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Detection And Mitigation Of Power Quality Disturbances Using DWT Technique And DVR

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ABSTRACT

Power quality (PQ) is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Improvement of PQ has a positive impact on sustain profitability of the distribution utility on the one hand and customer satisfaction on the other. To improve the power quality problems, the detection of PQ disturbances should be carried out first. The PQ problems vary in a wide range of time & frequency, which make automatic detection of PQ problems often difficult to analyse the cause of occurrence.There are numerous types of PQ disturbances according to IEEE standards that are concerned very often. As it is evident that if there is a problem then there will be a technique to solve that problem. As the same to detect the PQ problems and their disturbances waveform automatically, there are some techniques that are proposed such as Fast Fourier Transform, Short Time Fourier Transform and Wavelet Transform Technique. PQ disturbances also vary in a wide range of time and frequency and Discrete wavelet Transformation(DWT) with Fuzzy classifier have unique ability to examine the signal in time and frequency ranges. In this paper the mitigation of detected power quality problems can be done by the device Dynamic Voltage Restorer (DVR).

Keywords—Power quality, Detection of disturbance, Discrete wavelettransform, Fuzzy classifier, DVR.

I. INTRODUCTION

In an ideal ac power system, energy is supplied at a single constant frequency and specified voltage levels of constant magnitudes. However, this situation is difficult to achieve in practice. The undesirable deviation from a perfect sinusoidal waveform is generally expressed in the terms of power quality. The power quality is an umbrella concept for many individual types of power system disturbances such as harmonic distortion, transients, voltage variations, voltage flicker, etc. Of all power line disturbances harmonics are probably the most degenerative condition to power quality because of being a steady state condition .Electric powerquality may be defined as a measure of how well electric power service can be utilized by customers. The term power quality means different things to different people. There is no agreed definition for power quality, it may be defined as the problems manifested in voltage, frequency and the effect of harmonics, poor power factor that results in mis-operation/failure of customer equipment. Certain type of power quality degradation results in losses and thus losses in transmission and distribution system have come under greater scrutiny in recent years. When wave shapes are irregular, voltage is poorly regulated, harmonics and flickers are present, or there are momentary events that distort the usually sinusoidal wave, and the power utilization is degraded. This paper outlines the issue relating to power quality and their impact on Energy Conservation. Due to the advantages in technology and the increasing growing of industrial/commercial facilities in regions, the power quality has been a major concern among industries. Thus in order to maintain the consistent standard of power quality in the near feature with the increasing number of industries and commercial facilities; it would be extremely urgent and tackle the power quality challengers. This is then lead to time wasted while trying to solve the problems. However certain appropriate measures can be taken to protect the affected equipment or to raise the quality of power supply. Power supply quality issues and resulting problems are the consequences of the increasing use of solid state switching devices, nonlinear and power electronically switched loads, unbalanced power system, lightning controls, computer and data processing equipment, as well as industrial plant rectifiers and inverters.A power quality problem usually involves a variation in the electric service voltage or current, such as voltage dips and fluctuations, momentary interruptions, harmonics and oscillatory transient causing failure, or mis-operation of the power service equipment[1,2].

With the common use of all kinds of electronic sensitive equipment, electric power quality, including voltage sag, voltage swell, voltage harmonics, and oscillatory transients has attracted great attention. How to extract the features of disturbances from a large number of power signals and how to recognize them automatically are important for further understanding and improving power quality. Hence, to improve the power quality, it is required to know the sources of power system disturbances and find ways to mitigate them.

Signal processing techniques have been widely used for analysing power signals for the purpose of automatic power quality (PQ) disturbance recognition. Among the different signal processing techniques used in the extracting of features of disturbances from a large number of power signals, the most widely used techniques are fast Fourier transform (FFT) and the windowed Fourier transform which comprises of the short time Fourier transform (STFT) and the wavelet transform (WT). The FFT is ideal for calculating magnitudes of the steady state sinusoidal signals but it does not have the capability of copying with sharp changes and discontinuities in the signals. Although the modified version of the Fourier transform referred to as the STFT can resolve some of the drawbacks of the FFT, it still has some technical problems. In the STFT technique, its resolution is greatly dependent on the width of the window function in which if the window is of finite length, the technique covers only a portion of the signal, thus causing poor frequency resolution. On the other hand, if the length of the window in the STFT is infinite so as to obtain the perfect frequency resolution, then all the time information will be lost. Due to this reason, researchers have switched to wavelet transform from the STFT[3,4].

Some of the well-known wavelet transforms are the continuous wavelet transform (CWT) and the discrete wavelet transform (DWT). Wavelet analysis is based on the decomposition of the signal according to time-scale, rather than frequency, using basis functions with the adaptable scaling properties which are known as multi-resolution analysis. A wavelet transform expands a signal not in terms of a trigonometric polynomial but by wavelets, generated using transition (shift in time) and dilation (compression in time) of a fixed wavelet function. The wavelet function is localized in time and frequency yielding wavelet coefficients at different scales. Several types of wavelets have been considered for detection, and localization of power quality problems as both time and frequency information are available by multi-resolution analysis. Most of the proposed systems uses either the Fourier transform (FT) or the wavelet transform for feature extraction and the artificial neural network (ANN) or fuzzy logic (FL) for event classification. ANN have several drawbacks, including their inherent need of a large numbers of training cycles. The key benefit of FL is that its knowledge representation is explicit in utilizing simple "IF-THEN" relation. The wavelet transform has the capability to extract information from the signal in both time and frequency domains simultaneously. Recently, the wavelet transform has been applied in the detection and classification of the power quality events[5].

A major concern in the classification of process of power quality disturbances, which may lead to poor classification accuracy in the ANN and the FL methods, is the non-uniform time alignment between the test signal and the prestored templates. The time alignment issue can be most efficiently handled by applying the DWT algorithm, which has been extensively used in the speech recognition. The DWT is a template matching algorithm derived from dynamic programming. Conceptually, template matching is based on the comparison of the test signal against all of the stored templates in the dictionary. A measure of similarity is calculated, and then used to achieve a recognition decision.

Among the power quality problems (sags, swells, interruptions) voltage sags are the mostsevere disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like line voltageharmonics compensation, reduction of transients in voltage and fault current limitations[6,7].

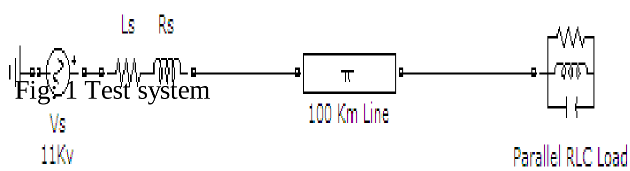

Fig. 1 Test system

II. Power Quality Problems In Distribution systems

A wide diversity of solution to power quality problems is available to the both the distribution network operator and the end user. More sophisticated monitoring equipment is readily affordable to end-users, who empower with information related to the level of power quality measurable quantities or occurrences.Most of the more important international standards defines power quality as the physical characteristic of the electrical supply provided under normal operating conditions that do not disturb the customer's processes. Therefore, a power quality problem exists if any voltage, current or frequency deviation results in a failure or in a bad operation of customer's equipment. Power quality problems are common in most of commercial, industrial and utility networks. Natural phenomena, such as lightning are the most frequent case of power quality problems. Switching phenomena resulting in oscillatory transients in the electricalsupply, for example when capacitors are switched, also contribute substantially to power quality disturbances. Also, the connection of high power non-linear loads contributes to the generation of current and voltage harmonic components., leading to costly interruptions of production. Power disturbances are caused by the generation, distribution and use of power, and lightning. A power disturbance can be defined as unwanted excess energy that is presented to the load.

The various power quality disturbances are

2.1 Voltage Sag:

Voltage sag is a short term reduction in, RMS voltage in the range of 0.1 to 0.9 p.u. for the duration greater than half the mains cycle and less than 1 minute. It is specified in terms of duration and retained voltage, usually expressed as the percentage of nominal RMS voltage remaining at the lowest point during the dip. Voltage sag (dip) means that the required energy is not being delivered to the load and this can have serious consequences depending on the type of load involved.

2.2 Voltage Swell:

A voltage swell is increase in the RMS voltage in the range of 1.1 to 1.8 p.u. for duration greater than half the mains cycle and less than 1 minute. It is caused by load switching and capacitor switching.

2.3 Momentary Interruption:

A type of short duration in which the complete loss of voltage on one or more phase conductors for a time period between 0.5 cycles and 3 seconds.

2.4 Impulsive Transients:

A sudden non power frequency change in the steady state condition of voltage or current i.e. unidirectional polarity (primarily either positive or negative).

III.POWER QUALITY ANALYSIS USING DISCRETE WAVELET TRANFORM (DWT

The DWT is considerably easier to implement when compared to the CWT. The basic concepts of the DWT will be introduced in this section along with its properties and the algorithms used to compute it. As in the previous chapters, examples are provided to aid in the interpretation of the DWT.

3.1 Sub band coding

In the discrete case, filters of different cut-off frequencies are used to analyze the signal at different scales. The signal is passed through a series of high pass filters to analyze the high frequencies, and it is passed through a series of low pass filters to analyze the low frequencies. The resolution of the signal, which is a measure of the amount of detail information in the signal, is changed by the filtering operations, and the scale is changed by up sampling and down sampling operations. For example, sub sampling by two refers to dropping every other sample of the signal. Sub sampling by a factor *n* reduces the number of samples in the signal *n* times. The procedure starts with passing this signal through a half band digital low pass filter with impulse response h[n].

The convolution operation in discrete time is defined as follows:

$$x[n]*h[n]=\sum_{k=-\infty}^{\infty}x[k].h[n-k] \rightarrow (3.1)$$

Half band low pass filtering removes half of the frequencies, which can be interpreted as losing half of the information.The signal is then subsampled by 2 since half of the number of samples are redundant. This doubles the scale

This procedure can mathematically be expressed as:

$$y[n]=\sum_{k=-\infty}^{\infty}h[k].x[2n-k] \qquad \rightarrow (3.2)$$

DWT employs two sets of functions, called scaling functions and wavelet functions, which are associated with low pass and high pass filters, respectively. The original signal x[n] is first passed through a halfband highpass filter g[n] and a lowpass filter h[n].

This constitutes one level of decomposition and can mathematically be expressed as follows:

$$yhigh[k]=\sum_{n}x[n].g[2k-n] \quad \rightarrow (3.3)$$

$$ylow[k]=\sum_{n}x[n].h[2k-n] \quad \rightarrow (3.4)$$

Where $y_{high}[k]$ and $y_{low}[k]$ are the outputs of the highpass and lowpass filters, respectively, after subsampling by 2.The highpass and lowpass filters are not independent of each other, and they are related by:

$$g[L-1-n]=(-1)^n.h[n] \qquad \rightarrow (3.5)$$

However, if the filters are not ideal halfband, then perfect reconstruction cannot be achieved. Although it is not possible to realize ideal filters, under certain conditions it is possible to find filters that provide perfect reconstruction. The most famous ones are the ones developed by Ingrid Daubechies, and they are known as Daubechies' wavelets.

IV.SIMULATION RESULTS AND OUTPUTS

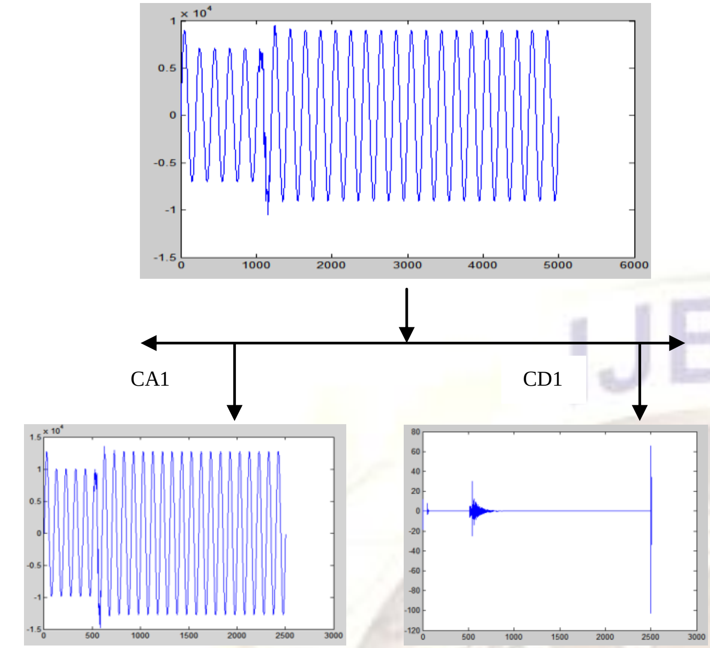

Fig 4.1Extraction of coefficients for sag using DWT

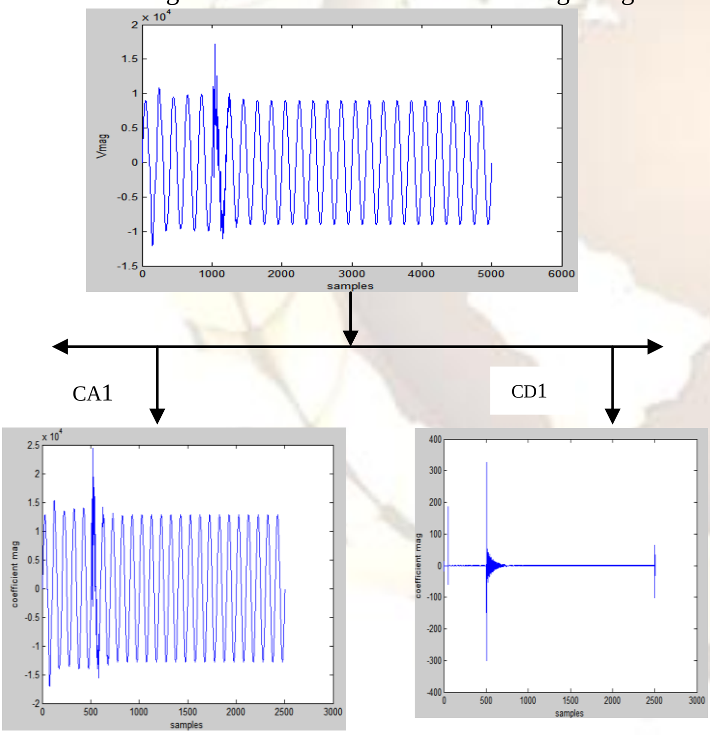

Fig 4.2 Extraction of coefficients for swell using DWT

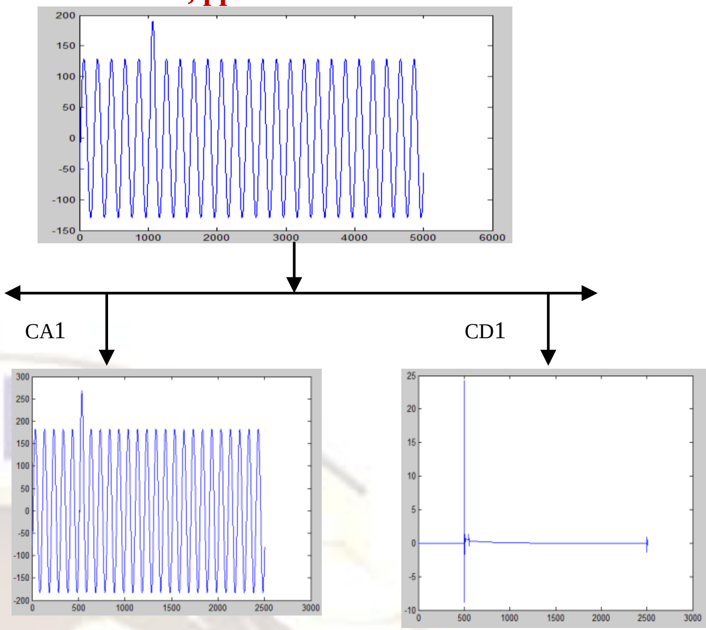

Fig 4.3 Extraction of coefficients for Impulse Transientsusing DWT

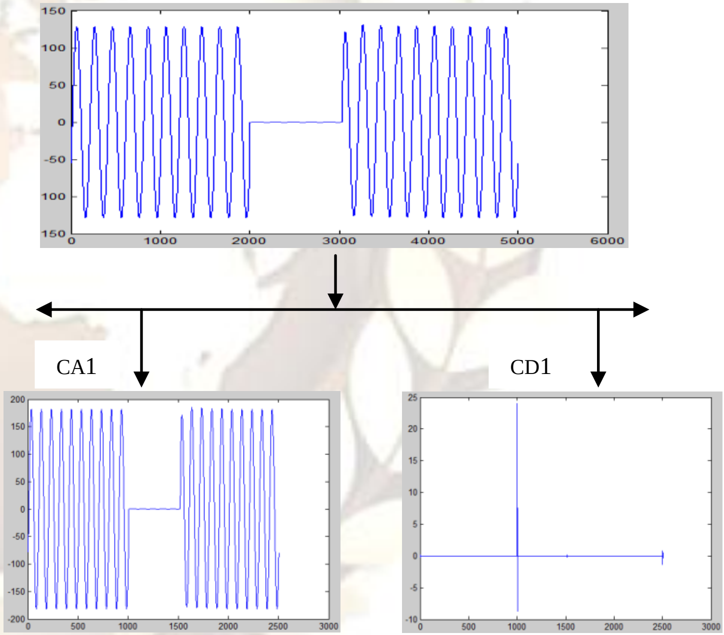

Fig 4.4Extraction of coefficients for Momentary Interruptions

Table 4.1: Matlab Results for Sag

Percentage Of Sag (%)	Load (MVAR)	First peak coefficients
10	0.44	2.075
20	0.98	3.514
30	1.64	4.5
40	2.55	6.2871
50	3.84	8.679
60	5.68	11.815
70	8.95	16.672
80	15.5	24.045
90	35.4	126.23

Table 4.2: Matlab Results for Swell

Percentage Of Swell (%)	Load (MVAR)	First peak coefficients
10	0.175	59.92
20	0.235	58.6
30	0.31	59.8
40	0.41	60.76
50	0.558	61.58
60	0.82	62.28
70	1.9	63.18

Table 4.3: Matlab Results for Impulse Transients

Load (MVAR)	First peak coefficient	First peak time (sec)
20	97.1816	0.1102

Table 4.4: Matlab Results for Momentary Interruptions

Fault Impedance (ohms)	First peak coefficient	First Peak time(sec)
0.001	6.805	0.2002

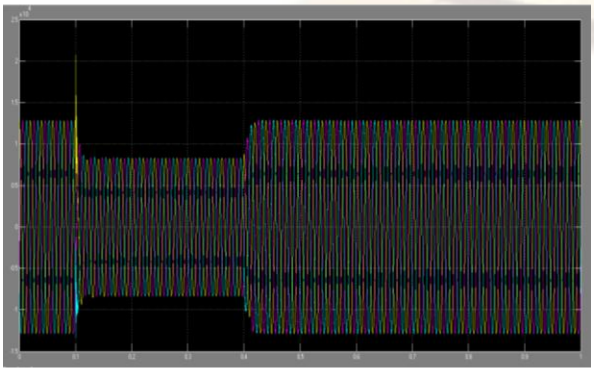

Fig 4.5: Simulation wave formwithout using DVR

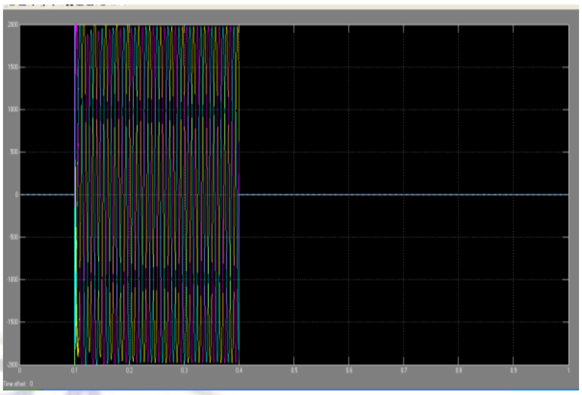

Fig 4.6: Simulation wave form withusing DVR

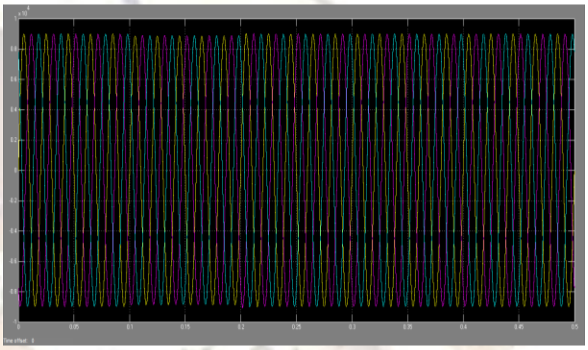

Fig 4.7: Simulation Full wave form withusing DVR

V. CONCLUSION

The discrete wavelet transform termed as DWT is used in this project as powerful analysis tool for monitoring , detecting and classification of power quality disturbances . The DWT gave the perfect time – frequency plot by which it became easier to analyse the power quality disturbances which has occurred in the power system network.The proposed method is simple and effective methodology for the detection and classification of power quality disturbances. By applying the DWT to the distorted voltage signals of the disturbances, the DWT coefficients are extracted, in which the cD1 (Detail coefficients at level1) is used to analyse the disturbance. The first peak of the cD1 is taken for all the four PQ disturbances i.e., the magnitude of the first peak is taken and given as the input to the fuzzy classifier. A MATLAB program has been developed for the detection and classification of PQ disturbances where it gives the information about the time duration of the disturbance, magnitude of the coefficients (cD1) and classifies what kind of PQ disturbance has occurred. Several power quality disturbances such as voltage sag, voltage swell, impulse transients and momentary interruptions have been analysed and recognized using the Discrete Wavelet Transform(DWT).

This paper has presented the power quality problems such as voltage sags, swells and interruptions and mitigation techniques of custom power electronic device DVR. The design and applications of DVR for voltage sag results are presented.A new PWM-based control scheme has been implemented to control the electronic valves in the two-level VSC used in the DVR. As opposed to fundamentalfrequency switching schemes already available in the MATLAB/ SIMULINK, this PWM control scheme only requires voltage measurements. The simulations carried out showed that the DVR provides relatively better voltage regulation capabilities.

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