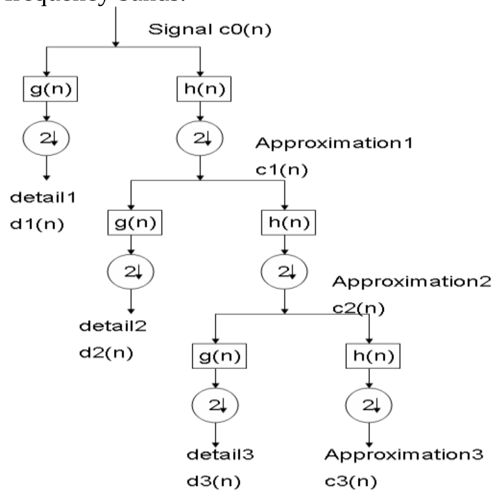

Fig.1 Multi resolution analysis

III. MODIFIED WAVELET TRANSFORM OR S-TRANSFORM

By using s-transform amplitude matrix[8] Max-Curve, Fund-Curve,Std-Curve, and Mean-Curve's are plotted. for power quality disturbance classification, the following important features are extracted from the S-transform Amplitude Matrix of the disturbance signal.

C1:Number of main frequencies, which equals to the peak number of the Max-Curve.so c1=1 for sag,swell,c1>1 for harmonic and transient.

C2: If there is a peak in the STD-Curve near the fundamental frequency then c2=1 else c2=0.

C3:If there is a peak near a high frequency component in the STD-Curve then c3=1 else c3=0.

C4:The mean of FUND-Curve which is obtained as following

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$$C4 = \frac{1}{N} \sum_{k=0}^{k=N\_1} A\,(f1, kT) \text{-- (5)}$$

Where k is the Sampling count, T is the Sampling time interval, f1 is the fundamental frequency, f =50Hz, T=1/(50*100) s.

C5:The degree of sag and swell. find out the spots of min and max of FUND-Curve.

$$Rmax = \sqrt{\frac{1}{T/2} \sum_{K=Kmax-T/4}^{K=Kmax+\left(\frac{T}{4}\right)-1} h^2(kT)} \text{------------------------------------ (6)}$$

$$Rmin = \sqrt{\frac{1}{T/2} \sum_{K=Kmin-T/4}^{K=Kmin+\left(\frac{T}{4}\right)-1} h^2(kT)} \text{ -------------------------------- (7)}$$

C5 is considered as Rmin/Rmax for sag and Rmax/Rn for swell.where Rn is rms of normal signal.

IV. POWER QUALITY EVENT DETECTION

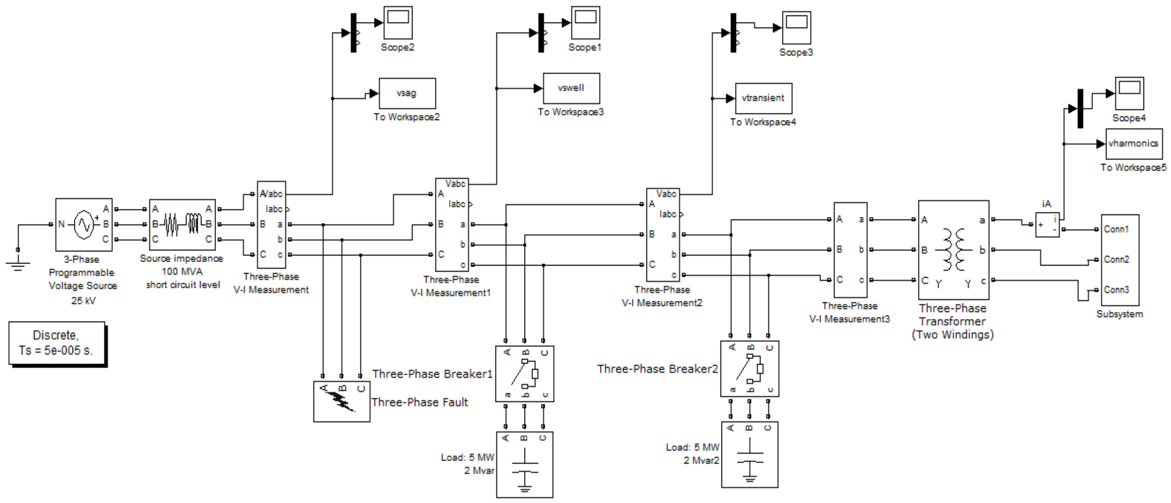

Figure.2 Distribution network considered for analysis

Power quality disturbance signals are generated in matlab simulink using diagram shown in fig:1. A 25kv Distribution network consist of three phase loads and one nonlinear load, various power quality disturbances like voltage sag, swell, transients and harmonics have been simulated. Simulation particulars: Total simulation time=1sec, Number of cycles observed=50.

Sag is between the instants of 0.2sec and 0.6 sec the voltage wave form will dip to the 80% or 90% of original value, and the severity of the fault can be changed based on fault resistance. The percentage swell of the particular wave form can be changed by changing the reactive power consumption of capacitor connected through the three phase circuit breaker. The severity of transient is changed by the capacitance of the capacitive load. Voltage transient appeared between 0.2and0.24sec Harmonics are generated by connecting a non linear load to the distribution system. Generated harmonics can be controlled by the firing angle given as one of the input to the synchronous pulse generator.

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V. WAVELET TRANSFORMATION ANALYSIS OF POWER QUALITY DISTURBANCES.

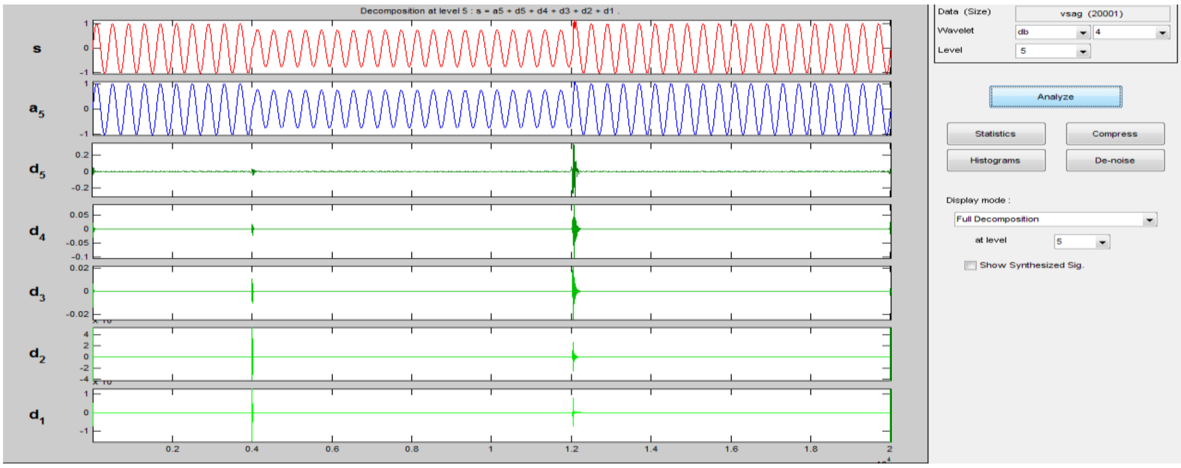
VI. 

Fig.3 Wavelet analysis of voltage sag waveform

Wavelet transform analysis has been carried out on sag waveform by considering debachies-4 mother wavelet up to five level decomposition. The five level decomposition gives five detail coefficients. The standard deviations of detail coefficients are different for each and every power quality disturbance. is for remaining disturbances are shown below.

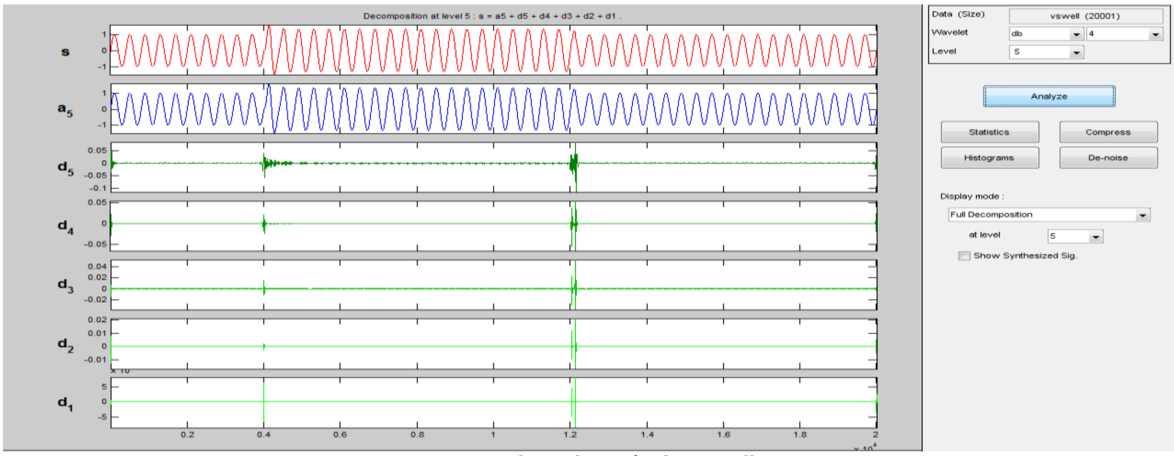


Fig.4 Wavelet analysis of voltage swell

By loading the swell samples collected from the system in to the wavelet transform and by analysing the above figure can be obtained and the swell signal is detected at the starting and ending points of the signal where the wavelet shows the detail extraction.

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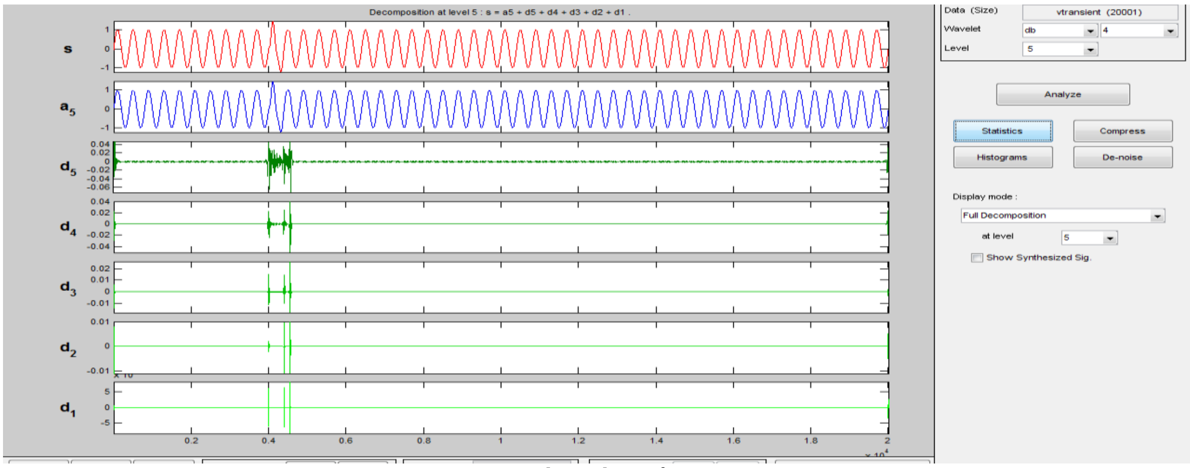

Fig.5 Wavelet analysis of transient

The transient period is for two cycles that is 0.2sec to 0.24sec's is generated and given to the wavelet tool and the detail coefficients have been obtained for hundred samples and given to the classifier.

Fig.6 Wavelet analysis of harmonics

If we Observe the wavelet transform analysis of all the power quality disturbances the signals sag, swell and transients are having high frequency components at starting and ending of its occurrence but in the harmonics case it is different, all low frequency and high frequency components were present .The amplitude of high frequency components is more in transients rather than sag and swell

VI. S-TRANSFORM ANALYSIS OF POWER QUALITY DISTURBANCES

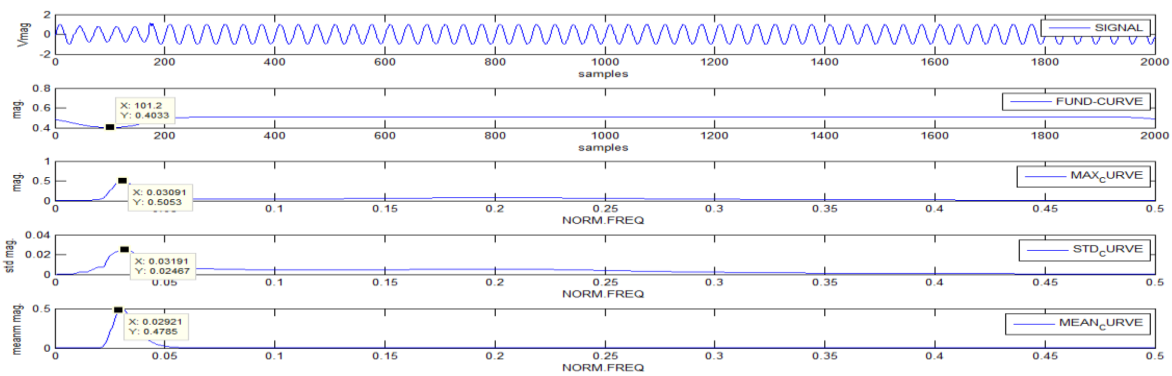

Fig .7 S-Transform analysis of sag disturbance signal

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Fig 7b is a fund curve which shows fundamental frequency-amplitude curve which displays the STA at fundamental frequency. Fund curve value during sag period is less than the normal average value of the fund curve.

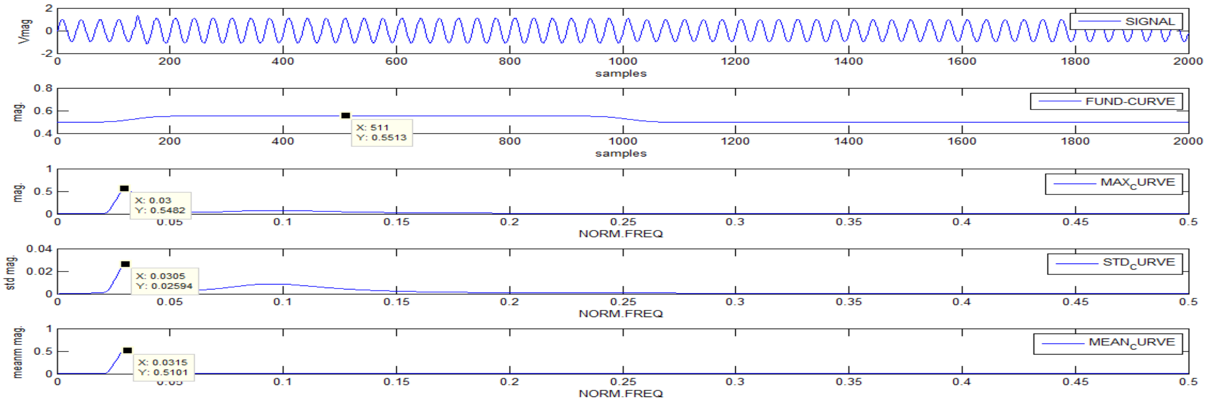

Fig. 8 S-Transform analysis of swell disturbance signal

In Fig8b is the swell is above the normal voltage and Max-curve has only one peak therefore the signal consists of only one main frequency component. Fund-curve value during swell period is above the normal average value.

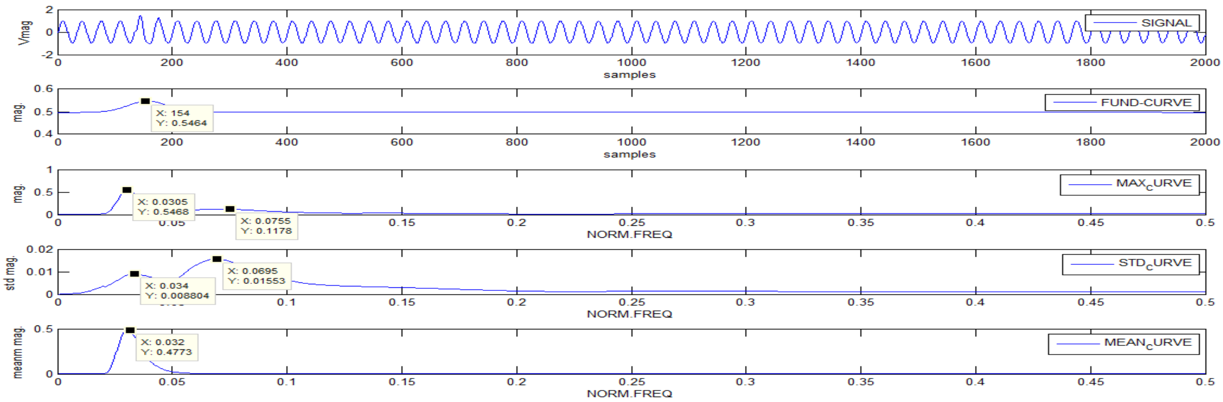

Fig.9 S-Transform analysis of transient disturbance signal

FUND CURVE showing the RMS value greater than the normal curve so it is found that there is a high frequency component. Observing the MAX CURVE there are two peaks near the fundamental frequency so that it is a transient

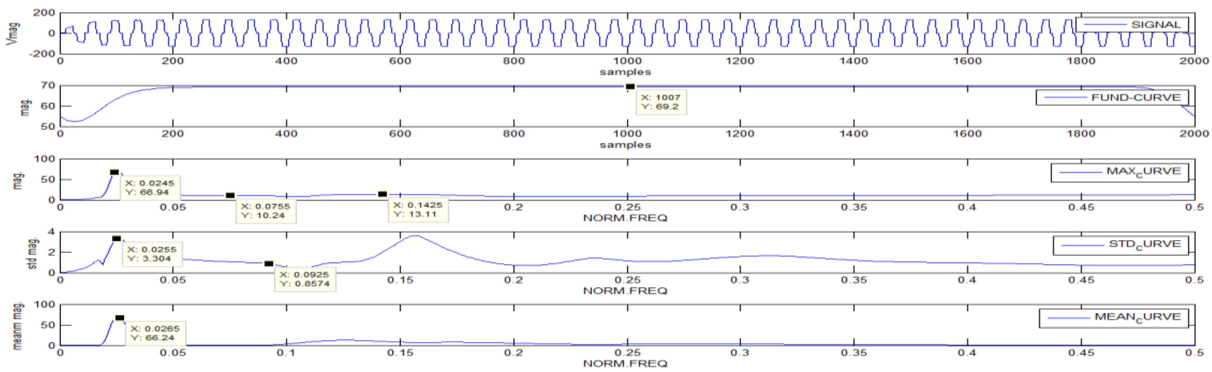

Fig.10 S-Transform analysis of Harmonics

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Because of non-linear load in network we can observe harmonics as shown in fig. In above shown fig10 Max-curve has three peaks therefore the signal consist of three main frequency components.

VII. POWER QUALITY PROBLEM CLASSIFICATION

The most important part of the classification of power quality disturbance using neural networks is the training of the neural network. The standard deviation samples collected from the wavelet analysis of four power quality problems are four hundred.2000 standard deviations comes for four hundred signals.

A. *Training of Back Propagation Neural network*

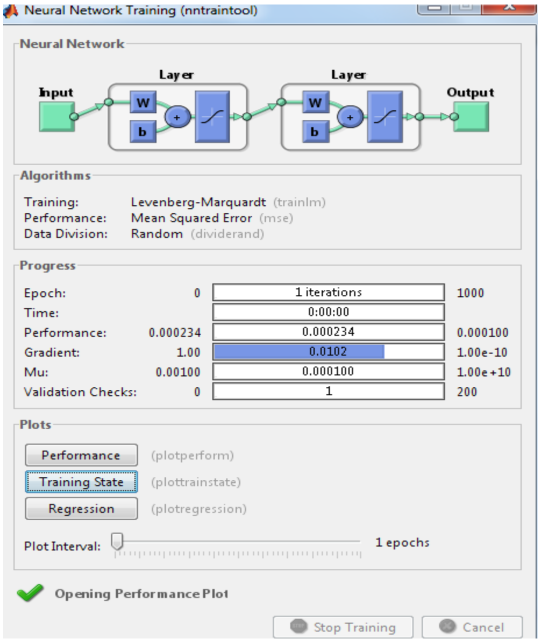

Fig.11 Converged neural network training tool

Fig 11 shows the structure and training of the neural network. The network used for this particular problem is feed forward back propagation Weights of this created network will be initialized to random values .The rule used in this network is steepest decent method that is based on the rule that "error corrects the weights" .The neural network converged in one iteration. The goal set here is 0.0001.

B. *Training of Probabilistic Neural Network*

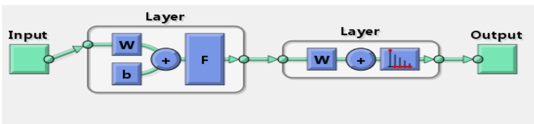

Fig.12 Structure of probabilistic neural network

The structure of the PNN network is as shown in the fig12 which contains two layers called radial basis layer and competitive layer. Features from the S-transform analysis are taken as inputs to the PNN and the outputs are binary values 0's and 1's. Neural network Learning carried out with the speed constant of 0.1**classifier performance**

The classifier performance can be evaluated by testing the trained neural network. The trained neural network is now used for testing ,for this purpose 100 patterns were taken and applied to the neural network .The results are as shown in the fig 13.

INPUT WAVEFORMS GIVEN TO NEURAL NETWORK	ANN CLASSIFIED DISTURBANCE
1-25	VOLTAGE SAG
26-50	VOLTAGE SWELL
51-75	VOLTAGE TRANSIENT
76-100	VOLTAGE HARMONICS

Table2

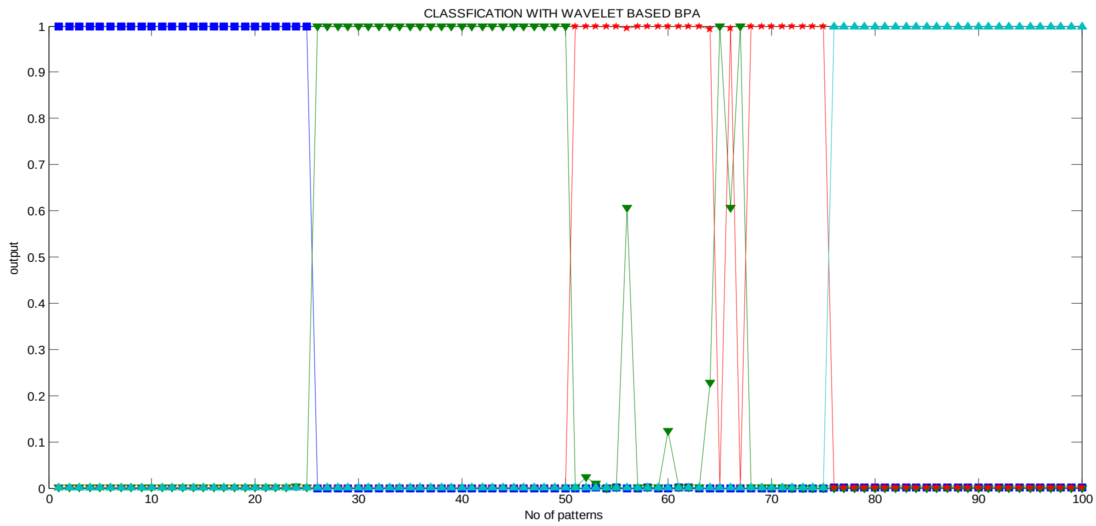

Fig.13 Classification of PQ disturbances using wavelet based BPA

The above figure shows power quality problem classification using wave transform based back propagation algorithm and the power quality problems voltage sag, voltage swell and harmonics have been classified but the classifier has failed to classify the transient disturbance.

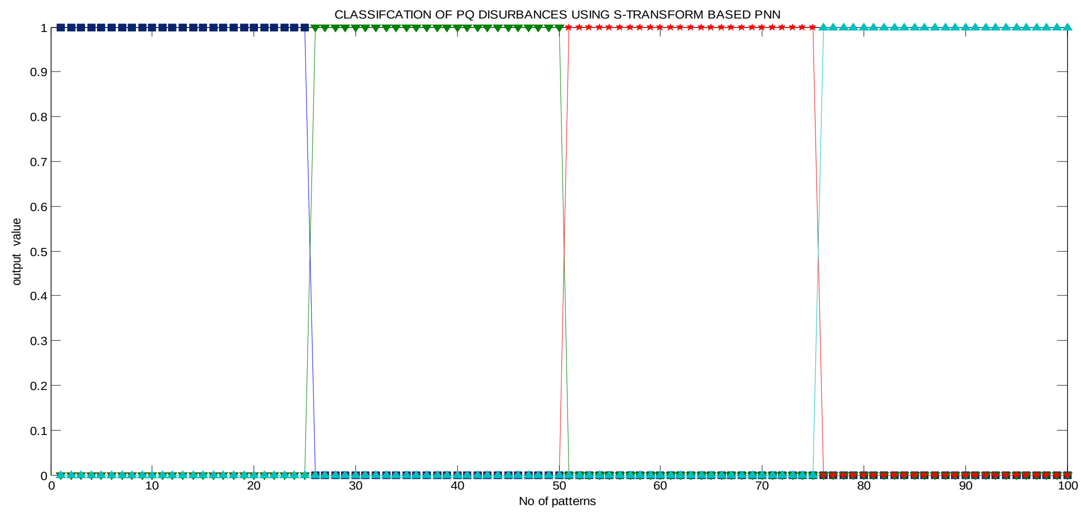

Fig.14 Classification of PQ disturbances using S-transform based Probabilistic Neural Network

By observing the waveforms shown in fig13 and fig 14 the power quality disturbances have been classified with an accuracy of 95%. With wavelet based feed forward back propagation Neural network and with 99% accuracy for s-transform based probabilistic neural network with the better accuracy.

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VIII. CONCLUSION

This paper presented the application of wavelet transform and S-transform combined with Ann technique. This analyses the visualization of voltage distortions with time_varing amplitudes. The S-transform based probabilistic neural network shows clear advantage compared to wavelet transform based back propagation algorithm.

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BIOGRAPHY

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