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Classification of Power Quality Disturbances using Wavelet Transform and Neural Network

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***Abstract*—This Paper focuses on power quality event, detection and classification of power quality disturbances. The PQD detection and classification are valuable tasks for protection of power system network. In this work a new technique is used for categorizing PQ disturbances using MRA techniques of wavelet transform and neural network. These process having through three main components. First a simulator is used to generate power signal disturbances. The second component is a detector which uses the technique of DWT to detect the power signal disturbances. DWT is used to extract features in power signal. The third component is neural network architecture to classify the power signals disturbances with increased accuracy of classification.**

***Keywords*—: Power quality Disturbances, Discrete wavelet Transform, MRA, Artificial Neural network**

I. Introduction

Now-a-days increasing the demand of clean power supply, so it is clear that main problem in power system is electrical power quality. Because of more power quality sensitive equipments are being utilized in electrical utilities. These problems create due to increase of power electronics component in this equipment which is sensitive to power quality. Electrical utilities unable to current control but able to control voltage level and quality. Thus all the time utilities should control and maintain the bus voltage quality foe obtain clean power. This phenomenon leads to consider that voltage quality equal to power quality. Power signal voltage current or frequencies are fluctuates in any case that can affects the consumer side equipments. Which are called disturbances of power quality, so customers and electrical utilities both are mindful the disturbances of PQ. Reduction in power quality principally because of disturbances of power quality for example, voltage sag, flicker, voltage swell, interruption etc. Since, when starting the electrical motor these are drowns large current then motor are running at the rated speed. So, motor starting cause of voltage sag. Electricity consumers have become major problem of quality of power supply. Power quality is worse in light of hazards, breakdown, and brief time and so on. Power quality is poor on account of variable rate drives, inductive burden exchanging and capacitive bank burden exchanging, welding machine, curve heaters.[1] The disturbances must be recognizing precisely for nature of power supply change Power quality occasion ought to be recognized and grouped precisely. Advances in advancements of signal handling and counterfeit consciousness have made it plausible to grow more refined computerized distinguishment methods.[2] For calculating time span of disturbances utilize continuous wavelet transform and for calculating amplitude of disturbances used DWT. DWT is utilized in this work to catch the transient event time and disturbances of power signal frequency features extracted. These coefficients applied as to the NN oblige more time for learning and extensive memory. Misshaped signals were created through Sim Power block in MATLAB. Wavelet used for enhancing accuracy rate. The exactness rate is enhanced by utilizing wavelets alongside the measurable separation of the different disturbances of power signals.

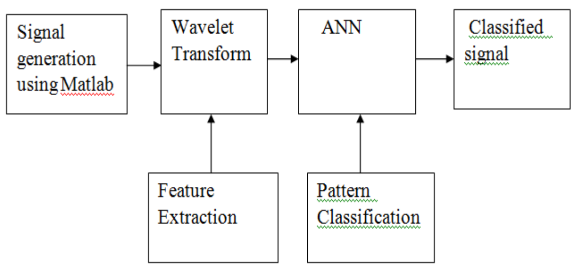

Fig 1 General block diagram of disturbances classification

II. Wavelet Transform Theory

Presently a-days power quality disturbances are observed online and on location with the coming of advanced procedures. As of late for power quality disturbances identification wavelet transform has risen as a capable apparatus. For wavelet work utilizes Wavelet Transform as the premise capacity investigation as per the recurrence. The plan gives superior results in light of the fact that the premise capacity utilized as a part of the WT is a wavelet rather than an exponential capacity utilized as a part STFT and FT. The signal is decayed into distinctive frequency stage and displayed as wavelet coefficients by using WT. Contingent upon the sorts of signal, discrete wavelet transform and continuous wavelet transform are utilized. CWT based deterioration is embraced for constant time signal and DWT based disintegration for discrete time signal is utilized. However all the signals demonstrated are discrete in character in this work henceforth based on DWT deterioration is utilized for example, voltage Sag, voltage Swell, flicker and interruption are produced utilizing Matlab and afterward

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decayed utilizing disintegration calculation of WT . Wavelet is called momentary wave which demonstrates that the function is brief time span. Non-oscillatory signals prompted wave which is a sinusoidal wave. Variable wavering produced wavelet. Negative and positive side wave amplitudes decline to zero quickly respect to time. Wavelet signal having two situations, (a) wavelet must be oscillatory wave, (b) wave amplitude are nonzero in short interim time. Wavelets are numerical capacities that deteriorate information into diverse recurrence parts, afterward mull over every part with a determination coordinated. [3]-[5].

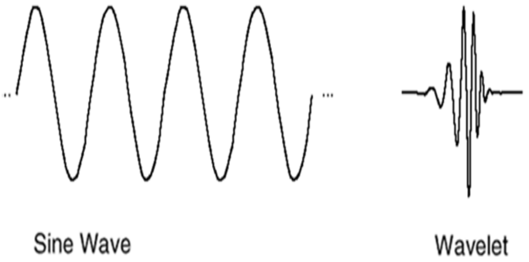

Fig1.6. Sinusoidal and wavelet waveform

A. *Discrete Wavelet Transform*

Wavelets give effective and quick calculations to speak to a signal part in its unmistakable frequency groups utilizing MRA. In center signal handling applications like sound and feature pressure and so forth, the properties like orthogonality symmetry help in remaking of the signal with insignificant mistake. As different wavelets used in distinctive branches of signals preparing. Here furnishes with essentials of wavelets took after by multi- resolution analysis and the identification calculation for disturbances of power quality recognition. A period representation of a sign f(t) can be shown in (1) and its frequency representation or the Fourier space representation will be as in (2). We can watch that (1) gives data of most extreme time determination and no frequency data on the other hand (2)gives the frequency data and no time confinement.

$$f(t) = \int_{-\infty}^{\infty} f(u)\alpha(t-u)du \qquad \text{..(1)}$$

$$f(w) = \int_{-\infty}^{\infty} f(t)e^{iwt}\,dw \qquad \text{..(2)}$$

Where the extent is from less endlessness to in addition to interminability, so at whatever point the segment with frequency w shows up in time, it will influence the aftereffect of the incorporation similarly also. The absence of time data in Fourier Transform offers ascend to a Windowed Fourier Transform. For this situation, the signal is separated into little fragments, where these sections can be thought to be stationary. At the same time to make the signal stationary we may need to restricted the window and these outcomes in a poorer frequency resolution. Wavelets can be characterized as function class used to limit a given flag in both time and frequency spaces. This arrangement of wavelets would be built from a mother wavelet, which expanded or extended to change the measure of the window. This infers that an enlarged wavelet gives a greater amount of the time data and an extended form of it investigates the frequency data. Subsequently wavelets adjust to both low frequency and high frequency segments consequently by utilizing different window sizes. Wavelets as characterized above are created from a mother wavelet Ψ, utilizing expansions and development.

$$\Psi a,b(x) = \frac{1}{|a|}\Psi\left(\frac{x-b}{a}\right) \qquad \text{... ....(3)}$$

Where Ψ must satisfy $\int \Psi(x)\,dx = 0$.

III. DISTURBANCE SIGNALS GENERATED

Different Power Quality disturbances such as Voltage sag, Voltage Swell, Flicker and interruption are generated with different magnitudes and time duration using Matlab/simulink according to the give parameter and equation in Table-1. These generated signal parameters take fs =1000 Hz sampling frequency, f= 50Hz supply frequency, T=1/fs.

TABLE-I DIFFERENT TYPES OF POWER QUALITY DISTURBANCES

DISTURBANCES	EQUATION	PARAMETERS
Pure sine wave	$y(t)=\sin(\omega dt)$	$\omega_d = 2\pi f$ rad/sec
Sag	$y(t)=\sin(\omega dt).[1-\alpha(u(t-t_1)-u(t-t_2))]$	$0.1 \le \alpha \le 0.9, T \le t_2 - t_1 \le 9T$
Swell	$y(t)=\sin(\omega dt).[1+\alpha(u(t-t_1)-u(t-t_2))]$	$0.1 \le \alpha \le 0.8, T \le t_2 - t_1 \le 9T$
Flicker	$y(t)=[1+\alpha\sin(2\pi\beta t)].\sin(\omega dt)$	$0.1 \le \alpha \le 0.2, 5Hz \le \beta \le 20Hz$
Interruption	$y(t)=\sin(\omega dt).[1-\alpha(u(t-t_1)-u(t-t_2))]$	$0.9 \le \alpha \le 1, T \le t_2 - t_1 \le 9T$

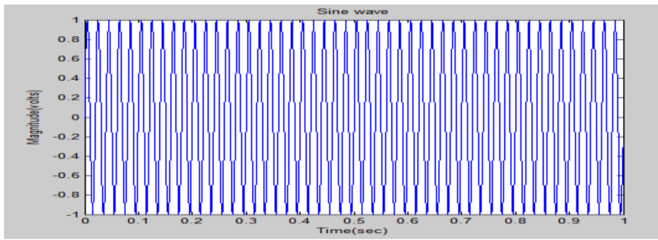

Fig .2 Sinusoidal signals in time domain

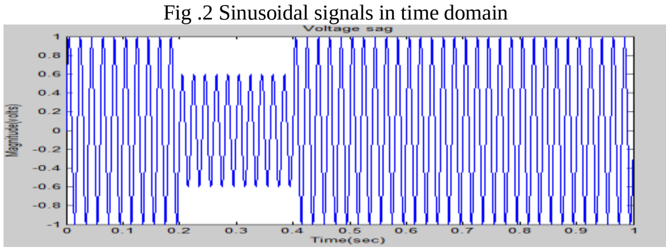

Fig.3 Voltage Sag signal in time domain

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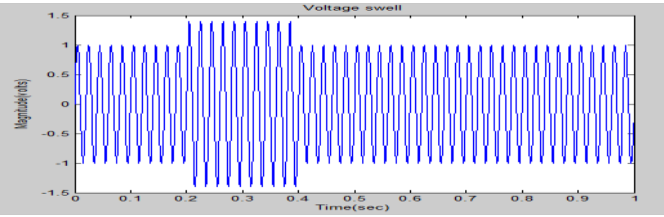

Fig.4 Voltage Swell signal in time domain

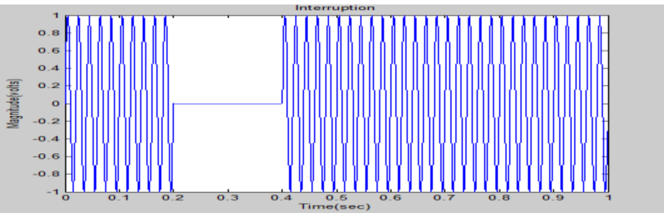

Fig.5 Voltage Interruption signal in time domain

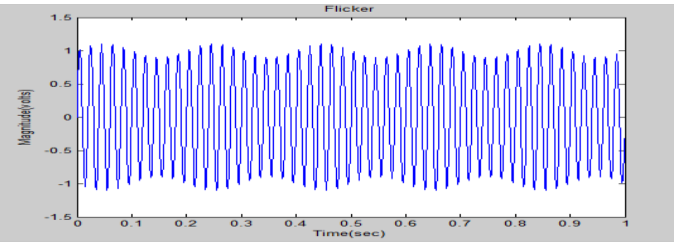

Fig.6 Flicker signal in time domain

IV. WAVELET TRANSFORMATION ANALYSIS OF POWER QUALITY DISTURBANCES

Decomposition by wavelet at the distinctive levels of these disturbances signals are indicated in Figs. The signal is taken a gander at diverse scales or determination which is otherwise called multi recognition analysis or sub bands. With increment in every level time Determination reductions with the increment of every level time while frequency determination increments. The exceptional fluctuation of every disturbances of PQ from the first pure sine wave is recognized coefficients of detailed and approximate. Study various disturbances at various levels. Typically, maybe a couple scale signal deterioration is sufficient to segregate disturbances from their experience on the grounds that the disintegrated signals have high time limitation at lower scales. As such, signal deterioration at high scale is not essential since it gives poor time restriction. For this situation diverse PQD are decomposed for identification up to 4^{th}level.[7]

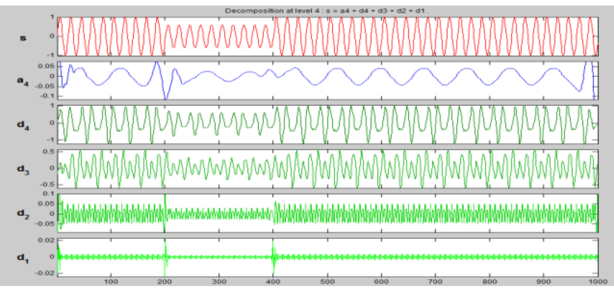

Fig.7. Voltage Sag analysis using wavelet toolbox

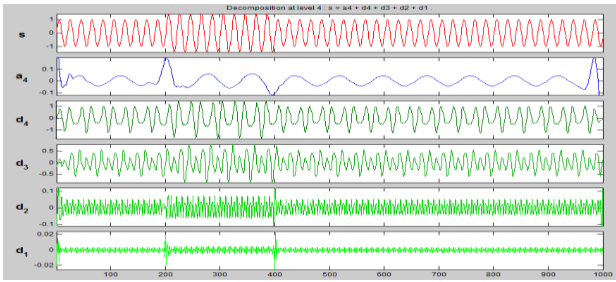

Fig.8 Voltage Swell analysis using Wavelet toolbox

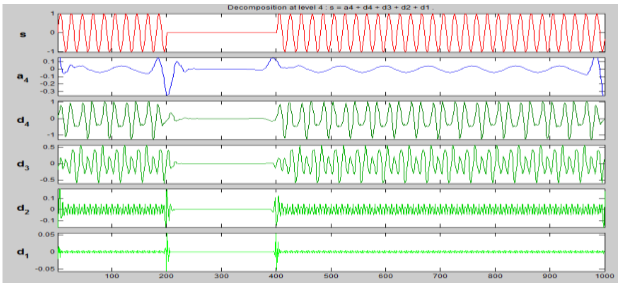

Fig.9 Interruption analysis using Wavelet toolbox

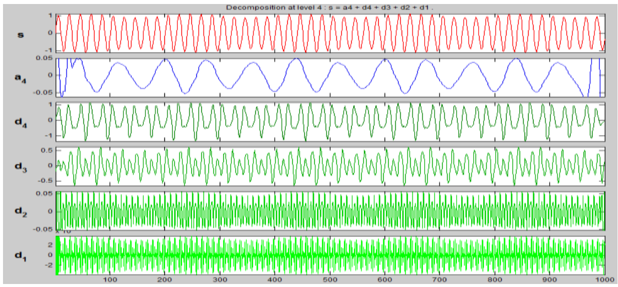

Fig.10. Flicker analysis using Wavelet toolbox

V. NEURAL NETWORK STRUCTURE FOR DISTURBANCES CLASSIFICATION

The input to the network is from the wavelets. For 1000 samples of data in each class of disturbance the various statistical details like mean, standard deviation. Maximum and minimum of detailed coefficient at decomposition level 4 taken. All these data found from Appendix-A. The data for a normal sine waveform is also given to the neural network architecture. The patterns generated for each of the disturbance is applied as input to the neural network. For each of the pattern the target is specified. For a sag pattern the target is specified as [0 1 0 0 0]. For a pattern with swell the target is specified as [0 0 1 0 0], for interruption target is [0 0 0 1 0] and flicker pattern target is [0 0 0 0 1]. Similarly for each pattern classification, the target is specified such that the particular patterns target is classified as 1 and the rest of the classes is made zero. There are five neurons in the output. For a pure sine wave the target is [1 0 0 0 0]. The output of the ANN structure will be Normal sine waveform, signal with sag, signal with swell, signal with interruption, and signal with flicker. 10 data in each type of disturbance were used for training. After training the network, 50 test data were applied to the network for checking out the classification. MSE of the

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signal is used for classification. This type of classification was not accurate as feature extraction was not done properly.[1]

Fig.3.11 Feature Vector matrix

TABLE-.2 TRAINING PERFORMANCE OF ANN USING 'newff'

No. of Neurons in hidden layer	Learning epochs	Training accuracy %	Training time (sec)
8	87	100	44
10	**41**	**100**	**2**
12	53	100	7
18	112	100	2
20	50	100	5

For neural network simulation in Matlab 'Scaled Conjugate Gradient (trainscg)' training function is used. NN performance is demonstrated. Total 50 dataset, 10of each class taken for training. Each data consist of four feature illustrated in previous section 3. The training performance of 'newff' is shown for different number of neurons in hidden layer, epochs and training time in Table .2. From table 4.2 its seen that both 10 and 18 number of neurons in same time at different epochs give the training accuracy 100%. However, based on less number of epochs we found that 10 neurons in hidden layer gives the best performance (depicted in bold letter). Number of neurons and epochs the combination in hidden layer, when neural network trained then training time is taken to be 2 sec. For classification trained NN is tested for five class each class having 10 data.

TABLE-.3 CLASSIFICATION RESULTS OF THE ANN USING 'newff' TRAINING FUNCTION

Class	Sine wave	Sag	Swell	Interruptions	Flicker
Sine wave	**10**	0	0	0	0
Sag	0	**10**	0	0	0
Swell	0	0	**10**	0	0
Interruption	0	0	0	**10**	0
Flicker	0	0	0	0	**10**
	Overall accuracy=100%				

The results of classification are shown in Table .3. Correct classified Power quality classes are represent diagonal (shown by bold latter) and misclassified represent off diagonal elements. The overall accuracy of 'newff' is obtained by average of diagonal element that is 100% found. Hence 'newff' is good training function for application of classification.

VI. CONCLUSSION

In this paper, power quality disturbances have been classified by using combination of wavelet transform and neural network procedure done in three stages. For this work Matlab/simulink used. Power quality disturbances are decomposed through Db-4 at 4 level discrete wavelet filter used and extract features such as mean, standard deviation, maximum and minimum values of pure sine wave and power quality disturbances detailed coefficients distribution are achieved. Powerful classifier tool is used as MFNN for classification.

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REFERENCES

[1] S. Suja and Jovitha Jerome,"Power Quality Disturbance Classification Using Wavelet Based Neural Network" Serbian Journal of electrical engineering vol.4,no.1, Jun 2007,71-83.

[2] Valdomiro VEGA and Cesar Duarte, "Automatic Power Quality Disturbances Detection and Classification Based on Discrete Transform and Support Vector Machines" CIRED, 19 international conference on electricity distribution Viena, 21-24 may2007, paper-0827

[3] D. Saxena and K.S. Verma, " Power Quality event Classification: an overview and key issues" International Journal of Engineering, Science and Technology Vol.2, No.3,2010, pp.186-199.

[4] K.K. Minu and M.C. Lineesh , " Wavelet Neural Network for Nonlinear Time Series Analysis" Applied Mathematical Sciences, Vol. 4, 2010, No.50, 2485-2495

[5] Soo-Hwan Cho and Gilsoo Jang, " Time- Frequency Analysis of Power Quality Disturbances via the Gabor-Winger Transform" IEEE Transactions on Power delivery , Vol.25, No.1, January 2010

[6] Subhamita Roy and Sudipta Nath , "Classification of Power Quality Disturbances using features of signals" International Journal ofr scientific and Research Publications ,Volume 2, Issue 11 November 2012.ISSN-2250-3153

[7] P Sai revathi and G.V.Marutheswar, "classification of power quality disturbances using wavelet transform and s-transform based artificial neural network" IJAREEIE vol .2 Dec 2012. ISSN:2023-3765

[8] Aslam P.Memon and Zubair A. Memon,"Wavelet Transform and Artificial Neural Network Based Novel Approach For The Detection and Classification of Electrical Power Quality Disturbances," Science Institute (Lahore) 26(4), 1507-1514,2014, ISSN 1013-5316.

[9] M.Karthikeyan and V.Malathi, "Wavelet-Support Vector Machine Approach for classification of Power Quality Disturbances" International Journal of Recent Trends in Engineering, Vol.1, No.3, May,2009

[10] Suriya Kaewarsa and Kitty Attakitmongcol, " Recognition of power quality events by using multi-wavelet-based neural network" Electrical and energy system 30 (2008), 254-260.

[11] Murat Uyar and Selcuk Yildirim(2008), " An effective wavelet-based feature extraction method for classification of power quality disturbance signals" Electrical Power system research 78 (2008) 1747-1755

[12] .Aneeta S Antony and Silpa R, "Detection and classification of power quality distutbances using wavelet transforms and probablistic neural network" Proceedings of Eleventh IRF International Conference, 17th August 2014, Chennai, India, ISBN: 978-93-84209-47-6.

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