Dwt-Ann Approach to Classify Power Quality Disturbances

Prof. Abhijit P. Padol
Department of Electrical Engineering,
MGICOET Shegaon.
abhijit.padol@gmail.com

Prof. K. K. Rajput
Department of Electrical Engineering,
MGICOET Shegaon.
kavishwarrajput@yahoo.co.in

Prof. Pratik W. Choudhary
Department of Electrical Engineering.
MGICOET Shegaon.
c.pratik55@gmail.com

Prof. Nishant W. Labade
Department of Electronics & Telecommunication,
MGICOET Shegaon.
nishantlabade@gmail.com

Mr. Mohammad Zubair
Department of Electrical Engineering.
MGICOET Shegaon.
muhd.zubair2016@gmail.com

Abstract— In this paper, an actual 33/11 KV MSEDCL Distribution system is taken under study to detect and classify power quality disturbances. The disturbances to be classified from actual Distribution system consisting of 11 KV Industrial Feeder simulated in Power System Computer Aided Design (PSCAD). This paper mainly detects and classify Power quality disturbances such as Voltage sag, Voltage swell and Interruption. Discrete Wavelet Transform (DWT) is used to detect and Artificial Neural Network (ANN) is used to classify Power quality disturbance. Power quality disturbances are localized by Discrete Wavelet Transform in in time and frequency domain. Six statistical parameters are calculated from detailed coefficient of DWT which is given as input to ANN to classify Power quality disturbances.

Keywords- *Discrete Wavelet Transform, Artificial Neural Networks, Multi Resolution Analysis, Multi-Layer Perceptron.*

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I. INTRODUCTION

A. Power Quality is an important issue for utilities and End users. Power Quality issues and resulting problems are consequences of the increasing use of solid state switching devices, non-linear loads and power electronically switch loads, electronic type load. The advent and wide spread of high power semiconductor switches at utilization, distribution and transmission leaves have non-sinusoidal currents which results in poor Power Quality The electronics load causes many Power Quality problems resulting in the failure of End user equipment. For improvement of Power Quality, the disturbances should be detected , localized and mitigate.

B. Related Work

Reference [1] presents a Distribution system to study the disturbance affecting Power Quality. In this paper, DWT technique to detect and locate the disturbance in a power signal. The energy of each disturbance is calculated and given as input to ANN for classification.

Reference [2] present a new method of on-line voltage disturbance detection based on Wavelet transform which depends on simulation of large number of faults and Capacitor switching incident. In this, a probability function is defined and decision is made using Maximum Likelihood criteria which based on maximizing the probability function of the features.

Z. L. Gaing [3] proposed a Wavelet based Neural network classifier to detect and classify the power quality disturbance. Using Multi Resolution Analysis technique of DWT, 13-level decomposition of each disturbance signal is performed. Parsewal theorem is used to calculate the energy which is given as input to ANN for classification.

Reference [4] proposed a new technique consisting of Fourier linear combiner and a Fuzzy expert system for classification of power quality disturbance. Using peak amplitude and computed slope obtained from Fourier linear combiner are given to Fuzzy expert diagnostic module to compute the truth value of signal. Then the disturbances are classified as Sag, Swell and Interruption using defined Fuzzy set.

Reference [5] presents a s- transform based Neural network classifier to detect and classify the power quality disturbance. In this paper, s- transform is used to detect the disturbance in a power signal and classified using PNN which shows that s-transform has better detection capability and Probalistic Neural Network (PNN) gives best classification results.

C. Objective of work:

The main objective of this paper is detection and classification following Power Quality disturbances such as (i) Voltage Sag (ii) Voltage Swell (iii) Interruption. Power quality disturbance are detected using Discrete Wavelet Transform and classify using Artificial Neural Network.

II.WAVELET TRANSFORM:

A wave is an oscillating function of time or space and is periodic. In contrast, wavelets are localized waves. They have their energy concentrated in time or space and are suited to analysis of transient signals. While Fourier Transform and Short Time Fourier Transform (STFT) use waves to analyse signals, the Wavelet Transform uses wavelets of finite energy.

The wavelet analysis is done similar to the STFT analysis. The signal to be analyzed is multiplied with a wavelet function just as it is multiplied with a window function in STFT, and then the transform is computed for each segment generated. However, unlike STFT, in Wavelet Transform, the width of the wavelet function changes with each spectral component. The Wavelet Transform, at high frequencies, gives good time resolution and poor frequency resolution, while at low frequencies; the Wavelet Transform gives good frequency resolution and poor time resolution.

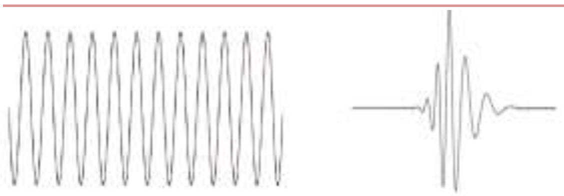

Fig. 1 Wavelet representation

There are different wavelets such as Haar, Daubechies 4, Symlet and Coiflet which are used as mother wavelet.

III. DISCRETE WAVELET TRANSFORM (DWT):

DWT is any wavelet transform in which the wavelet is discretely sampled. DWT transforms the distorted signal into different time frequency scales which detect disturbances present in the power signal.

The DWT of f(t) is defined as:

$$\text{DWT } f(a,b) = \sum f(t)\, \Psi_{a,b}(t) \quad (1)$$

Where $\Psi_{a,b}$ is the mother wavelet

a, b are scale and translation factor

A. Multi Resolution Analysis (MRA):

The first main characteristic of Wavelet transform is Multi resolution analysis. The signal is analysis at different frequencies with different resolution in Multi resolution analysis technique. This technique decomposes the given signal into several other signals with different levels of resolution and provides valuable information in time and frequency domain. Fig.I shows seven level decomposition of DWT which uses the wavelet function (ϕ) and scaling function (φ) It decompose the signal into high frequency components and low frequency components by processing the signal through high and low pass filters. The wavelet function ϕ generate – detailed coefficient (high frequency component) and scaling function φ generate – approximated coefficient (low frequency component).

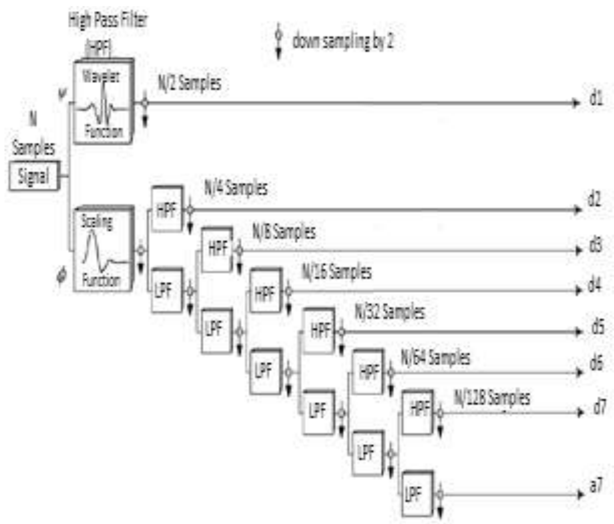

Fig. 2 Seven level decomposition of DWT

Table I. Level of Decomposition

Levels	Approximations –cAi	Detail-cDi
Frequency Band width		
1^0	0 – 1920	1920 – 3840
2^0	0 – 960	960 – 1920
3^0	0 – 480	480 – 960
4^0	0 – 240	240 – 480
5^0	0 – 120	120 – 240
6^0	0 – 60	60 – 120
7^0	0 – 30	30 – 60

IV. CASE STUDY:

Fig.II. shows a single line diagram MSEDCL Distribution system. The system under study is a actual MSEDCL Distribution system consisting of 11 KV Industrial Feeder of Shegaon Substation. Fig shows the single line diagram of a actual Distribution system. The Distribution system taken under study to detect and classify Power quality disturbance occurred in it. This Distribution system consists of a Substation transformer (Power transformer 33/11 KV, 5 MVA), 8 Distribution Transformer (11/0.4 KV), a Capacitor bank and load.

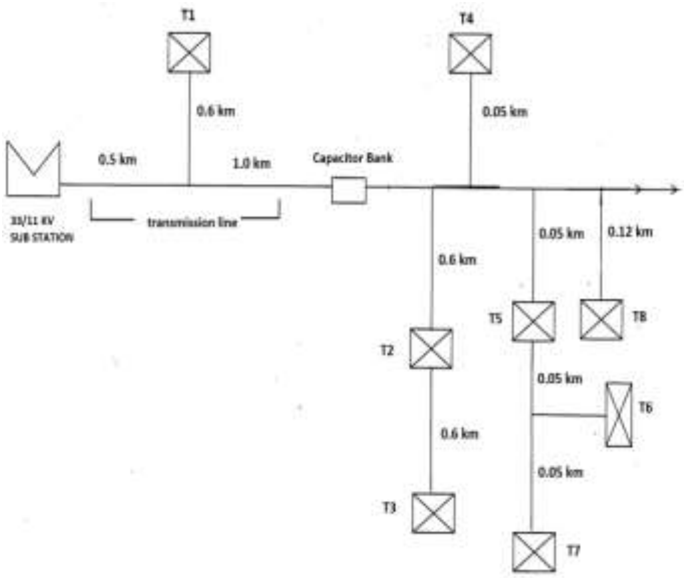

Fig. 3 Single line diagram of a 33/11 MSEDCL Distribution system

Fig 4. shows PSCAD simulation of 33/11 KV MSEDCL Distribution system. It consists of total 26 Buses, 8 Load Buses, 1 Substation Transformer, 8 Distribution Transformer, a Capacitor bank and 8 load Buses. Power Quality disturbances such as Voltage sag, Voltage swell, and Interruption is created at Bus No. 15 and Voltage signal for these disturbances is captured for further analysis.

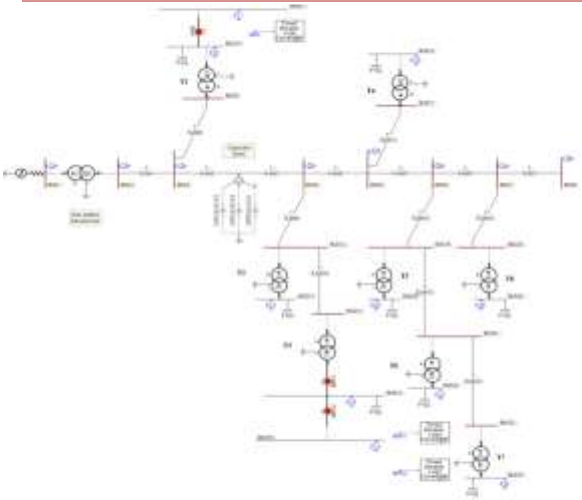

Fig.4 PSCAD Simulation of 33/11 KV MSEDCL Distribution system

V. PROPOSED METHODOLOGY:

The 33/11 KV MSEDCL Distribution system is simulated in PSCAD software. Power quality disturbance such as voltage sag, voltage swell and interruption are generated at different inception angles. The voltage signals are taken at different buses and sampling them at 7680 Hz after saving in the excel sheets. These excel sheets are given to MATLAB program for DWT analysis. Here db4 wavelet is used for DWT analysis and seven level decomposition is carried out. Six statistical parameter such as Minimum, Maximum, Energy, Standard deviation, Skewness, Kurtosis are calculated from detailed coefficients. These six statistical parameter parameters are given as input to ANN for classification.

VI. FLOWCHART

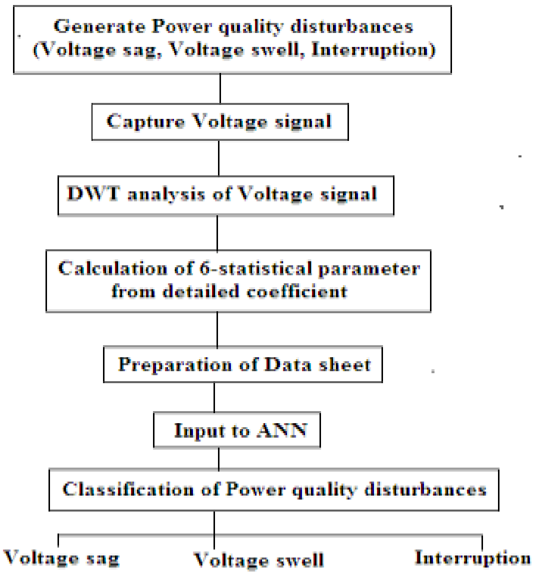

Fig. 5 Flowchart of Proposed Methodology

VI. PSCAD SIMULATION WAVEFORMS:

(i) Voltage Sag : The voltage waveform at Bus No. 15 when a LG fault occurs is as shown below.

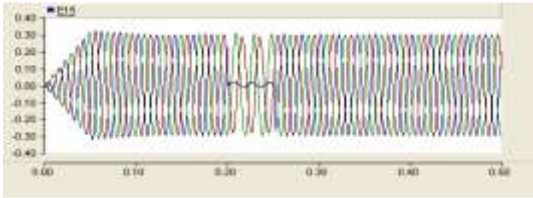

Fig. 6 Voltage waveform for Voltage sag on Bus 15

(ii) Voltage swell: The voltage waveform at Bus No.15 when a heavy load is switch-off is as shown below.

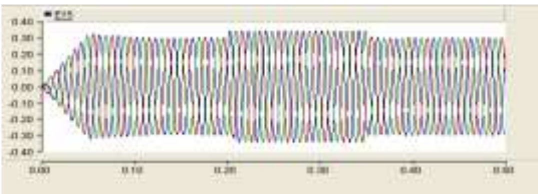

Fig.7 Voltage waveforms for Voltage swell on Bus no. 15

(iii) Interruption: The voltage waveform at bus no.15 when a inadvertent operation of a Circuit breaker take place is shown below.

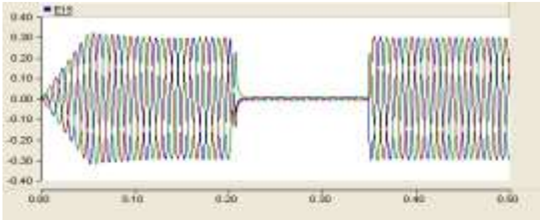

Fig.8 Voltage waveform for Interruption on Bus No.15

VII. DWT WAVEFORMS FOR 7-LEVEL DECOMPOSITION:

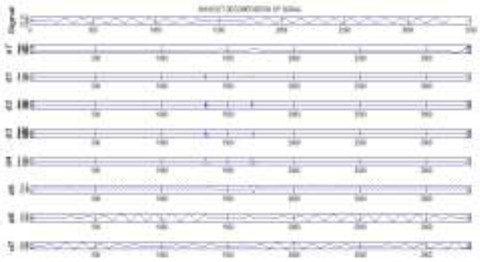

Fig.9 DWT waveform of B -phase for Voltage sag on Bus No.15

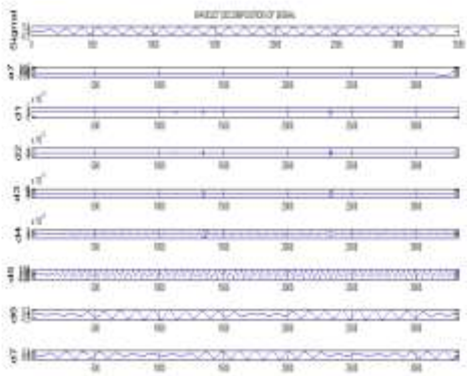

Fig.10 DWT waveform of B-phase for Voltage swell on Bus No.15

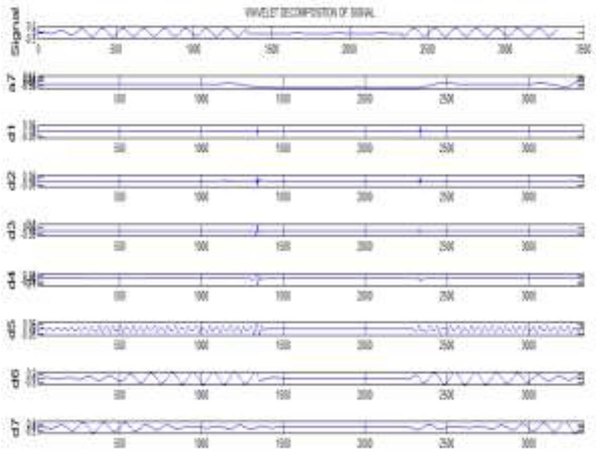

Fig.11 DWT waveform of B-phase for Interruption on Bus No.15

VIII. ARTIFICIAL NEURAL NETWORK (ANN) AS A CLASSIFIER:

ANN is defined as a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs. An artificial neural network is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system. Neural networks are typically organized in layers. Layers are made of a number of interconnected 'nodes' which contain 'activation function'. Patterns are presented to the the network via the 'input layer', which communicates to one or more 'hidden layers' where the actual processing is done via a system of weighted 'connection'. The hidden layers then link to an 'output layer' where the answer is output as shown in the Fig. below.

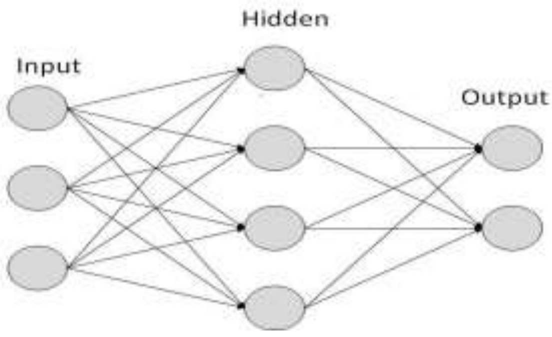

Fig.12 Artificial Neural Network (ANN)

A. ANN Network details:
The learning Rule: Momentum
Training data : 75 %
Testing data: 25 %
Step size: 1.00000
Momentum : 7.00000
Transfer: TanhAxon
Network used: Multi layer Perceptron (MLP)
Hidden layer : 3

B. ANN Output :
For 4-processing elements and 3- hidden layers, ANN gives the following output.

Table II. ANN Output:

Performance	Sag	Swell	Interruption
MSE	0.000517	0.000967	0.0010193
NMSE	0.002464	0.003907	0.005436
MAE	0.020741	0.029646	0.027658
Min Abs Error	0.007247	0.018844	0.000323
Max Abs Error	0.039400	0.052946	0.0464060
r	0.999860	0.999810	0.999889
Percent Correct	100	100	100

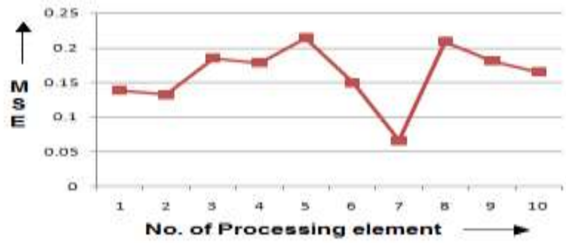

Fig.13 Variations of MSE with Number of Processing element

IX. CONCLUSION:

This paper presents a method to detect and classify types of Power quality disturbances. The disturbances to be classify from the actual Distribution system are Voltage sag, Voltage swell and Interruption. These Power quality disturbances are detected, classified accurately and further appropriate action can be taken to mitigate it which improves the performance of the system. ANN which is used as classifier gives 100 % accuracy for classification.

APPENDIX:

Distribution system configuration of Fig. 3:

Table II. Detail configuration of Transformer:

Sr. No.	Transformer	KVA rating	primary voltage	secondary voltage
1.	Substation	5 MVA	33 KV	11 KV
2.	T1	200 KVA	11 KV	0.4 KV
3.	T2	100 KVA	11 KV	0.4 KV
4.	T3	100 KVA	11 KV	0.4 KV

5.	T4	25 KVA	11 KV	0.4 KV
6.	T5	100 KVA	11 KV	0.4 KV
7.	T6	200 KVA	11 KV	0.4 KV
8.	T7	100 KVA	11 KV	0.4 KV
9.	T8	100 KVA	11 KV	0.4 KV

Table III. Detail configuration of Transmission line:

Code Name	WOLF ACSR
Area	158.1 mm^2
Radius	0.008 m
Resistance	0.1884 ohm/km
Capacitive Reactance	0.26942 ohm/km
Inductive Reactance	0.21666 ohm/km

Table IV. Detail configuration of Tower:

Height from ground	9 m
vertical spacing	1.03 m
Horizontal spacing	1 m

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X. FUTURE SCOPE:

Detection of Power quality disturbance by other techniques and also classification of more Power quality disturbance and there mitigation offline and online.