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Implementation of Discrete Wavelet Transform on FPGA to Detect Electrical Power System Disturbances

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***Abstract*— Wavelet Transform is a time-frequency representation of the input signal. Realization of wavelet transform on field-programmable gate array (FPGA) device for the detection of power system disturbances is proposed in this thesis. This approach provides an integral signal-processing paradigm, where its embedded wavelet basis serves as a window function to monitor the signal variations very efficiently. By using this technique, the time information and frequency information can be unified as a visualization scheme, facilitating the supervision of electrical power signals. To improve its computation performance, the proposed method starts with the software simulation of wavelet transform in order to formulate the mathematical model. This is followed by the circuit synthesis and timing analysis for the validation of the designated circuit. Then, the designated portfolio is programmed into the FPGA chip through the download cable. And the completed prototype is tested through software-generated signals, in which test scenarios covering several kinds of electrical power quality disturbances are examined thoroughly.**

***Key words*— Power disturbances, Wavelet transform, DWT.**

.INTRODUCTION

Various types of disturbances like voltage sags, voltage swells, and momentary interruptions occur in power systems due to faults, nonlinear loads and dynamic operations [1]. But sensitive electronic circuitry and devices used by industries and residential consumers' demands quality power. To improve the quality of power, monitoring devices that are used at customer sites, would create huge amount of measured data and overload the system. Thus automatic tools are needed for assessment of measured data to help utilities and customers for clear understanding. Analysis of voltage waveforms will give understanding of underlying event (power quality disturbance). Efficient detection and characterization of events help maintenance and control of the system for improving system stability and reliability.

A simple approximation of amplitude of a sinusoidal voltage uses the root mean square (RMS) method evaluated over a cycle or half cycle. RMS gives rough approximation of fundamental frequency profile of the waveform under observation. This method maybe simple and fast but cannot distinguish between fundamental frequency, noise components or harmonics. Also in RMS techniques, phase-angle information is lost. Hence, transformer saturation, induction motor starting and capacitor switching cannot be distinguished clearly. Progress in signal analysis has led to the development of new techniques for characterizing and identifying various power quality disturbances. Discrete Fourier Transform (DFT) is well known for its ability to estimate fundamental amplitude and phase-angel of a signal. DFT transforms the signal simply from time-domain to frequency-domain. Using DFT it is possible to estimate fundamental amplitude and its harmonics with reasonable approximation [2]. It also estimates periodic stationary signals. But it is very poor in detecting sudden or fast changes in waveform i.e., transients or voltage dips [3]. Filters are best suitable to extract signals in a specified band-width, i.e., low-pass band, band-pass and high-pass band filters [4] [5]. Filters banks were used for detailed study of specific band of frequency spectrum. Use of wavelets was applied to non-stationary harmonics distortion in power-systems [6]-[12]. The technique is to decompose the signal in different frequency bands and to study its characteristics separately. As said, wavelets are good with non-periodic signals that have short duration impulse components that usually occur in power-system transients [13]. There are different types of wavelets like Daubechies, Coiets, Morlet and spline wavelets which are suitable for power quality studies.

II. Power Quality is Voltage Quality

Technically, in engineering terms, power is the rate of energy delivery and is proportional to the product of the voltage and current. It would be difficult to define the quality of this quantity in any meaningful manner. The power supply system can only control the quality of the voltage; it has no control over the currents that particular loads might draw. Hence, the standards in the power quality area are devoted to maintaining the supply voltage within certain limits. AC power systems are designed to operate at a sinusoidal voltage of a given frequency [typically 50 or 60 hertz (Hz)] and magnitude. Any significant variation in the magnitude, frequency, or purity is a power quality problem[21]. Although the generators may provide a near-perfect sine-wave voltage, the current passing through the impedance of the system can cause a variety of disturbances to the voltage. For example,

1. The current resulting from a short circuit causes the voltage to sag or disappear completely [22].
2. Lightning strokes result in high-currents that pass through the power system and cause high-impulse voltages that frequently flash over insulation and lead to other phenomena, such as short circuits [23].
3. Distorted currents produced by loads also distort the voltage as they pass through the system impedance to other end users [23].

Therefore, while it is the voltage with which we are ultimately concerned, we must also address phenomena in the current to understand the basis of many power quality problems.

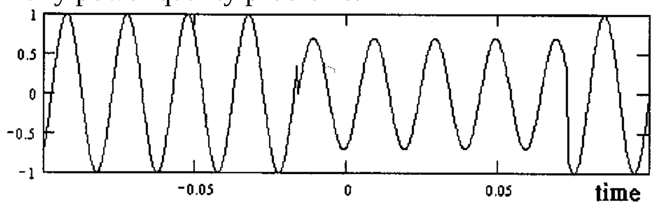

Fig 2.1.1 Voltage Sag

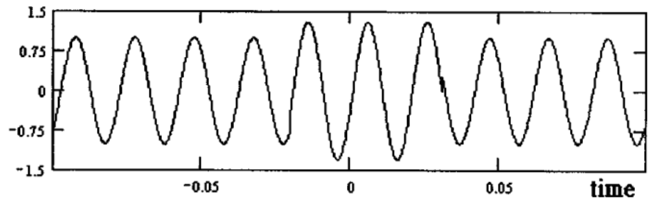

Fig 2.1.2 Voltage swell

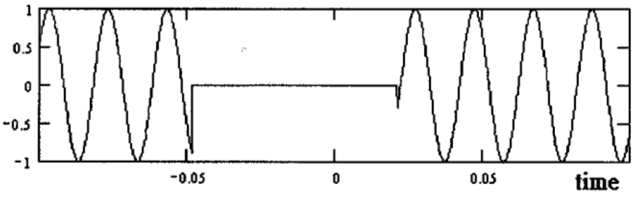

Fig 2.1.3 Momentary Interruption

III. Application to detect Power Quality

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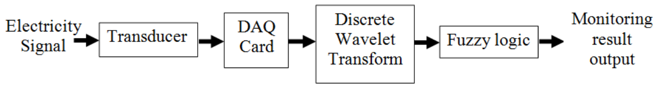
Power Quality monitoring platform topology is as show below



. Power Quality monitoring system

IV. Implementation on FPGA and Hardware Co-Simulation

The Hardware Architectures that are synthesized and implemented as said previously can be simulated by applying input to the FPGA. This input must be of fixed point type.

But in reality it is very time consuming to generate Wave forms that replicate Power Quality problems and then discritize and sample at FPGA operating frequency and then finally convert this Real data type samples into Fixed-point data type samples. Instead the easy way is to go for Hardware Co-Simulation. This is a feature of Xilinx System Generator. This allows input generated from Simulink MATLAB to be applied to FPGA in real-time and stream back the output from FPGA to Simulink for monitoring purpose or further usage.

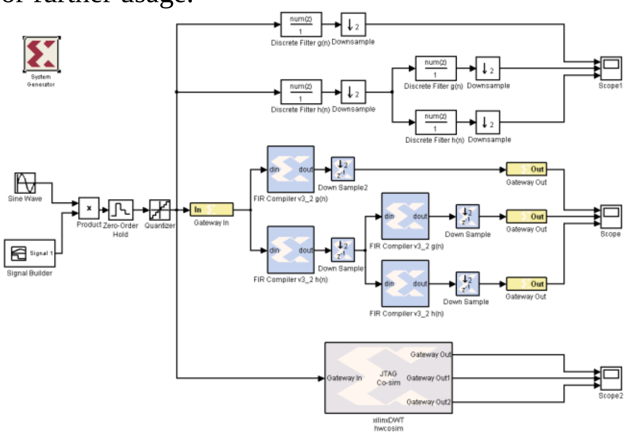
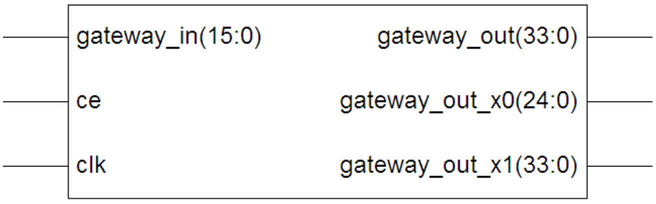


Fig 4.4 Simulink Environment

V. EXPERIMENTAL RESULTS

RTL Schematic of DWT:

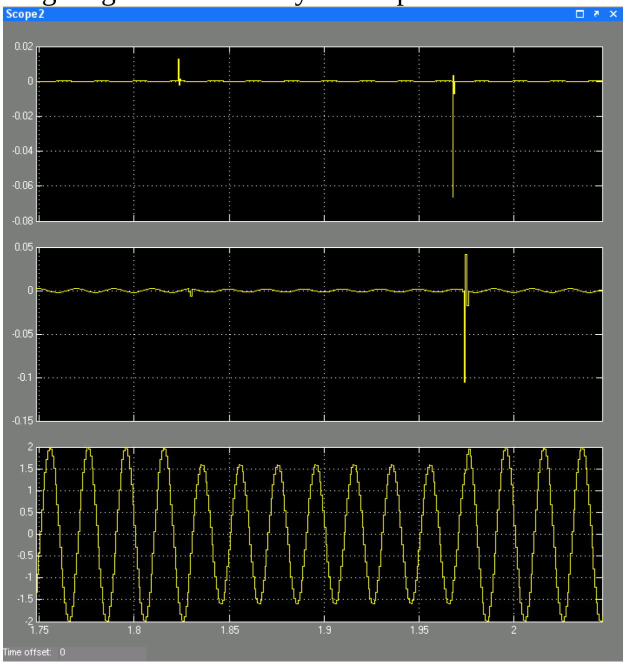


The figures below show the comparison of Detailed and Approximation Coefficients D1, D2, S2 of simulink model and FPGA output side by side.

Since the FPGA architecture is similar in mathematical model to that of DWT model designed in simulink using Xilinx, and as the applied input is also same, there is no much difference in outputs of simulink model and FPGA.

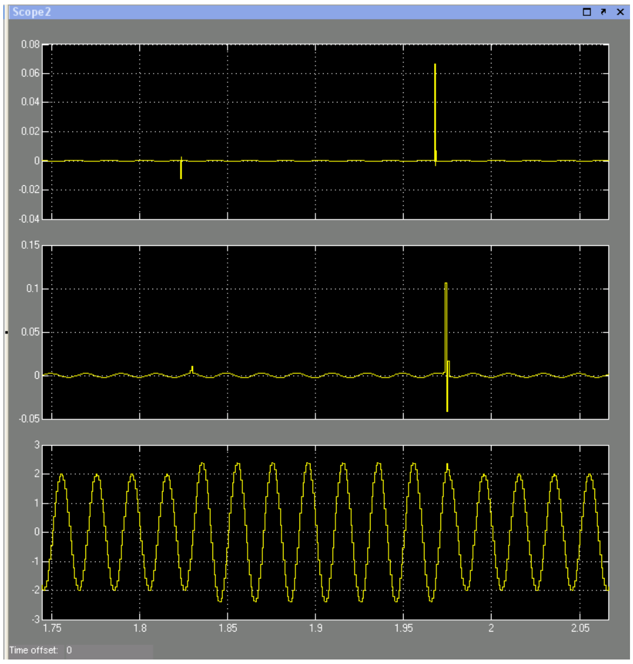
Figure 4.5 is the output of FPGA simulated with input voltage sag signal

Similarly 4.6 and 4.7 are outputs with input signal as Voltage sag and Momentary Interruption



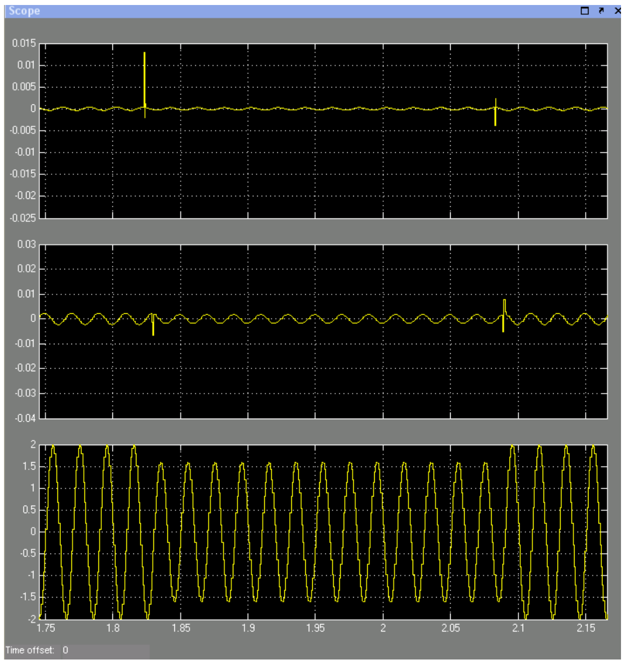
FPGA Output

Fig 4.5 Voltage Sag



FPGA Output

Fig 4.6 Voltage Swell



FPGA Output

Fig 4.7 Momentary Interruption

VI. CONCLUSION

This work raised a number of challenges some of which are mentioned below. Choosing Mother Wavelet: daubechies3 wavelet was chosen because daubechies wavelets are efficient though they are bit complex to implement. I have targeted Virtex-5 Xilinx FPGA device “xc5vlx110t-1-ff1136” that has sufficient DSP48 slices and LUTs. For functional simulation, synthesis and implementation, Xilinx ISE 10.1i software has been used. And for Hardware Co-simulation Xilinx System Generator was used.

This method has the potential of being extended to detect other kinds of disturbances. The hardware complexity can be further reduced by exploiting the properties of particular wavelet and generating specific hardware architecture.

This work can be extended to detect power quality disturbances by applying the output from DWT to neural networks or fuzzy logic [37] to analyze, which are trained to detect specific power event looking at the approximation and detail coefficients.

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wavelets

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