

# WAVELET BASED FLICKER ANALYSIS AND REMOVAL SYSTEM USING LabVIEW

A

Thesis Report

Submitted in partial fulfillment of the requirement for the award of degree

## **MASTER OF ENGINEERING IN ELECTRONICS & INSTRUMENTATION**

Submitted By

**Er. Amrik Singh**

**Roll No. 801051034**

Electronics Instrumentation & Control Engineering

Department, Thapar University,

Patiala



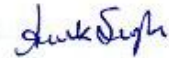
**ELECTRICAL AND INSTRUMENTATION ENGINEERING  
DEPARTMENT, THAPAR UNIVERSITY**

**PATIALA-147001**

## DECLARATION

It is to certify that the thesis titled, "WAVELET BASED FLICKER ANALYSIS AND REMOVAL SYSTEM USING LabVIEW" being submitted by me, in partial fulfillment of the requirements for the award of degree of MASTER OF ENGINEERING (Electronics Instrumentation & control engineering) at THAPAR UNIVERSITY, PATIALA is a bonafide work carried out by me under the guidance of Dr. S.K. Singla and that no part of this thesis has been submitted before for the award of any degree.

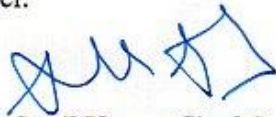
Date:



(Amrik Singh)

Roll No.801051034

I certify that the above statement made by the student is correct to the best of my knowledge and belief.



(Dr. Sunil Kumar Singla)

Assistant Professor  
Department of Electrical and Instrumentation Engineering  
Thapar University, Patiala  
PUNJAB.

Countersigned by



(Dr. Smarajit Ghosh)  
Head of Department  
Department of Electrical and Instrumentation  
Engineering, Thapar University, Patiala



(Dr. S. K. Mohapatra)  
Dean of Academic Affairs  
Thapar University, Patiala

## **ABSTRACT**

Flicker is defined as the state of unsteadiness of visual sensation induced by a light source whose luminance or spectral distribution varies with time. The basis of flicker is usually the use of large loads having quick fluctuating power demands. Humans can be sensitive to light flicker caused by voltage fluctuations. Our vision can be weakened with flicker and may cause discomfort and fatigue. In some situations, it can even result to accidents in workplace due to operator fatigue and reduced concentration levels. The objective of this thesis is to monitor the flicker by using suitable wavelet and to remove the flicker from the supply of General Service Connections (220 V supply). The thesis puts forward a method which uses a Wavelet based flicker analysis system where MATLAB and LabVIEW are integrated together to extract the characteristics of flicker. It can detect the amplitude modulation waveform of the voltage flicker, examine time and frequency content. After the analysis of the signal a control signal has been applied to overcome the effect of flicker.

## ACKNOWLEDGEMENTS

First and foremost, I would like to thank my father **S. Gursharan Singh** and my mother **Swaran Kaur** for all their prayers and blessings. Without their support and encouragement at crucial periods of my life, it would not have been possible for me to pursue graduate studies and aim for greater things in my career. Their positive attitude towards me is my main source of inspiration. I am proud to dedicate this thesis and all the good things in my life to them.

I am grateful to my guide Dr. Sunil Kumar Singla, Assistant Professor, department of Electrical and Instrumentation Engineering, Thapar University, Patiala for providing me the opportunity to work in an exciting and challenging field of research. His constant motivation, support and infectious enthusiasm have guided me towards the successful completion of this thesis. My interactions with him have been of immense help in defining my research goals and in identifying ways to achieve them. His encouraging words have often pushed me to put in my best possible efforts.

This section will look incomplete if I fail to thank all my near and dear friends who stood beside me, understood my academic goals and helped me to achieve it. Last but not by any means least, my heartiest thanks to all the persons, who made me what I am today; word fails to express my feelings for them.

I am also thankful to other members of my family including my brother and fiancé for their love, affection and timely help.

Amrik Singh

## Index

	<b>Chapter 1</b>	<b>1-10</b>
1	Introduction	1
1.1	Voltage	1-2
1.2	Instruments used for the measurement of voltage	2-3
1.3	Voltage fluctuation	3-4
1.3.1	Sources of fluctuation	4-5
1.3.2	Mitigation methods of voltage fluctuation	5-8
1.4	Flicker	8-10
1.4.1	Flicker levels and international standards	10
	<b>Chapter 2</b>	<b>11-26</b>
2.1	Introduction	11
2.2	Wavelet	11-12
2.3	Wavelet theory	12-13
2.4	Types of Wavelets	13-17
2.5	LabVIEW	17-19
2.6	MATLAB	19-20
2.7	Theoretical survey of flicker by various scientists and researchers	20-26
	<b>Chapter 3</b>	<b>27-38</b>
3.1	Introduction	27
3.2	Objectives of the chapter	27-28
3.3	Decomposition and reconstruction of the signal	28-31
3.4	Instruction of MATLAB written in formula node of LabVIEW	31-32
3.5	Block diagram built in LabVIEW	32-38
	<b>Chapter 4</b>	<b>39-49</b>
4.0	Results of voltage flicker monitoring	39-49
	<b>Chapter 5</b>	<b>49-51</b>
5.1	Conclusion	49- 50
5.2	Future work	51
6.0	Bibliography	52-56

## List of Tables

<b>Table</b>	<b>Name</b>	<b>Page</b>
4.1	Performance parameters of all wavelets.	44

## List of Graph

<b>Graphs</b>	<b>Name</b>	<b>Page</b>
4.1	Haar Wavelet Voltage Comparison	45
4.2	Symlet Wavelet Voltage Comparison	45
4.3	Coiflet Wavelet Voltage Comparison	46
4.4	Biorthogonal Wavelet Voltage Comparison	46
4.5	Db-4 Wavelet Voltage Comparison	47

# CHAPTER 1

## INTRODUCTION

The use of non-resistive and impact loads degraded the performance of a power system because it generate voltage flicker and fluctuation in the system. The examples of non-resistive loads are; large capability arc furnaces, spot welding machines and compressors, etc. These non-resistive loads gave rise to a lot of problems in our daily life and industry such as lighting equipments flicker, control unit disoperation, motor fluctuation etc. To improve and reduce their influence, it is very necessary to develop a monitoring and control system of voltage fluctuation and flicker [1]. Mainly three methods for monitoring the voltage fluctuation and flicker are used. These are

- a) Half-wave virtual value
- b) Square demodulation
- c) Full wave rectification

All these methods are not appropriate because these can explain only the amplitude and frequency of flicker but unable to detect the moment when voltage flicker occurs.

### 1.1 Voltage

In technical terms, voltage is well known by the name of “electrical potential difference” or “electric tension”. It is denoted by “V”. It is measured in volts or joule/coulomb. It is also known as the potential difference between two points or sometimes called the difference in electrical potential energy per unit charge between two points [2]. A voltmeter is an instrument which is most widely used to measure the voltage (potential difference) between any two points. The voltage between two ends of a path is the total energy required to move a small electric charge along that path and is divided by the magnitude of the charge [3]. Voltage may be calculated as;

$$\text{Voltage difference} = V_1 - V_2 = \frac{\text{Work Done}}{\text{Charge Transported}} = \frac{\text{Work Done}}{\text{Current} \times \text{Time}} = \frac{W}{I \times T}$$

## 1.2. Instruments used for the measurement of voltage

Instead of the voltmeter, voltage can be measured by many other instruments for example, the potentiometer and the oscilloscope. The voltmeter works on the principle of ohm's law by virtue of which a current is measured, passing through a fixed resistor, is proportional to the voltage across resistor, whereas potentiometer works by balancing the unknown voltage against a known voltage in a bridge circuit. In cathode-ray oscilloscope the voltage is amplified, to deflect an electron beam from a straight path, so that the deflection of the electron beam is proportional to the voltage [4].



Figure: 1 Multimeter used for measuring voltage [54]

Voltage is the description of the electric potential energy per unit charge. If a unit of electrical charge is placed in a position, the voltage shows the potential energy of it at that point. In other words, it is the amount of the energy enclosed within an electric field, or in an electric circuit, at a specified point.

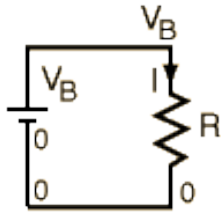


Figure:1.2

Used to express conservation of energy around a circuit in the voltage law [54].

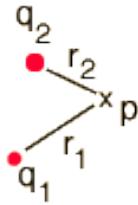


Figure:1.3

Used to calculate the potential from a distribution of charges [54].

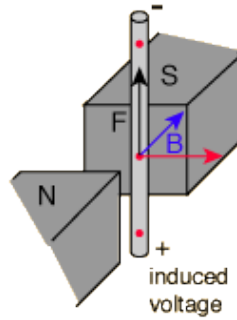


Figure:1.4

Voltage is generated by moving a wire in a magnetic field [54].

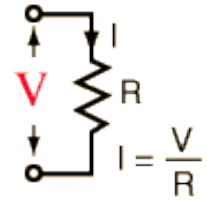


Figure:1.5

Used to calculate current in Ohm's law [54].

### 1.3. Voltage fluctuation

Voltage fluctuation is depicted as a sequence of root mean square voltage changes or a cyclic difference of the voltage waveform envelope. Some of the features of voltage fluctuations are:

- The variation in the amplitude of voltage value (difference of highest and lowest r.m.s or peak voltage value taking place throughout the disturbance).
- The number of voltage changes over a specified unit of time.
- The important belongings (such as flicker) of voltage changes related with the disturbances [5].

In power systems, a number of harmful technical problems occur due to voltage fluctuation, resulting in disturbance to production processes and considerable costs. But flicker has its negative physiological results, which can affect worker safety as well as productivity. Humans can be sensitive to light flicker caused by voltage fluctuations. Our vision ability can be weakened with flicker and leads to discomfort and fatigue. The physiology of this

phenomenon is complex. In general terms, our vision process and brain reaction is affected by flicker. It always produces discomfort and decline in work quality. Sometime, it can even result in workplace accidents due to operator fatigue and reduced concentration levels. By this, it affects the ergonomics of the production environment [6]. Recently, voltage fluctuations in power systems at the load terminals is characterized by using factors associated with the peak-to-peak r.m.s voltage change in the power system. While evaluating voltage fluctuations, the power of voltage fluctuations, their power spectrum and time duration are taken into account. Currently, the basic parameters that determine voltage fluctuations are short-term flicker severity, called the  $P_{ST}$  index, and long-term flicker severity, called the  $P_{LT}$  index. These parameters refer to voltage fluctuation effects on lighting and their influence on humans [7].

### **1.3.1 Sources of fluctuation**

The non-resistive loads used in the power system are the major source of fluctuation. Such fluctuating loads include arc furnaces, rolling mill drives, and main winder. All of these have loads with a high rate of change of power with respect to the short-circuit capacity at the point of common coupling (PCC). Small power loads also can be sources of flicker, such as starting of induction motors, welders, boilers, power regulators, electric saws and hammers, pumps and compressors, cranes, and elevators [8].

Other causes are capacitor switching and on-load transformer tap changers, which can change the inductive component of the source impedance. For example, in wind turbines, variations in generation capacity also can have an effect. Sometimes, voltage fluctuations are caused by low-frequency voltage inter-harmonics [9].

### **1.3.2 Mitigation methods for voltage fluctuation**

The properties of voltage fluctuations depend on following two points [10]

- a) Firstly, depend on their amplitude, determined by the features of the power system.
- b) Secondly depend on the time of their occurrence, determined by the kind of load and quality of its operation.

➤ *Examples for various types of equipment of mitigation methods include*

- 1) **Arc furnaces** — it include series reactors which make sure proper functioning of the electrode control arrangement, provide heating of charge.
- 2) **Welding plants** — in welding plants, a dedicated transformer is used to supply the plant which connect single-phase welders to a 3-phase network for balancing load distribution between phases and also connect single-phase welding machines to different phases from those powering lighting equipment.
- 3) **Adjustable speed drives** — Soft-start devices are used in these kinds of drives [11].

By increasing the short-circuit power with respect to the load power at the point of common coupling to which a fluctuating load is connected is an additional technique to decrease the amplitude of voltage fluctuations. This can be done by following manner [12].

- The loads are connected at a higher nominal voltage level.
- Dedicated lines are used to supply this type of loads.
- The fluctuating loads must be supplied from separate supply by using separate windings of a three-winding transformer.
- By increasing the rated power of the transformer supplying the load.
- By installing series capacitors.

### **1.3.3 Voltage stabilization solutions**

By reducing the use of non-resistive loads in the supply system leads to reduce the amplitude of voltage fluctuation. This is another way to reduce the amplitude of voltage fluctuations. It can be done by installing dynamic voltage stabilizers. Their effectiveness depends mainly on their rated power and speed of reaction.

By drawing reactive power at the fundamental frequency, dynamic voltage stabilizers generate voltage drops on the supply network impedances. The root mean square voltage value at the PCC can be increased or reduced depending on whether the reactive power is inductive or capacitive [13].

### **1.3.3.1 Synchronous machines**

Synchronous machines are the conventional sources of fundamental harmonic reactive power (lagging or leading) supplied in a continuous mode. In order to reach the standard limit level of voltage changes, the power rating of machines must be greater than the power of the load requiring stabilization. So without excitation current control it is useless to utilize a synchronous machine. So it is advantageous to operate a synchronous machine in a closed-loop voltage control system with fast excitation current control with the required dynamic parameters of the stabilization process. Such a key allows a fast rise time of the machine's reactive current.

### **1.3.3.2 Static compensators**

These devices utilize capacitive or inductive passive components that are switched, phase controlled or joined with controlled core saturation. Either in discrete steps or in a continuously variable method, they supply the required stabilizing reactive current. Both in technical and economic conditions, these compensators are considered to be the most beneficial solution for improving the power supply quality.

### **1.3.3.3 Compensators with saturable reactors**

For voltage stabilization, these devices make use of magnetic circuit saturation. There are two types of reactors, found a wide practical application in power system stability are listed below,

a) Self-saturable reactors (SRs)

b) Reactors with DC control circuit [13].

**1.3.3.4 Self-saturable reactors (SRs)** - At an industrial scale, these were one of the first static compensators connected in the circuits to mitigate the effects of voltage fluctuations. These are designed with minimum voltage range and the core is just below saturation as there is in an unloaded transformer, due to which a magnetizing current flows. Practically in this mode it has no control on voltage magnitude. The reactor becomes saturated at nominal

voltage by virtue of which a small change in the supply voltage results a huge change in current. Step-down transformer is not required while a compensator is connected to the supply network [10].

**1.3.3.5 Reactors with DC control circuit** - Reactors with DC control circuits are integrate with a parallel capacitor bank, which forms a filter for high order harmonics. It basically works as a transducer; where by varying the DC magnetizing current one can control the primary current magnitude. This technique allows the forcing of transient current which provide more rapid action of the system. The reactor's primary current changes from zero (unsaturated core) to the maximum value (saturated core) over the full range of the primary current. One of the main disadvantages of this solution is the generation of high order current harmonics. These harmonics can be eliminated by the use of a larger number of slots and appropriate linking of numerous windings, but at the cost of slower system response.

**1.3.3.6 Thyristor switched capacitors (TSC)** By means of AC thyristor switches, the sectioned capacitor banks are connected phase-to-phase with each section switched (on or off) in this solution. The values of the compensator equivalent susceptances vary in a discrete way, depending on the number of active sections. A suitable large number of small sections are used to produce the required resolution for the change of susceptances, in case of a single step. By the synchronization of switching and initial recharging of the capacitors, the over currents and over voltages linked with capacitor switching can be prevented. For balanced operation, time of response does not exceed 20 milliseconds.

#### **1.3.3.7 Self-commutated converter voltage sources and reactive current/power sources**

The compensator includes a voltage source converter (VSC). The value and quality of reactive power (inductive or capacitive) is analyzed by the switching states of semiconductor devices. STATCOM is one of the most common compensator used in now days. It uses semiconductor devices with forced commutation. The principle of operation of static synchronous compensator is similar to the operation of the synchronous compensator. AC/DC converter is one of the most basic parts of the compensator. An inductive reactance is used to connect this converter to the network, usually the leakage inductance of transformer.

When the converter voltage is lower than the supply network voltage then the compensator behaves like an inductive load. In the same way, the compensator delivers reactive power to the network, when the converter voltage is greater than the supply voltage, thus it behaving like a capacitive load [14].

## **1.4 Flicker**

Flicker is defined as the feeling of unsteadiness of visual sensation induced by a light source whose luminance or spectral distribution varies with time. Usually, it applies to cyclic variation of light intensity resulting from fluctuation of the supply voltage, which in turn, can be caused by disturbances introduced during power generation, transmission, or distribution. However, the basis of flicker is usually the use of large loads having quickly fluctuating power demand. Humans can be sensitive to light flicker caused by voltage fluctuations. Our vision can be weakened much more with flicker and cause general discomfort and fatigue. In general terms, our vision process and brain reaction is affected by flicker, almost always producing discomfort and decline in work quality. In some situations, it can even result to accidents in workplace due to operator fatigue and reduced concentration levels. By this, it affects the ergonomics of the production environment. A rapid, repeated change in light intensity i.e. the light that appears to flutter and be unsteady is referred to light flicker. It is caused when the voltage supplied to a light source changes or when the power line voltage itself fluctuates [15].

Flicker is a subjective phenomenon. Due to this reason it is not easy to determine the direct cost of its consequence, because the cost of flicker is usually depend on the cost of method, used to mitigate it. The severity of the flicker depends on several factors.

- The time rate at which voltage fluctuates,
- The change in the amplitude of voltage value, due to fluctuation.
- The kind of bulbs or tubes used such as, incandescent, fluorescent, or HID - high intensity discharge lighting systems).
- The gain factor of the light which measures the change in light intensity when the value of voltage, fluctuates.

Light flickering at a frequency of 50 Hertz (Hz, cycles per second), is produced by lamps operating on AC electric systems (alternating current). The power is turning on and off 50 times a second. The phenomenon of flickering in light sources is not the latest one, takes place since the beginning of power distribution systems. Due to the increase in number of residential customers and factories, the problem of flicker is increasing day by day in the power system.

Study on the process of visual sensitivity has a history going back more than 40 years. On the basis of these studies, the researchers analyzed perceptibility and flicker severity curves. These curves show the values of sinusoidal or rectangular voltage fluctuations on the vertical / Y-axis and frequency on the horizontal / X-axis. The area on top of the curve describes voltage fluctuations that produce unacceptable flicker, and the area lower than the curve defines acceptable flicker levels [16].

Due to the deep study of flicker by the electrical engineers, the Physiologists and Psychologists become able to develop improved mathematical models for the neuro-physiological processes. The results of the experiments offer the chance to move forward of relationship between the sensitivity of the human naked eye to light stimuli and also to find the frequency characteristic of an electrical signal.

Other studies confirmed that the response of the human eye is same as that of a band-pass filter in the frequency range of 0.5 Hz and 35 Hz, the maximum sensitivity to the luminous flux is at a frequency of around 8 Hz to 9 Hz.

For incandescent light sources, voltage fluctuations of around 0.3% of the average value can be detected at this frequency. Physiological effects depend on the various factors such as, change in amplitude of luminous flux, the spectrum of frequency and the disturbance duration [17].

The brain response to the light input has an inertial feature, with a time constant of about three hundred milliseconds. It is concluded that small change in luminous flux can be observed whereas the fast changes of luminous flux cannot be noticed. For example, in a single change there are two short changes in the luminous flux, occurring within three

hundred milliseconds. Short changes of luminous flux are more irritating, followed by a longer pause.

The occurrence of flicker is more advance in the area of the visual field than in those areas on which the observer's attention is focused. The voltage fluctuation is independent of the type of supply voltage (AC or DC) used for the lamp, necessary to produce perceptible flicker.

### **1.4.1 Flicker Levels and International Standards**

According to Alex McEachern of Power Standards Lab, Alameda, California, two types of parameters characterize flicker levels. These are

1)  $P_{st}$  - A value calculated over 10 minutes distinguish the probability, due to which it becomes easier to detect that the voltage fluctuations would effect in detectable light flicker or not. The value 1.0 is used to represent the level so that it becomes easier to analyze flicker in a 60W incandescent bulb.

2)  $P_{lt}$  - When 12  $P_{st}$  values are joined in cubic relationship, one  $P_{lt}$  value is obtained. In other words it is derived from 2 hours of  $P_{st}$  values [18].

#### **sIEC 61000-2-2 specifies the following flicker compatibility levels [19]**

- For short- term flicker ( $P_{st}$ ) the compatibility level is 1.0.
- For long- term flicker ( $P_{lt}$ ) the compatibility level is 8.0.

According to McEachern it's not always possible to maintain flicker levels within these compatibility levels. To address this limitation, EN 50160, "Voltage Characteristics of Electricity Supplied by Public Distribution Systems," determines less restrictive necessities for the performance of supply system. According to the limit of EN 50160, 95% of the long-term flicker values ( $P_{lt}$ ) should be less than 1.0 in a one-week measurement period [19].

# CHAPTER-2

## LITERATURE REVIEW

### 2.1 Introduction

This chapter reviews the wide-range and multi disciplinary research on integration techniques in wavelet field. An analysis of collective information of existing systems reveals that the principal challenge in flicker and fluctuation monitoring is the issue of selecting the right approach. The ideas or actions intended to monitor the performance of flicker through LabVIEW and MATLAB revolves around the output of multiple graphs. When the combined signal of flicker and supply voltage is decomposed, then the output of the block diagram of LabVIEW is obtained in the form of number of graphs. This chapter contributes to the information sharing for literature review of different numbers of wavelets, LabVIEW and MATLAB.

### 2.2. Wavelet

A wavelet is a wave-like oscillation with amplitude that starts out at zero, increases and then decreases back to zero. The wavelet transform is a tool that cuts up data or functions or operators into different frequency component, and then studied each component with a resolution matched to its scale. Sometime the wavelet transform is often compared with the Fourier transform, in which signals are represented as a sum of sinusoids. The main difference is that wavelets are localized in both time and frequency whereas the standard Fourier transform is only localized in frequency [20]. If signal is already sampled, the discrete wavelet transform is used for data compression, and the CWT is used for signal analysis.

Wavelets can be used as a mathematical tool to extract information from many different kinds of data, including audio signals and images but unquestionably not limited to these. Sets of wavelets are required to examine data completely. A set of "complementary" wavelets will deconstruct data with no gaps or overlap so that the deconstruction process is mathematically reversible [21]. Hence, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms, where it is desirable to improve the original

information with minimal loss. The fundamental idea behind wavelets is to analyze according to scale. In fact, researchers in the wavelet field feel that, by using wavelets, one is adopting a complete new way of thinking or perspective in processing data. Wavelets are the functions that satisfy certain mathematical requirements and are used in representing data or other functions. Other applied fields include, astronomy, acoustics, nuclear engineering, sub-band coding, signal and image processing, neurophysiology, music, magnetic resonance imaging, speech discrimination, optics, fractals, turbulence, earthquake-prediction, radar, human vision, and pure mathematics applications such as solving partial differential equations are making use of wavelets [22].

### 2.3 Wavelet theory

Wavelet transforms are broadly divided into following two classes [23].

a) Continuous wavelet transforms (CWT)

b) Discrete wavelet transforms (DWT)

Both DWT and CWT are continuous-time (analog) transforms. They can be used to characterize continuous-time (analog) signals. CWTs operate over every possible scale and translation whereas; DWTs use a particular subset of scale and translation values or representation grid [24].

**2.4 Types of wavelets:** For the monitoring of flicker we are dealing with number of wavelets. A brief description of these wavelets is given below

#### 2.4.1 Biorthogonal wavelet

A biorthogonal wavelet is a wavelet where the associated wavelet transform is invertible but not necessarily orthogonal. Designing biorthogonal wavelets allows more degrees of freedom than orthogonal wavelet. The possibility to construct symmetric wavelet functions is one additional degree of freedom. In the biorthogonal case, there are two scaling functions  $\phi, \tilde{\phi}$ , which may generate different multi-resolution analyses, and accordingly two different wavelet functions  $\psi, \tilde{\psi}$ . So the numbers  $M$  and  $N$  of coefficients in the scaling sequences  $a, \tilde{a}$  may

differ. The Haar wavelet is the only orthogonal wavelet with linear phase; we can also design biorthogonal wavelets with linear phase. Biorthogonal wavelets feature a pair of scaling functions and associated scaling filters — one for analysis and one for synthesis. There is also a pair of wavelets and associated wavelet filters, one for analysis and another for synthesis. The analysis and synthesis wavelets can have different numbers of vanishing moments and regularity properties. In a sparse representation, we can use the wavelet with the greater number of vanishing moments for analysis resulting, while the smoother wavelet for reconstruction. Biorthogonal Wavelets are families of compactly supported symmetric wavelets. The dual scaling and wavelet functions have the following properties [24]:

1. They are zero outside of a segment.
2. They are very simple because the calculation algorithms are maintained.
3. The associated filters are symmetrical.
4. The functions used in the calculations are easier to build numerically than those function used in the Daubechies wavelets.

### **2.4.2. Coiflet wavelet**

Coiflet wavelet is a discrete wavelet designed by Ingrid Daubechies, to have scaling functions with vanishing moments. The wavelet is near symmetric, their wavelet functions have  $N / 3$  vanishing moments and scaling functions  $N / 3 - 1$ . The Coiflet wavelet is orthogonal and near symmetric. This property of near symmetry leads to the near linear phase characteristics of the Coiflet wavelet. Coiflet scaling functions also display vanishing moments. For both the wavelet and scaling functions,  $N$  is the number of vanishing moments in  $\text{coif}N$  [25].

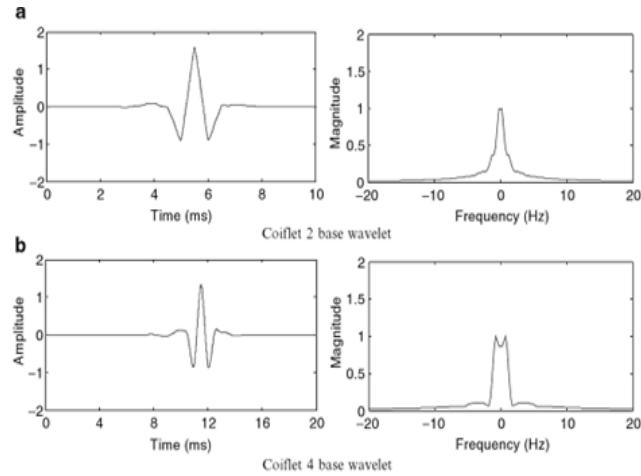


Figure.2.1: Coiflet wavelet (left) and its magnitude spectrum (right)

a) Coiflet 2 base wavelet , b) Coiflet 4 base wavelet [55]

### 2.4.3. Haar wavelet

The Haar wavelet is a sequence of rescaled "square-shaped" functions which together form a wavelet family or basis. The Haar sequence is recognized as the first known wavelet basis and extensively used as a teaching example in the theory of wavelets [26].

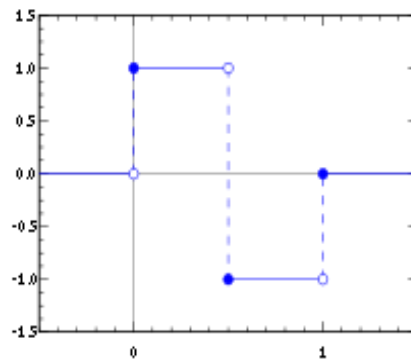


Figure 2.2: Actual waveform of Haar wavelet, (Square – tooth) [55]

The Haar sequence was proposed in 1909 by Alfred Haar. These functions were used by Haar to give an example of a countable orthogonal system for the space of square-integral function on the real line. The Haar wavelet is also known as D2, as a special case of the Daubchies wavelet. The Haar wavelet is also the simplest possible wavelet. Haar wavelet is not continuous, and therefore it is not differentiable, so this is a technical disadvantage of Haar

wavelet. For the analysis of signals with sudden transitions, such as monitoring of tool failure in machines, can, however, be advantages of this property. It is the first wavelet family of scale functions that is orthogonal and have finite vanishing moments. This property insures that the number of non-zero coefficients in the associated filter is finite. This is very useful for local analysis [27]. The Haar wavelet is the basis of the simplest wavelet transform. It is also the only symmetric wavelet in the Daubechies family. It is the only one that has an clear expression in discrete form. Haar wavelets are related to a mathematical operation called Haar transform, which serves as a prototype for all other wavelet transforms. The Haar transform decomposes a discrete signal into two sub-signals of half of its length, like all wavelet transforms. One subsignal is a running average or trend, and the other subsignal is a running difference or fluctuation. The Haar wavelet transform has the advantages of being theoretically simple, fast and memory efficient, since it can be calculated in place without a temporary array. Still, it is exactly reversible without the edge effects that are a problem of other wavelet transforms. On the other hand, its discontinuity, which can be a problem for some applications, like compression and noise removal of audio signal processing is a limitations of the Haar transform [28].

#### **2.4.4. Db-4 wavelet**

Daubechies wavelets are the family of orthogonal wavelets, which defines a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. There is a scaling function (also called father wavelet) with each wavelet type of this class, which generates an orthogonal multi-resolution analysis. The dbN wavelets are the Daubechies' external phase wavelets in which "N" refers to the number of vanishing moments. In the literature, these filters are also referred by the number of filter taps, which is  $2N$ . The db1 wavelet is also known as the Haar wavelet. In the same way as the Haarwavelet transform, the Daubechies wavelet transforms are defined by computing the running averages and differences using scalar products with scaling signals and wavelets. This family includes the Haar wavelet, written as "db1", the simplest wavelet imaginable and certainly the earliest [29].

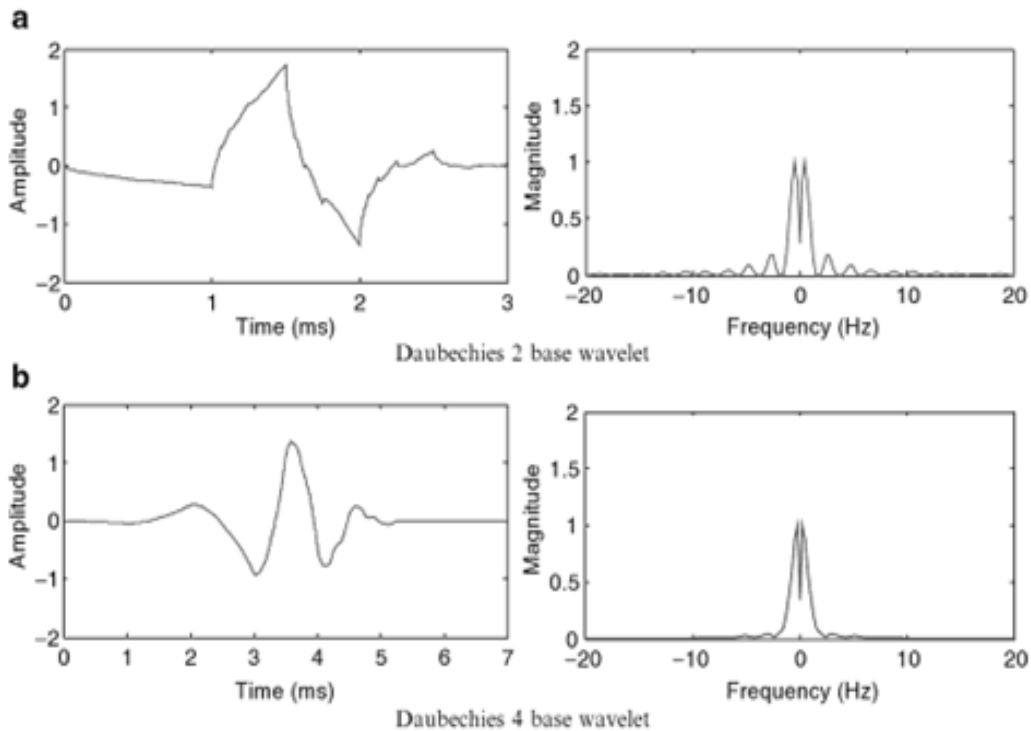


Figure 2.3: Daubechies wavelet (left) and its magnitude spectrum (right)

a) Daubechies 2 base wavelet, b) Daubechies 4 base wavelet [55]

### 2.4.5. Symlet Wavelets

The sym $N$  wavelets are also known as Daubechies' least-asymmetric wavelets. The symlets are more symmetric than the external phase wavelets. In sym $N$ , “ $N$ ” is the order, the number of vanishing moments. Some authors use “ $2N$ ” instead of “ $N$ ”. Symlet is only near symmetric but is not completely symmetric; as a result some authors do not call them symlets. In the literature, these filters are also referred by the number of filter taps, which is  $2N$ . The symlets have other properties similar to those of the db $N$ s [30].

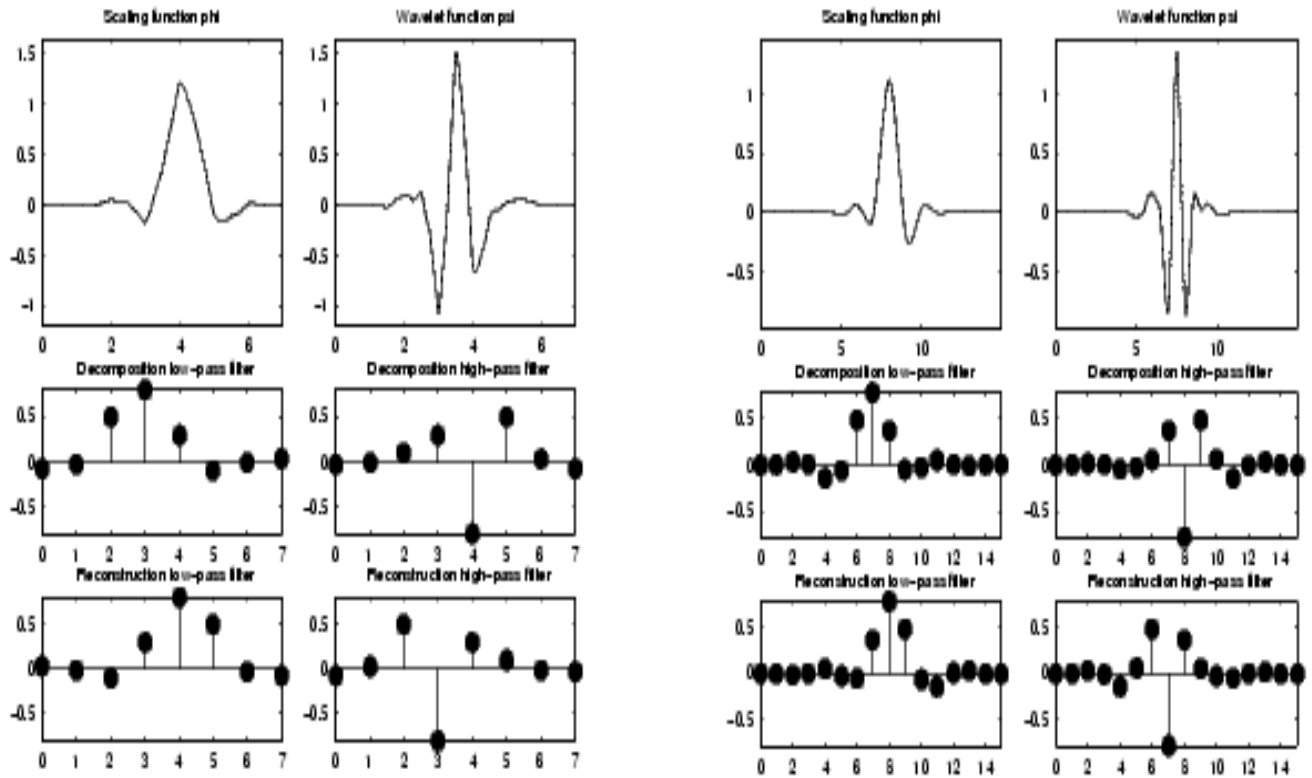


Figure 2.4: Symlet sym4 (Left) and sym8 (Right) [55]

## 2.5. Lab VIEW:

LabVIEW is a graphical programming language that uses icons instead of lines of Text to create applications. The name Lab VIEW stands for Laboratory Virtual Instrumentation Engineering Workbench. Lab VIEW is a system design platform and development environment for a visual programming language from National Instruments. In contrast to text-based programming languages, where instructions determine program execution, Lab VIEW uses dataflow programming, where the flow of data determines execution order. Lab VIEW also includes several wizards to help us quickly for configuring our DAQ Devices and computer-based instruments and build applications [31].

LabVIEW programs are called virtual instruments (VIs). Each Virtual Instrument contains three main parts.

1. **Front Panel** - How the user interacts with the virtual instrument.
2. **Block Diagram** - The code that controls the program.
3. **Icon/Connector** - Means of connecting a VI to other Vis.

## 1) FRONT PANEL

When the program is running, it is used to interact with the user. Users can control the program, change inputs, and see data updated in real time.

## 2) Block Diagram

The graphical source code is contained by the block diagram. Front panel objects appear as terminals on the block diagram. Additionally, the block diagram includes functions and structures from built-in Lab VIEW Virtual Instrument libraries. Including control and indicator terminals, functions and structures, wires connect each of the nodes on the block diagram.

## 3) Icon/Connector

The Block diagram includes functions. Each function may have number of inputs and outputs terminals. In LabVIEW programming, wiring to these terminals is an important part [32].

## Advantages of virtual instrumentation [33]

1. LabVIEW block diagram is flexible.
2. It has inbuilt instruments and control parameters.
3. It has all most all control and debuggers, it has 32 bit compiler.

4. There is no need of large and extra hardware's.
5. There is no need of writing programs like C++, JAVA in VI (Virtual Instrument).
6. It is very easy for modification of parameters.
7. It provides all hardware in the form of software.
8. It provides all the graphs and charts for analysis.
9. No need of maintenance or extra care.
10. Cost wise Virtual Instrument is cheaper.
11. Storage and back up is excellent as compared to traditional instruments.
12. Easily interfacing like with CAN, TCP/IP, USB, RS-232, GPIB, VXI, and PXI.
13. LabVIEW includes a text-based programming component called Math Script. Math Script can be integrated with graphical programming using "script nodes" and uses a syntax that is generally compatible with MATLAB.

## **2.6. MATLAB**

The full form of MATLAB stands for Matrix Laboratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects [34]. MATLAB is a high-performance language for technical computing. It integrates computation, visualization and programming environment. Still, MATLAB is a modern programming language environment. It has sophisticated data structures. It contains fixed editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research. MATLAB has many advantages in contrast to conventional computer languages (e.g., C, FORTRAN) for solving technical problems [35]. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphics

commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering. They are excellent in their specific applications [36].

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. It is developed by Math Works; MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran [37].

## **2.7. Theoretical survey of flicker by various scientists and researchers in different ways:**

### **1. Measurement Methods for Calculating the Direction to a Flicker Source**

AXELBERG [38] suggests a method to help in finding the source of small fast variations (FLICKER) of the voltage in a power system. He constructs a suitable working model from where the measurement methods could be derived. He used the defined model for determining the direction to a flicker source with respect to a monitoring point. It consists of a Thevenin's equivalent circuit with supplying a linear equivalent circuit, which consisting of series impedance representing a transmission line and two shunt impedances placed on both sides of the series impedance. Within the flicker frequency spectrum, the values of the impedances can fluctuate repeatedly with a frequency. In this model, a "monitoring point" is defined where the waveforms of voltage and current are obtained. With the help of this model and studying the voltage and current, envelopes (i.e. modulating signals) the direction to the flicker source can be determined.

### **2. Effects of Illumination and Viewing Angle on the Modeling of Flicker Perception in CRT Displays by Shane –Sidebottom**

This study calculated the utility of a psychophysical model as part of a new ANSI/HFES 100 standard for CRT flicker. Farrell developed a graph, which based upon flicker prediction

method. It was evaluated in 1987. The Farrell model is based on phosphor persistence, screen luminance, display size, and viewing distance. His graph based method assumes a worst case scenario (i.e. a white display screen shown on a display with P4 phosphor) [39]. The Farrell model requires photometric measurements to be taken using special equipment. The graph based method requires knowledge of the display size, viewing distance, screen luminance, and refresh rate CFF increased with increasing luminance and display size. Adequate illumination significantly increased CFF (critical flicker frequency). This study demonstrates that when tested under the same conditions it was developed under, the Farrell method successfully predicts flicker perception; however, when tested under conditions representative of real world working conditions, the Farrell model fails to predict flicker perception [40-41].

### **3. Understanding the mechanisms of Flicker defined form (FDF) processing**

Goren [42] mark a paper in which he describe that the Flicker defined form (FDF) is a temporally-dependent illusion created by the counter phase -Flicker of randomly positioned element dots that preferentially stimulate the magnocellular system. The study tried to determine how FDF varies or is similar to static, luminance defined stimuli. Current results from this procedure showed that FDF could be matched to particular spatial frequencies, and improved with increasing background structure and area. Goren discovers that FDF is a stimulus. It is defined by temporal dynamics and sometimes affected by spatial structure. This result has shown that FDF can be matched to spatial stimuli (*i.e.* spatial frequency), is easier to distinguish with increasing background structure and area (not just the contour). It can be distinguished and recognized, for certain shapes. These results suggest that FDF relies on motion pathways, but also benefits from overlap in function of shape recognition pathways.

### **4. Flicker: An Execution Infrastructure for TCB (Trusted Computing Base) Minimization**

McCune, et.al [43] illustrates the flicker as an infrastructure for executing security sensitive code in complete isolation while trusting as few as 250 lines of additional code. Flicker can also provide meaningful, née-grained attestation of the code executed (as well as its inputs and outputs) to a remote party. Flicker influences new product processors from AMD and Intel

and does not require a new OS or VMM. According to them, flicker allows code to variably execute with hardware forced isolation. Flicker itself adds as few as 250 lines of code to the application's TCB. Flicker significantly improves the security and reliability of the code it executes. As a result, our research brings a flicker of hope for securing commodity computers.

## **5. The Effect of Harmonic Power Fluctuation for Estimating Flicker**

Guan, et.al [44] studies the relationship between the voltage flicker problems and harmonic power variation for the power system with electric arc furnaces. This research discussed the effect of harmonic power fluctuation with flicker estimate value. The method of field measurement, statistics and simulation is used in this process. The analysis results display that 10  $\Delta V$  estimate must account for the effect of harmonic power variation. These researchers found that the estimated 10  $\Delta V$  is lower if the conventional means of estimating criteria is applied.

## **6. Comparison between Haar and Daubechies Wavelet Transforming on FPGA Technology**

Mahmoud, et.al [45] apply the Field Programmable Gate Array (FPGA) technology that recommends the potential of designing high performance systems at low cost. The principle of this paper are implement on the Haar and Daubechies wavelets using FPGA technology and also The Bit Error Rate (BER) between the input audio signal and the reconstructed Output signal for each wavelet is calculated. The design process has been explained and designed using Electronic Design Automation (EDA) tools for system design on FPGA. Simulation, synthesis and implementation on the FPGA target technology has been carried out. The simulation obtained results are compared from the Bit Error Rat (BER) point of view between the input audio signal and the reconstructed output signal. The Daubechies wavelet has proved to be more efficient for audio applications than Haar wavelet.

## **7. Application of Continuous Wavelet Transform for Study of Voltage Flicker-Generated Signals**

HUANG, et.al [46-47] proposed a generated signal used in an application of continuous wavelet transform (CWT) for the analysis of voltage flicker. They describe that with the time-

frequency localization characteristics embedded in wavelet. The time and frequency information of a waveform can be integrally presented, thereby enhancing the monitoring of voltage flicker-generated signals at different time intervals. The Morlet wavelet has been selected as the basis function for the CWT in the proposed method. The advantage of this method is that the signal component at any frequency of interest can be more easily monitored than by discrete wavelet transform (DWT). The high frequency required in the voltage flicker study can be also comfortably accomplished. This approach has been useful to investigate various simulated voltage flicker-generated signals, and examine the data recorded from the actual arc furnace operation [44].

## **8. Harmonics and Flicker Analysis in Arc Furnace Power Systems**

Sousa, et.al [48] presents guiding principle for the exact estimation of harmonics and flicker generated by ac electric arc furnaces. Its propagation is through transmission and distribution systems. They make use of typical case where a HV system supplies a high capacity arc furnace. The electrical network is simulated using the ATP version of the EMTP where a non-linear time-varying three-phase arc model is implemented in MODELS. To evaluate the harmonic distortion and the short-term flicker severity index (Pst) using the MATLAB programming language, they then used a time-domain simulations. They used a different steps of the prediction are as below. First step they used, a three-phase ac electric arc model is implemented using the MODELS programming language. After that, they used a time-domain simulation of the electric power system to which the arc furnace is connected is accomplished. Afterward, they used two built up MATLAB programs to evaluate the harmonic distortion and flicker severity linked with each location at the system. Sousa, et.al provided these guiding principles that allow the accurate prediction of the effects of the arc furnace connection. It also helps in the definition and design of the mitigation techniques needed to correct voltage and current distortions caused by arc furnaces operation.

## **9. Pressure, Plume Flicker, and Acoustic Data Correlation in Lab scale Hybrid Rockets**

Hudson, et.al [49] worked on the development of the hybrid rocket motor that has been plagued by combustion instabilities. These are usually monitored as fluctuations in chamber

pressure and are on the order of tens of Hz in frequency. Lab scale hybrid system has also indicated instabilities at these frequencies. Additional studies, in areas such as IR and other spectral monitoring have indicated that these oscillations are also present in the plume as light emission flicker. This document presents a study of these specific phenomena and attempts to compare plume flicker, acoustic data, and higher speed chamber pressure monitoring. They found that the plume flicker frequencies match those found using high speed pressure transducers while these light intensity fluctuations demonstrate greater amplitude. They believe that flicker data offers an inexpensive but sensitive alternative to high-speed pressure transducer use. It was possible to detect and correlate pressure and plume flicker oscillations in our lab scale hybrid motor. By using this method, future investigators may find a non-invasive alternative to the use of expensive pressure transducers for certain combustion monitoring activities.

## **10. Post-processing for flicker reduction in H.264/AVC**

Kuszpet1, et.al [50] describes a post-processing scheme for dealing with the flicker artifact. They generated a motion compensated version of the intra frame. It is based on its preceding inter frame, and is used to filter the intra frame in order to reduce the discontinuity. Additionally, a non-reference flicker measure is put forward, and is used as a basis for an adaptive flicker-reduction technique. Simulations express that the proposed technique can reduce the flicker measure by up to 30% while lowering the PSNR by no more than 0.5dB. Objective results with subjective impressions, point out that the proposed method significantly reduces the discontinuity, with an almost negligible drop in PSNR. In this paper, a novel post-processing technique for flicker reduction in H.264-coded videos was proposed. It is based on averaging received frames with their motion-compensated counterparts. The H.264/AVC standard mitigates some of the most noticeable artifacts of previous video coding standards, such as blocking and ringing. But, it shows a new temporal artifact, a visible discontinuity between an intra frame and its preceding inter frame, known as flicker.

## **12. Power System Flicker Analysis and Numeric Flicker Meter Emulation**

Yang, [51] Member, IEEE, et.al presents a methodology for flicker propagation analysis, numeric IEC flicker meter emulation and flicker source modeling. The main results are viewed by these researchers from this research are given below.

- a) To generate a distribution load model by which the flicker propagation from HV to MV can be studied.
- b) To build numeric IEC flicker meter with improved algorithm (demodulator and nonlinear classification).
- c) To build simplified actual disturbance source models.

A basic approach has been studied in this paper by using RMS value-based modeling. After combination of these models and a numeric flicker meter in frequency domain software, it is possible to create almost all low frequency electrical disturbances with very short computing time and to study interactions among them, such as between voltage dip and flicker. As they suggest that the distribution load behavior to flicker disturbance can be modeled by  $dQ/dV$  and  $Dp/dV$ . This will help to study flicker propagation in different voltage levels. RMS value-based flicker calculation by numeric IEC flicker-meter algorithm is a fast and easy way to perform flicker assessment. Their result from this procedure demonstrate the integration of numeric flicker-meter and flicker source models into load-flow software or frequency domain software gives a single platform to analyze flicker and other disturbances with very short computing time.

### **13. Critical flicker frequency and centrally acting Drugs**

Turner [52] suggests that the critical flicker frequency (CFF) has been used as a test of central nervous activity in response to drugs for many years. The critical flicker frequency (CFF) may be defined as the fastest rate at which a flickering source of light shows to be flickering as opposed to being steady. It has a number of determinants containing the luminance, wavelength, wave-form, and light-dark ratio of the stimulating light, the area, position, and light-adapted state of the retina illuminated, the duration of exposure, and the size of the pupil. The threshold may also be influenced by age and constitutional factors.

Recently [53], the importance of inter-sensory effects and previous adaptation to intermittent light has been highlighted by Turner in 1965. The measurement of critical flicker frequency after adaptation to intermittent light of varying frequencies has demonstrated changes in visual discrimination after modest therapeutic doses of centrally-acting drugs. It is a valuable test in the study of interaction and duration of action of these drugs. It also allows a comparison to be made of central activity between members of the same pharmacological or chemical class. The adaptation of critical flicker frequency to intermittent light is not modified by any of the drugs which have been studied.

# CHAPTER 3

## METHODOLOGY

### 3.1 Introduction

Although the problem of flicker has been studied in a widespread way, it is however, not an entirely solved problem. This thesis begins to deal with the information of flicker followed by some of the restrictions in existing monitoring systems. A system which deals with only Daubechies and Haar wavelet is obtained by using Field Programmable Gate Array (FPGA) technology. This technology has been developed to presents the potential of designing high performance systems at low cost. The results of these wavelets are depicted to carry out the significantly better results than any other conventional and pre-existing systems. But in this work, a new model of monitoring the flicker and fluctuation has been developed using LabVIEW. The model has been developed by integrating MATLAB and LabVIEW with decomposition and reconstruction instruction of MATLAB, written in formula node of LabVIEW. Furthermore, to present a comparative study three more wavelets named as COIFLET, SYMLET and BIORTHOGONAL have also been discussed. As earlier discussed, the existing system only deals with the BIT ERROR RATE of Haar and Daubechies wavelet but by using new methodology we are dealing with the frequency as well as voltage of different number of wavelets with respect to flicker voltage.

### 3.2 Objectives of the chapter

1. To study the DECOMPOSITION and RECONSTRUCTION instructions for a combined signal (supply voltage + flicker) in MATLAB.
2. To study the APPROXIMATION and DETAIL signal information in MATLAB.
3. To collect the information, how two LABS software (LabVIEW and MATLAB) can be combine to each other?
4. To develop a block diagram of LabVIEW for estimating the frequency and the voltage of different number of wavelets.
5. To extract Scale Invariant Key Points for the effective verification of flicker

### 3.3 Decomposition and reconstruction of the signal

#### 3.3.1 One-Stage Filtering: Approximations and Details

One of the most important parts for many signals is the low frequency content. The low frequency content is responsible for the identity of the signal, whereas the high-frequency content contributes flavor or nuance. Similarly in wavelet analysis, the approximations are the high-scale, low-frequency components of the signal, while the details are the low-scale, high-frequency components of the signals.

The basic level of the filtering process appears like this [56].

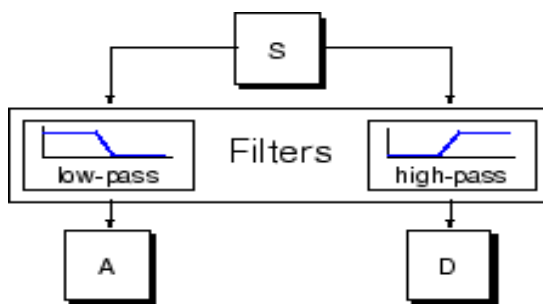


Figure 3.1. Approximation and Detail Signal [56]

When we pass the original signal, 'S' through two complementary filters, two signals A and D comes out across the output. Unfortunately, if we actually perform this operation practically, we conclude double the data as we started with. For example, the original signal 'S' contains 500 samples of data then the resulting signals will each have 500 samples, for a total of 1000.

These signals A and D are so interesting because we get 1000 values instead of the 500 we had earlier. There exists a more insubstantial way to perform the decomposition using wavelets. By looking carefully at the calculation, we keep only one point out of two in each of the two 1000-length samples to get the complete information. This is the basic idea of down sampling. We produce two sequences called cA and cD.

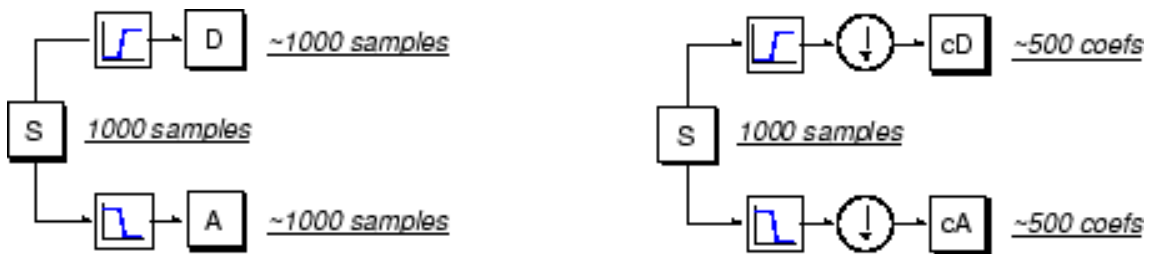


Figure 3.2. Down Sampling [56]

The process on the right hand side is known as down sampling, produces DWT coefficients.

### 3.3.2 Multiple-Level Decomposition

The decomposition process can be repeated, with successive approximations, so that one signal can break down into many lower resolution components. This is known as multiple-level decomposition.

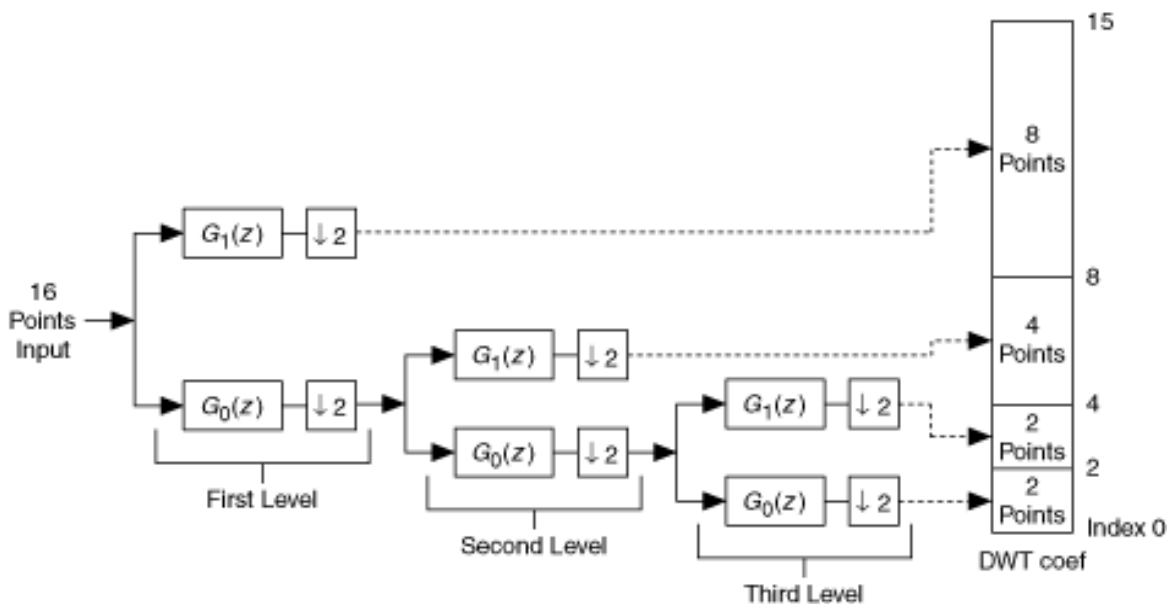


Figure 3.3. Multilevel Decomposition [56]

### 3.3.3 Wavelet Reconstruction

The discrete wavelet transform can be used to analyze or decompose the signals and images. This process is known as decomposition or analysis. The process of assembling back, these components into original one, without loss of information is called reconstruction, or synthesis.

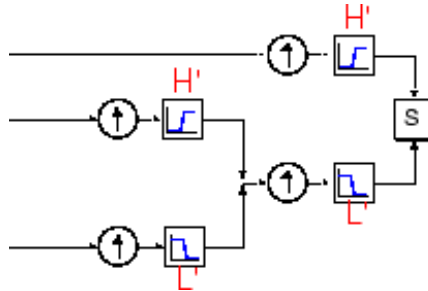


Figure 3.4. Wavelet Reconstruction [57]

The mathematical operation that effects reconstruction is known as inverse discrete wavelet transforms (IDWT). The wavelet reconstruction process consists of main two parts; up sampling and filtering. The process of lengthening a signal component by adding zeros between samples is called Up sampling.

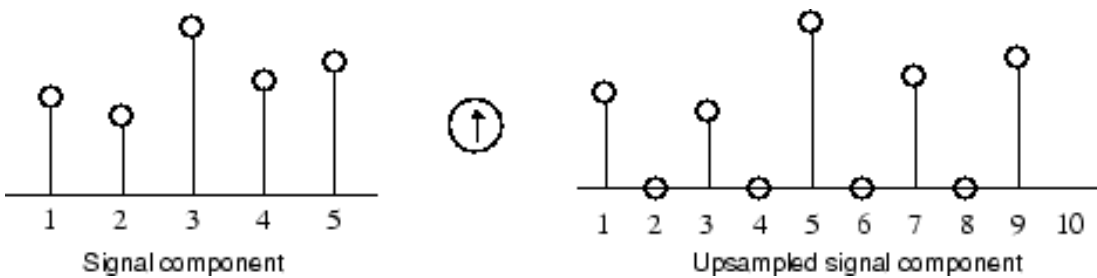


Figure 3.5. Up Sampling [57]

For one-dimensional signals the toolbox consists of commands, IDWT and WAVEDREC that perform single-level and multilevel reconstruction respectively.

**3.3.4 Multistep Decomposition and Reconstruction**

This process consists of two main parts: breaking up a signal to achieve the wavelet coefficients and reassembling the signal from these coefficients. We perform wavelet analysis because the coefficients thus obtained have many known uses, de-noising and compression being foremost among them.

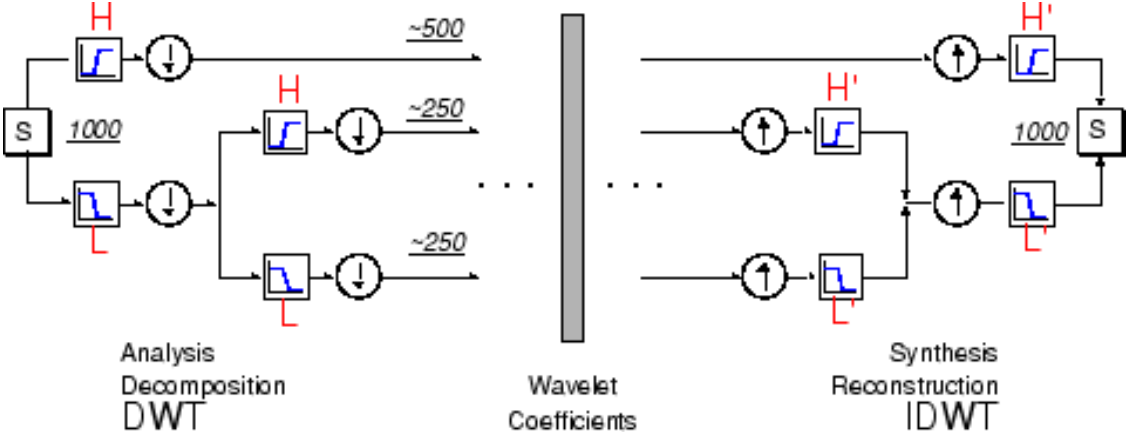


Figure 3.6: A Multistep Analysis –Synthesis Process [57]

**3.4 Instruction of MATLAB written in FORMULA NODE of LabVIEW**

Figure 3.7 clear the instructions written in formula node where X is the signal which is to be decomposed into number of components in the form of approximation (ap6) and detail (dt1 to dt6) signals. SYM8 is the type of wavelet to be used. S is the bookkeeper where these signals are stored in the form of array. 1, 2, 3, 4, 5, 6 ...n are the decomposition levels, which can be

increased or decreased according to the requirements. The instruction, wavedec is used to decompose the signal whereas wrcoef is used for the reconstruction of the signal.

```
MATLAB Script

[c,s]=wavedec(X,6,'sym8');

ap1=wrcoef('a',c,s,'sym8',1);
ap2=wrcoef('a',c,s,'sym8',2);
ap3=wrcoef('a',c,s,'sym8',3);
ap4=wrcoef('a',c,s,'sym8',4);
ap5=wrcoef('a',c,s,'sym8',5);
ap6=wrcoef('a',c,s,'sym8',6);

dt1=wrcoef('d',c,s,'sym8',1);
dt2=wrcoef('d',c,s,'sym8',2);
dt3=wrcoef('d',c,s,'sym8',3);
dt4=wrcoef('d',c,s,'sym8',4);
dt5=wrcoef('d',c,s,'sym8',5);
dt6=wrcoef('d',c,s,'sym8',6);
```

Figure.3.7. Formula Node Used in the block diagram

Where,s

- wrcoef = reconstructs the coefficients of the given signal.
- X = the signal to be decompose
- ap = approximation of the signal
- dt = detail of the signal
- wavedec = decomposition of the signal
- 1,2,.....,6.....,n = number of levels

- S = bookkeeper,
- C = wavelet decomposition vector or coefficient and SYM8 is the type of wavelet.

### 3.5. Block diagram of the program built in LabVIEW

To monitor the flicker and fluctuation in the power system, the block diagram in LabVIEW is drawn below:-

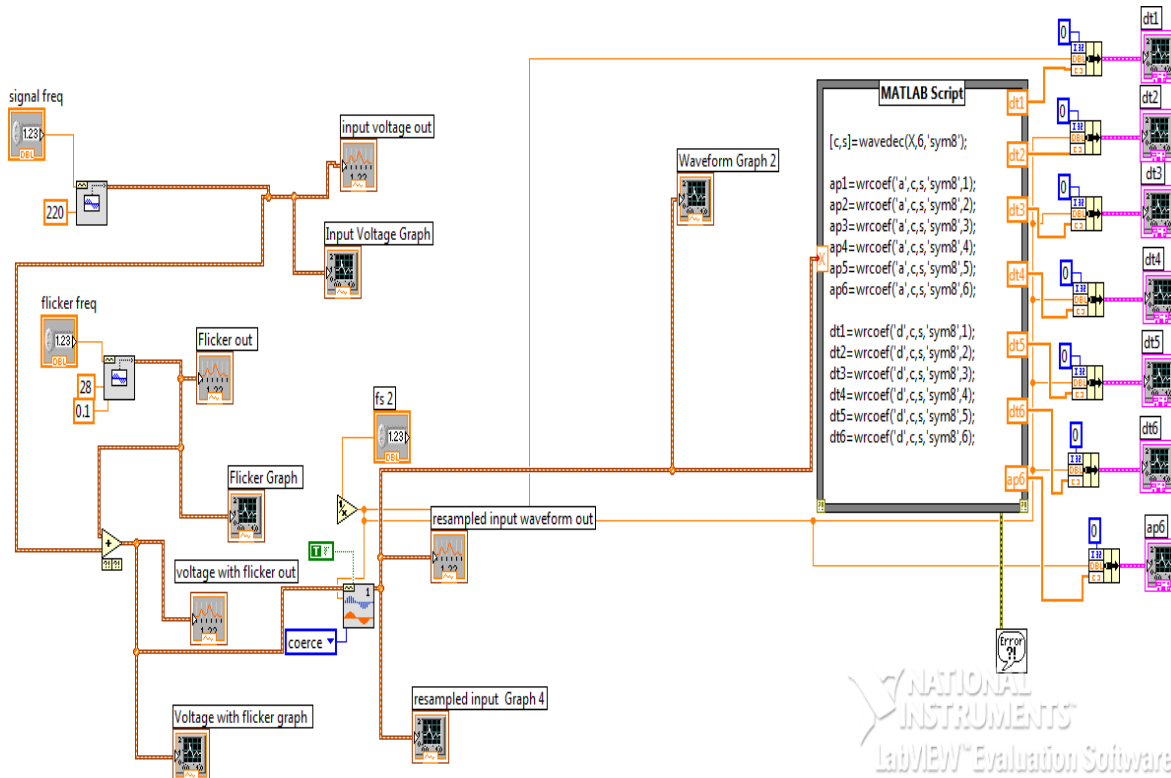


Figure 3.8. Block Diagram of Flicker Monitoring by SYMLET Wavelet

In figure 3.8 two waveforms are generated; one is of supply voltage and other is a flicker voltage. Supply voltage is of 220 V and 50Hz frequency while the flicker sine wave is of 28 V and 6 Hz. Both these waves are superimposed together to produce the time signal. The time signal is then resampled at suitable frequency. The wavelet transform is then applied over it

with the help of MATLAB Script Node where the commands for wavelet decomposition are written as shown in the figure 3.9. The signal is decomposed up to six level .i.e.dt1 to dt6. The approximation and detail signal information of various levels are shown in the form of graphs in figure 3.9.

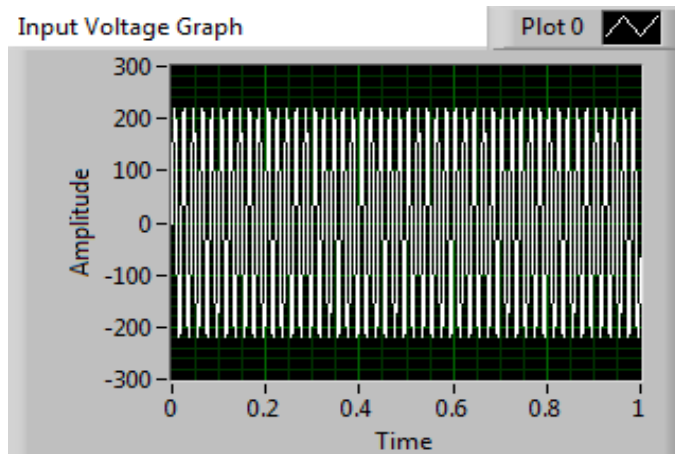


Figure 3.9(a)

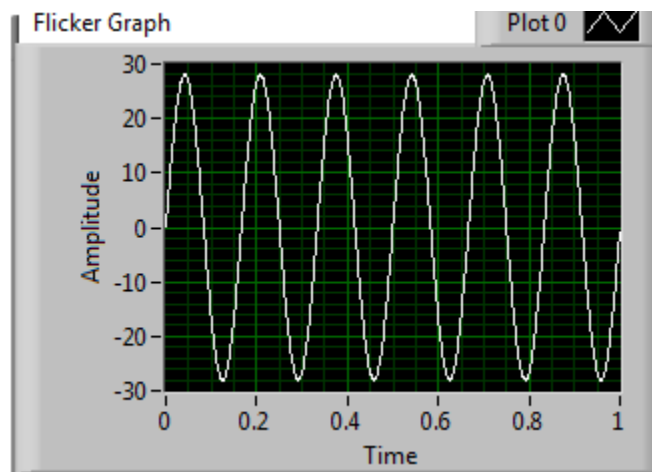


Figure 3.9(b)

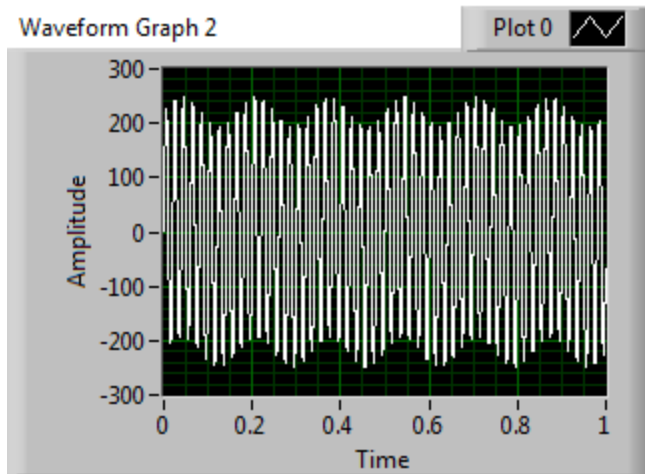


Figure 3.9(c)

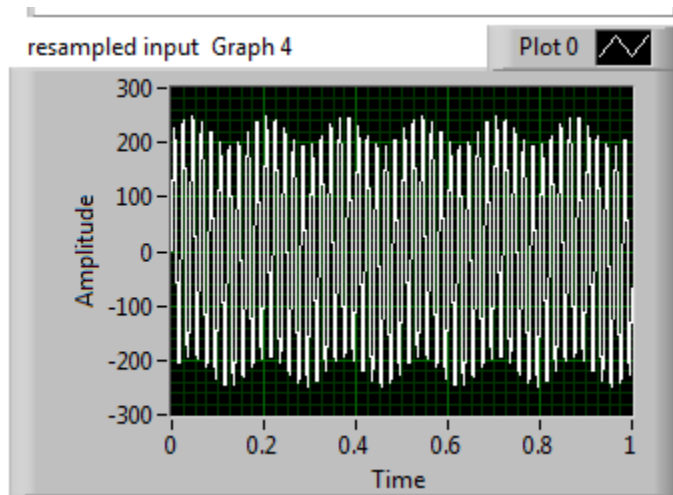


Figure 3.9(d)

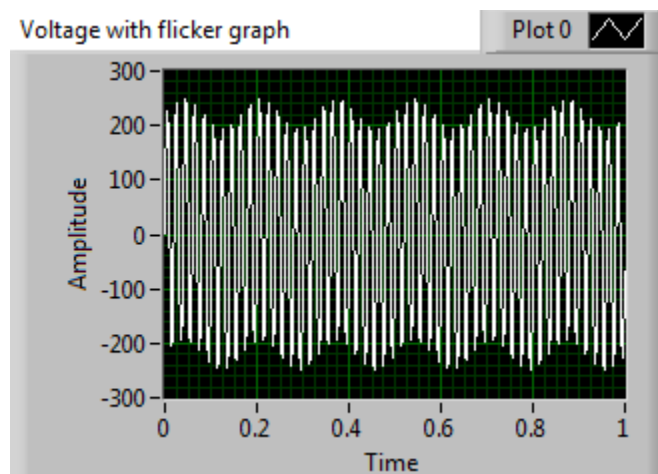


Figure 3.9(e)

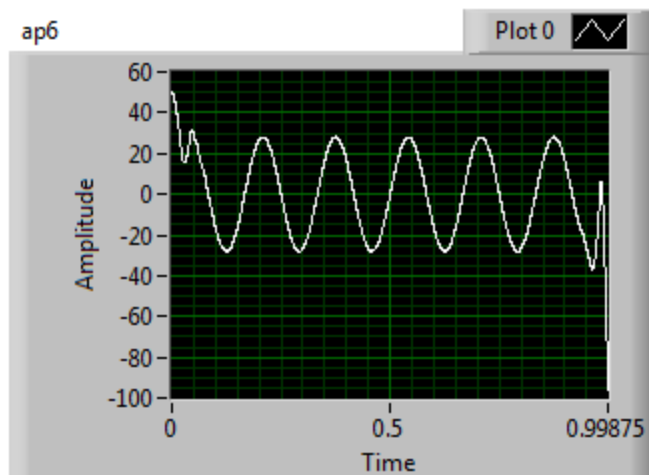


Figure 3.9(f)

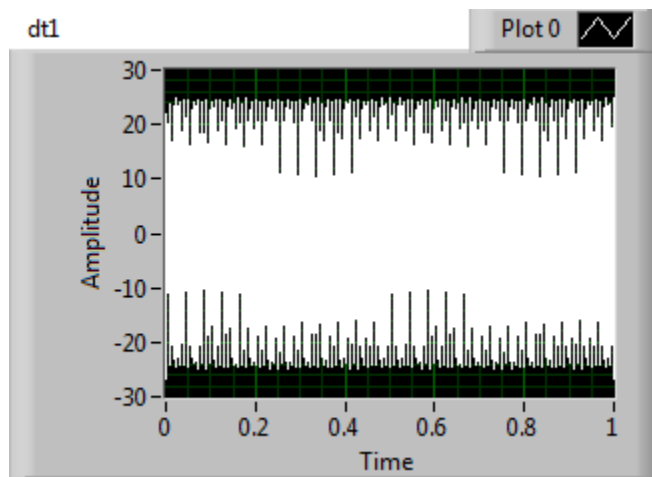


Figure 3.9(g)

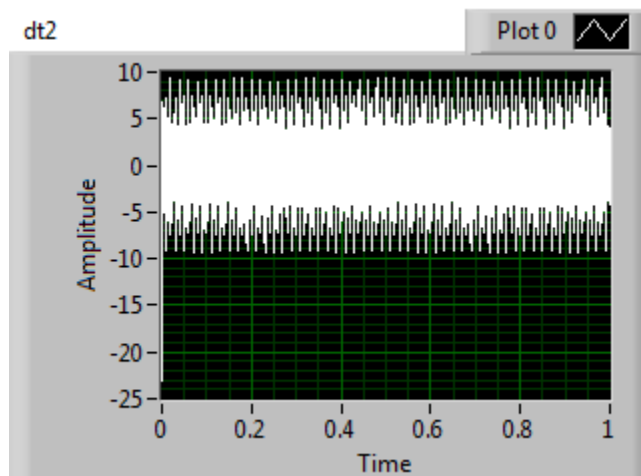


Figure 3.9(h)

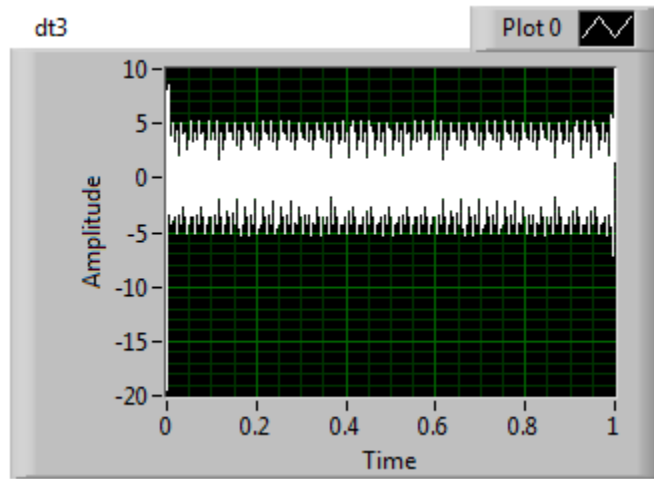


Figure 3.9(i)

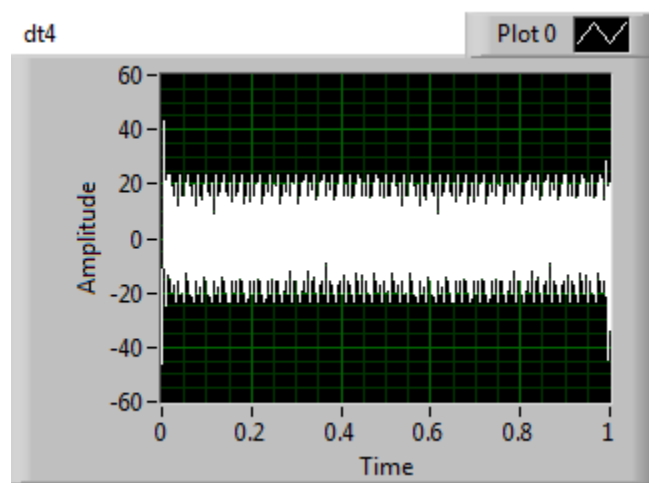


Figure 3.9(j)

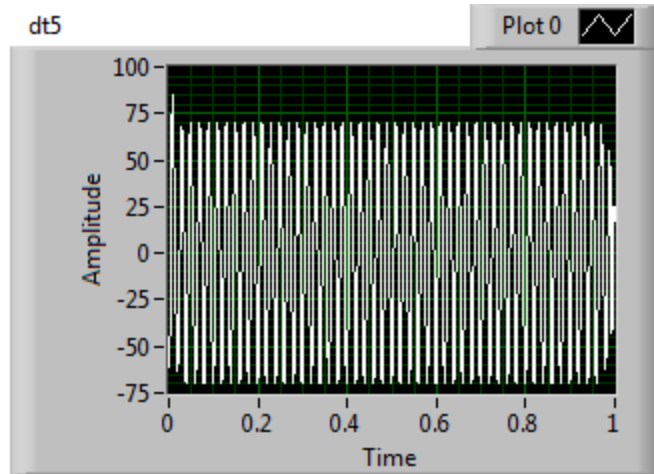


Figure 3.9(k)

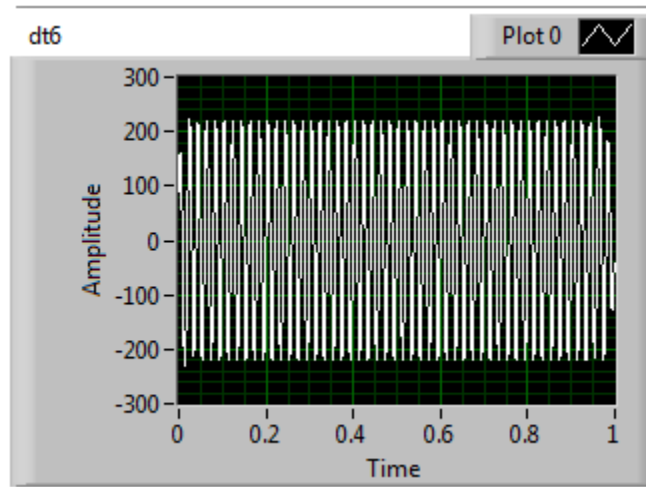


Figure 3.9(l)

Figure 3.9. Approximation and Detail Signals of Symlet wavelet

It is clear from the figure 3.9 that there are 12 graphs in the approximation and detail signal information. The figure 3.9 (a) and 3.9 (b) represent two sine waves of 220 V, 50 Hz (supply voltage) and 28 V, 6Hz (flicker voltage) respectively. In figure 3.9(c) and 3.9(d) these signals are superimposed together to get the time signal. Here, figure 3.9(e) represents the resampled signal at a suitable frequency (3200 Hz). In addition to this, figure 3.9(f) represents the approximation detail of flicker, denoted by ap6 in the formula node. Furthermore, figure 3.9(g) to 3.9(l) represent the detail signal information from dt1 to dt6 in formula node.

The results have been obtained by applying five different wavelets over the signal named as:- HAAR, SYMLET, COIFLET, BIORTHOGONAL and DAUBECHIES wavelet. All wavelets have different approximation and detail signal information at various levels.

# CHAPTER 4

## RESULTS OF VOLTAGE FLICKER MONITORING

**4.1. Haar wavelet:** The actual waveform of HAAR wavelet is a square tooth waveform. For the analysis of HAAR wavelet, we will write 'haar' in the FORMULA NODE of block diagram as shown in the figure 4.1.

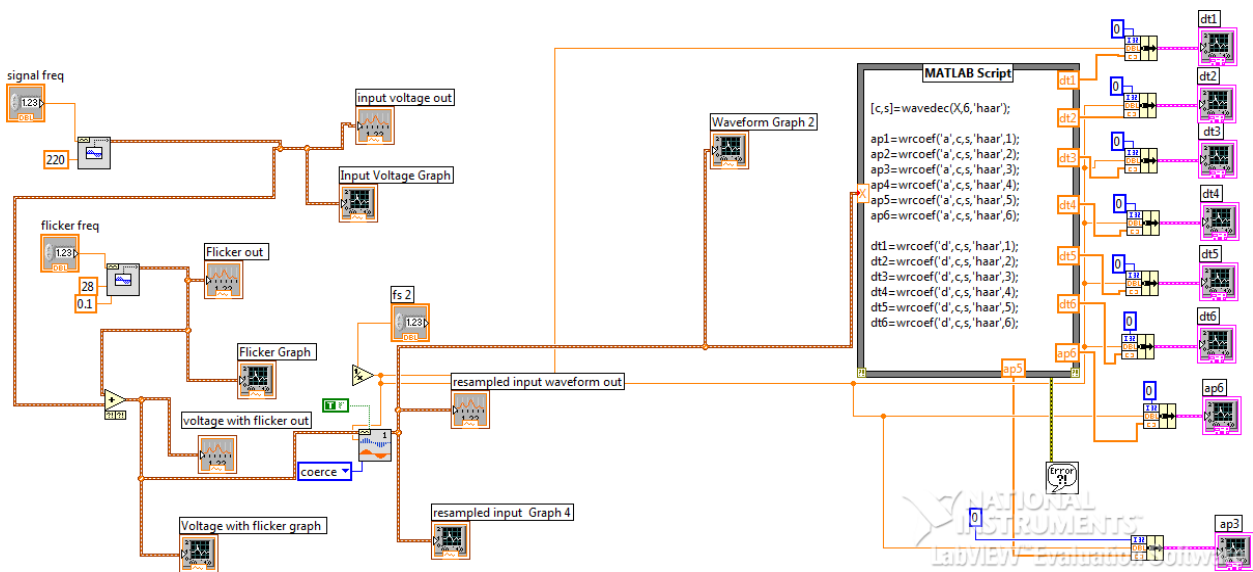


Figure 4.1. Block Diagram to Monitor Flicker by Using HAAR Wavelet

When we run the block diagram we get the approximation signal waveform of HAAR wavelet, shown in figure 4.2.

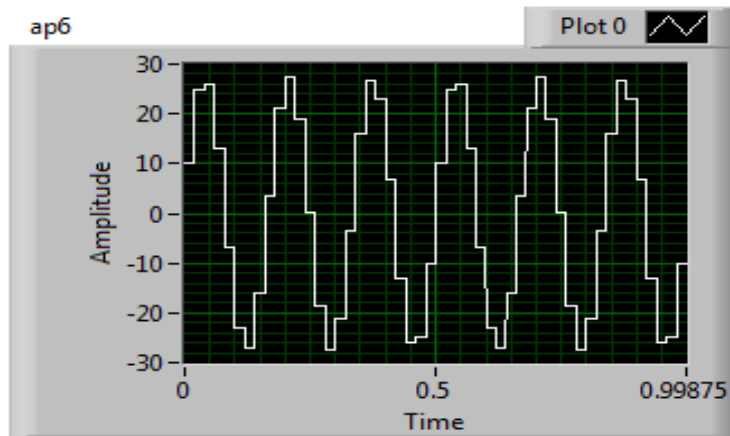


Figure 4.2. Approximation Signal of Haar Wavelet

It is clear from the figure 4.2 that the voltage with the HAAR wavelet is 26V which is less than that of actual voltage (28 V) representing an error of -2V. Note that we are dealing with 6 Hz frequency of flicker in all the cases. The detail signal information of HAAR wavelet is drawn below from level 1 to 6.i.e. dt1 to dt6 in figure 4.3.

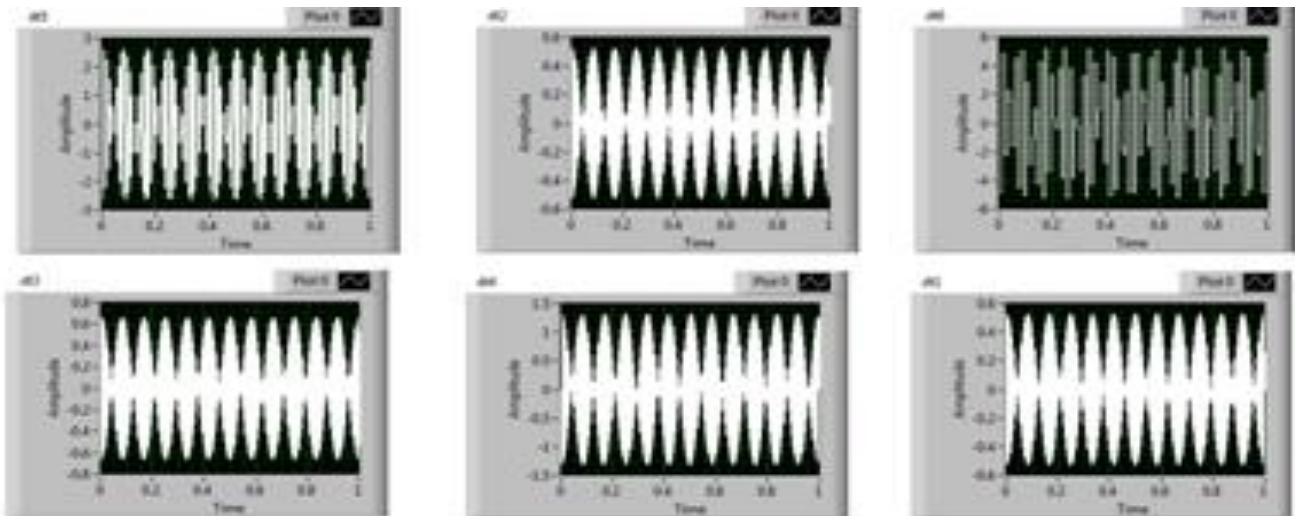


Figure 4.3. Detail Signal of Haar Wavelet

**4.2. Daubechies wavelet (DB-4):** The actual waveform of Daubechies wavelet is similar to a sine wave. The short form for the DAUBECHIES wavelet to write down in the FORMULA

NODE is DB-4, where 4 refer to the number of vanishing moments. The block diagram for flicker monitoring, using DB-4 wavelet is shown in figure 4.4,

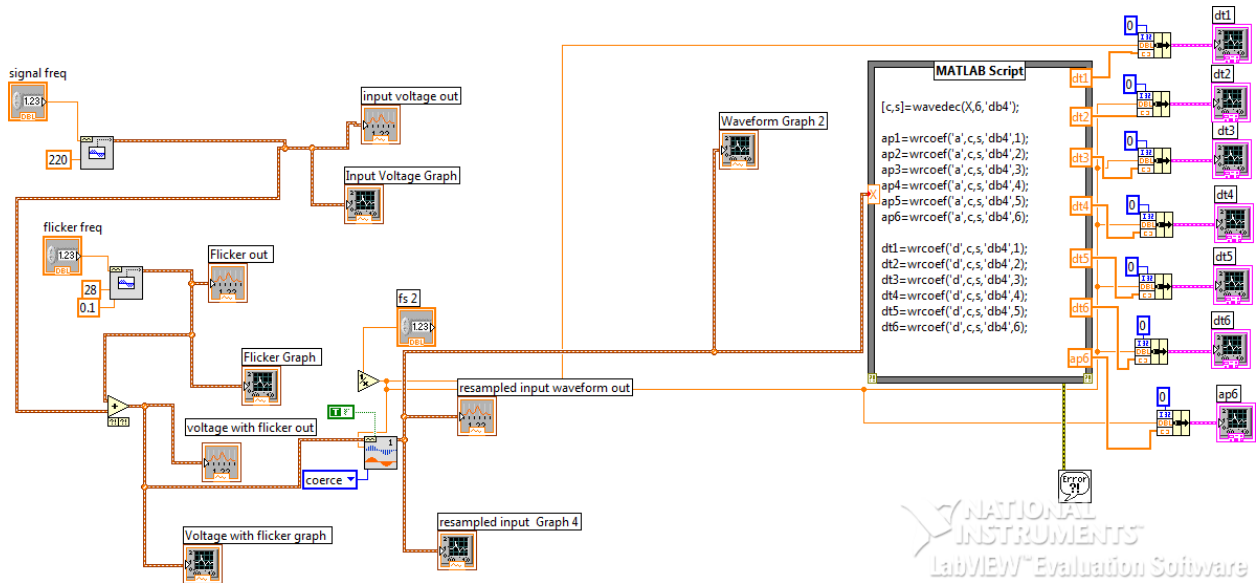


Figure 4.4 Block Diagram to Monitor Flicker by Using Db-4 Wavelet

The approximation detail of DB-4 wavelet is shown in figure 4.5,

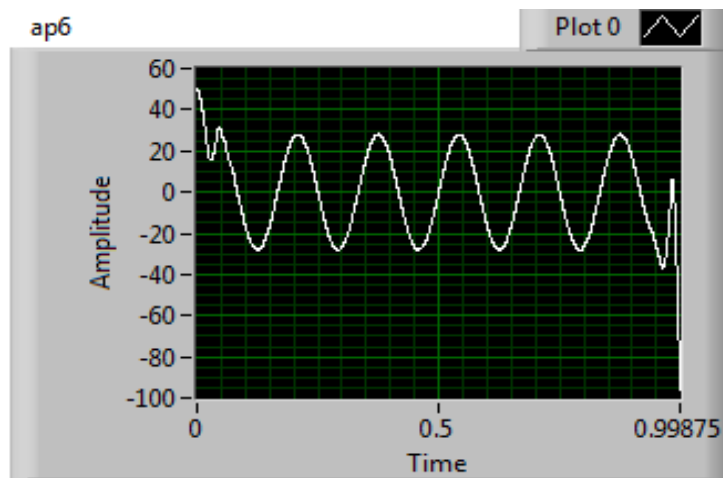


Figure 4.5. Approximation Signal of Db-4 Wavelet

It is clear from the figure 4.5 that the voltage obtained is exactly equal to that of actual voltage (28 V). So there is no error in case of db-4 wavelet. The detail signal information of DB-4 is shown below in figure 4.6.

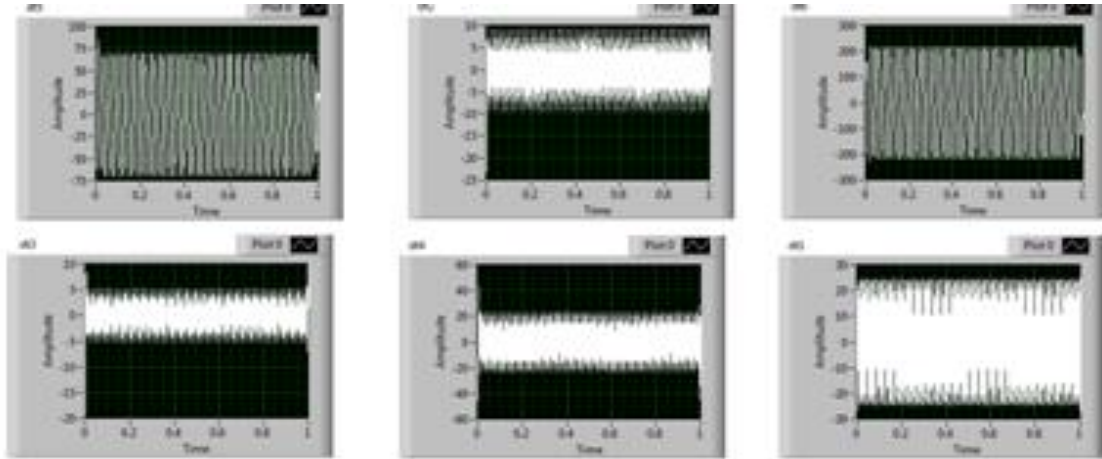


Figure 4.6. Detail Signal of Db-4 Wavelet of dt1 to dt6

**4.3 Symlet wavelet:** The SYMLET wavelet is written as SYMN, where N is the number of vanishing moments. We are using eight vanishing moments, so SYM8 is written in the formula node as shown in figure 4.7.

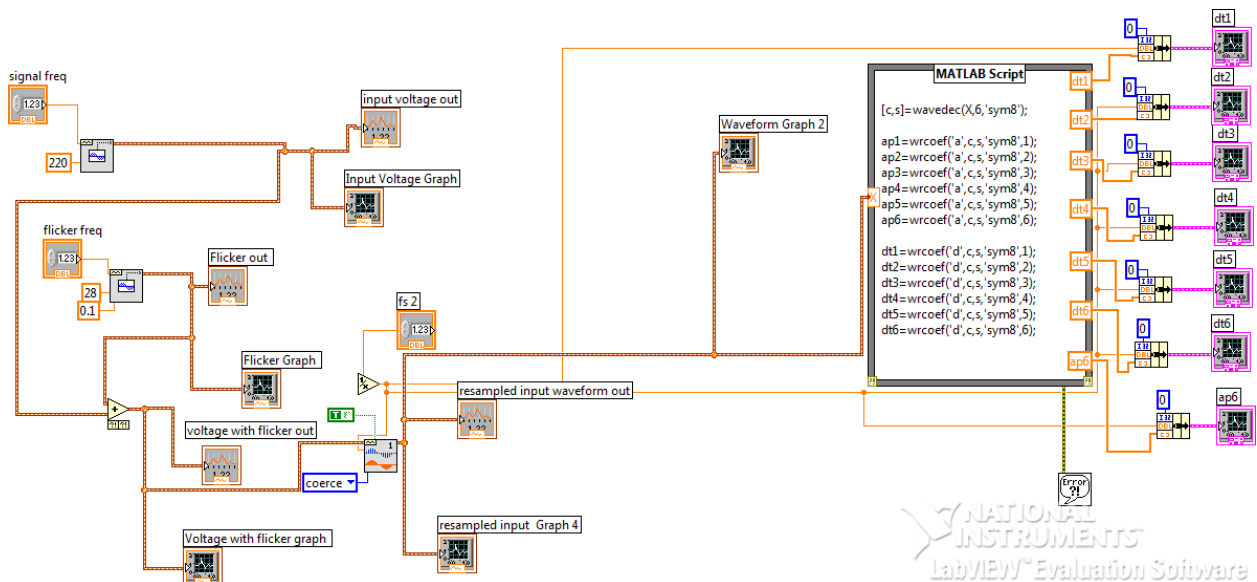


Figure 4.7: Block Diagram to Monitor Flicker by Using Symlet Wavelet

The approximation signal detail of SYMLET wavelet is shown in figure 4.8.

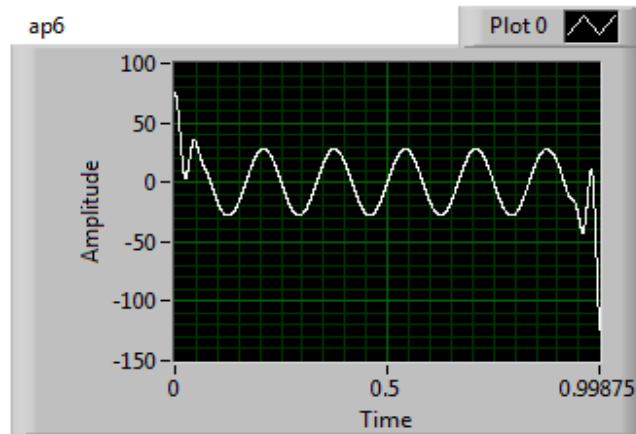


Figure 4.8. Approximation Signal of Symlet Wavelet

It is clear from Figure 4.8 that the voltage obtained is more than that of actual voltage (28 V) having a value of 30V, so there is an error of +2V in case of SYMLET. The detail signal information of SYMLET wavelet is shown in figure 4.9.

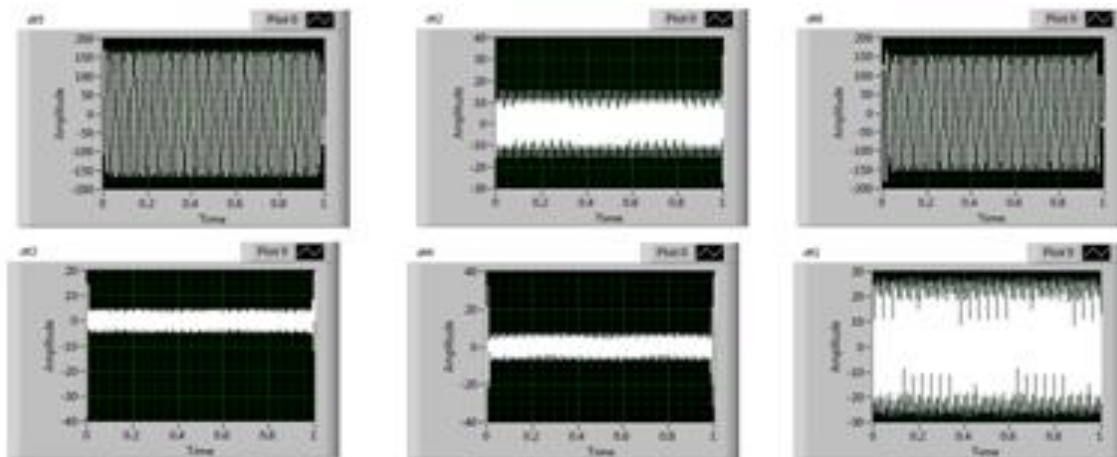


Figure 4.9. Detail Signal of Symlet Wavelet

#### 4.4 COIFLET and BIORTHOGONAL wavelet

The approximation signal and detail signals information of COIFLET wavelet is similar to SYMLET wavelet while the approximation and detail signal characteristics of BIORTHOGONAL wavelet is similar to DAUBECHIES wavelet.

We have taken the value of voltage flicker, 28V in all the cases of wavelets in the block diagram. But now we will vary the frequency of flicker from 6 Hz to 24 Hz and note down the readings of different wavelets at these variations. The table of all the readings is drawn below,

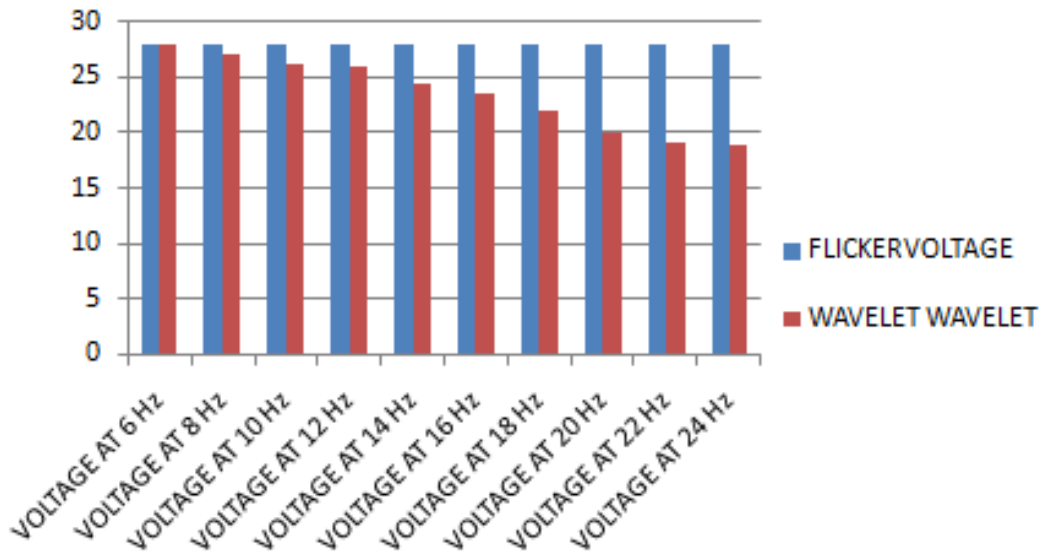
**4.5. Comparison of Different Number of Wavelets at Different Number of Flicker Frequencies With Respect to Voltage:**

Table 4.1 Performance parameters of all wavelets

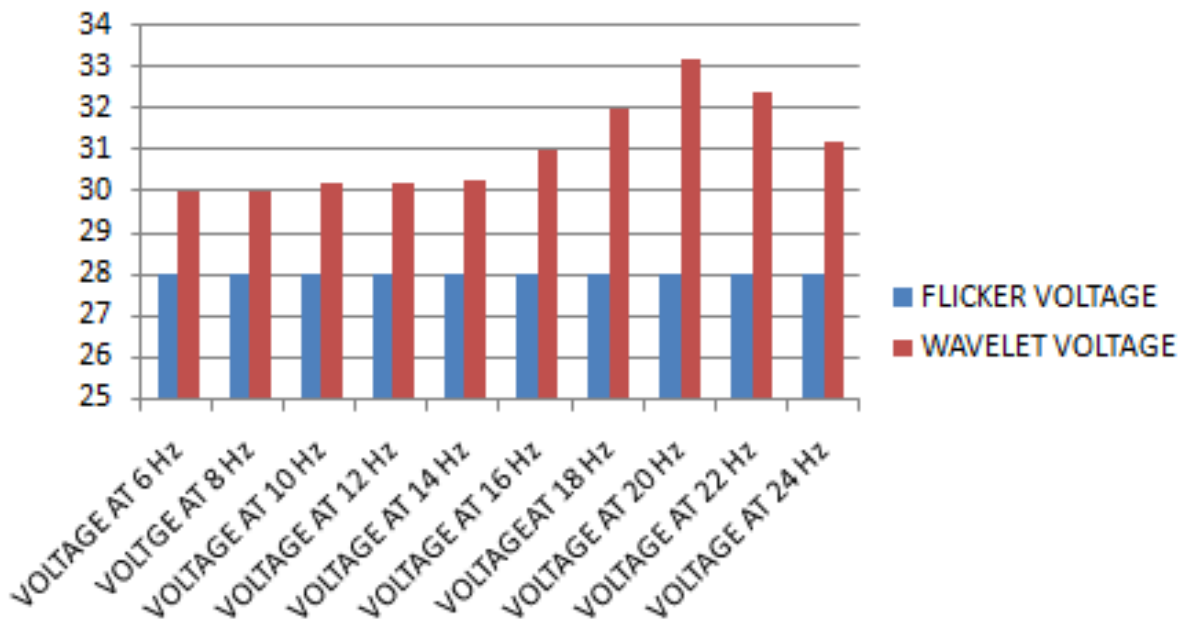
Variation in frequency	Flicker Voltage	HAAR Wavelet Voltage	SYMLET Wavelet Voltage	COIFLET Wavelet Voltage	BIORTHOGONAL Wavelet Voltage	DB-4 Wavelet Voltage
6	28 V	28V	30V	30V	28V	28V
8	28V	27V	30V	30V	28V	28V
10	28V	26.3V	30.2V	30V	28V	28V
12	28V	26V	30.2V	30V	28V	28V
14	28V	24.5V	30.3V	30V	28V	28V
16	28V	23.5V	31V	32V	28V	28V
18	28V	22V	32V	33V	30V	28V
20	28V	20V	33.2V	35V	30V	28V
22	28V	19.2V	32.4V	35V	29V	28V
24	28V	19V	31.2	32V	28V	28V

From table 4.1 it is clear that DB-4 WAVELET monitor the voltage very accurately as compared to the other wavelets.

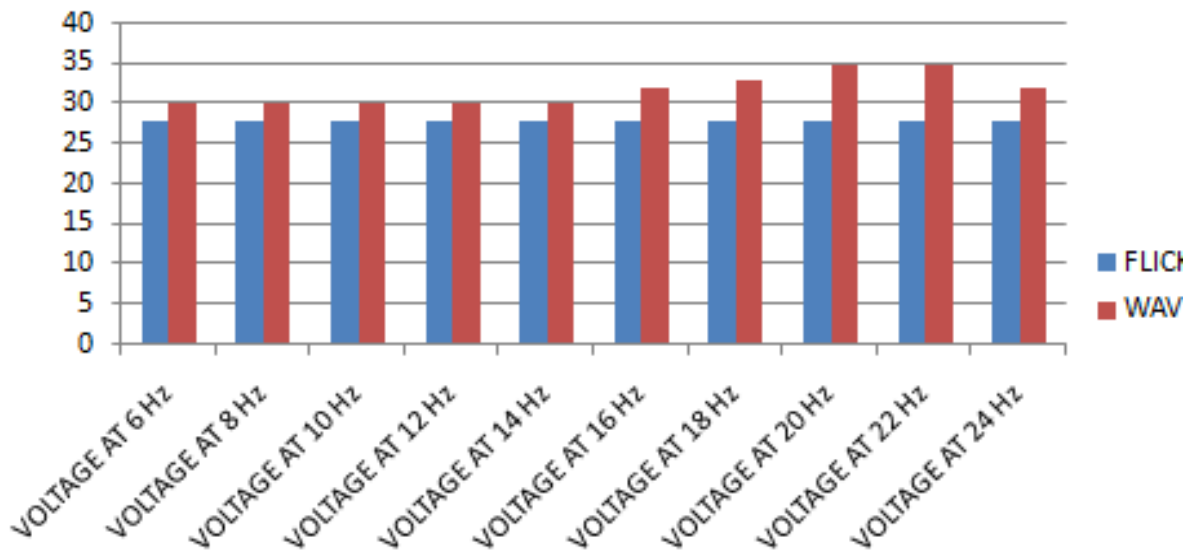
#### 4.6. Graphical Comparison of Actual Voltage w.r.t Different Wavelet's Voltage



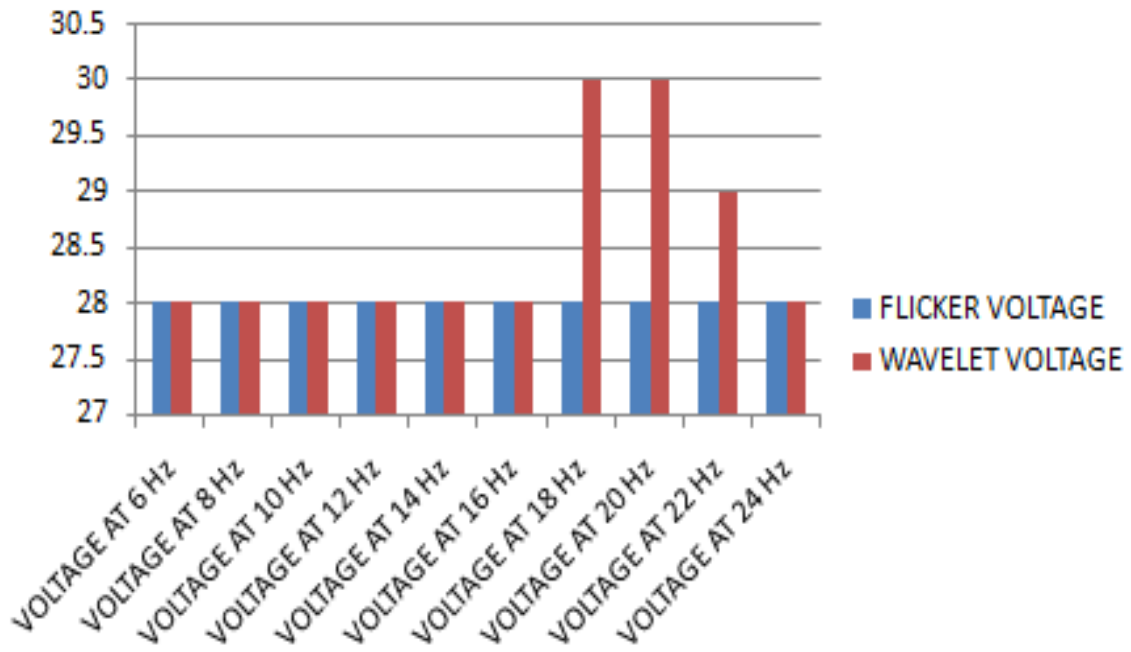
Graph 4.1.Haar Wavelet Voltage Comparison



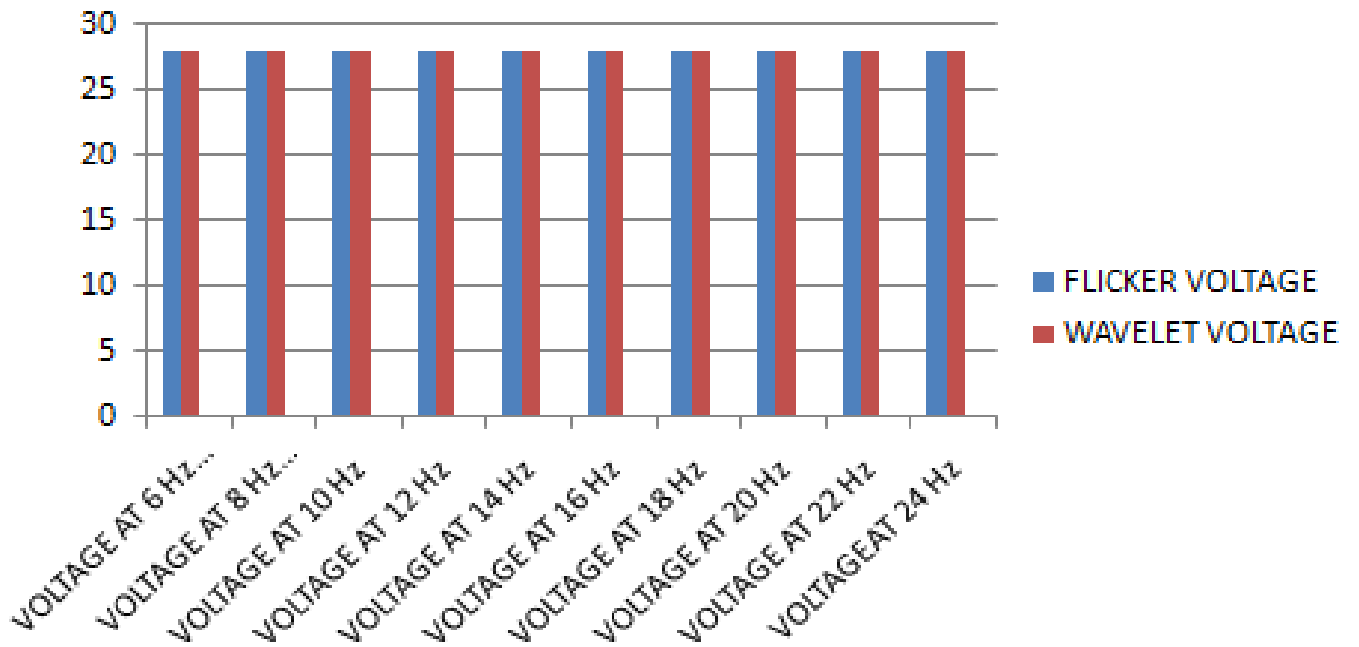
Graph 4.2.Symlet Wavelet Voltage Comparison



Graph 4.3.Coilet Wavelet Voltage Comparison



Graph 4.4. Biorthogonal Wavelet Voltage Comparison



Graph 4.5. Db-4 Wavelet Voltage Comparison

**4.7. Removal of flicker after monitoring:** After dealing with frequency and voltage measurements with different number of wavelets, now we will control and eliminate the flicker voltage (28 V), so that we get the accurate voltage of 220 V for the home appliances. For this purpose we will reduce the coefficients to zero in which flicker is dominantly present. From the previously done analysis, it is quite evident that the flicker is mainly present in the Sixth level wavelet Approximation. To accomplish this we have developed a module, where decomposition and reconstruction functions are written. The function for the above explained purpose is written as below.

```

MATLAB Script
ap2=wrcoef('a',c,s,'db4',2);
ap3=wrcoef('a',c,s,'db4',3);
ap4=wrcoef('a',c,s,'db4',4);
ap5=wrcoef('a',c,s,'db4',5);
ap6=wrcoef('a',c,s,'db4',6);

dt1=wrcoef('d',c,s,'db4',1);
dt2=wrcoef('d',c,s,'db4',2);
dt3=wrcoef('d',c,s,'db4',3);
dt4=wrcoef('d',c,s,'db4',4);
dt5=wrcoef('d',c,s,'db4',5);
dt6=wrcoef('d',c,s,'db4',6);

for i= 1 : s(1,1)
c(i)=0;
end

X2=waverec(c,s,'db4');
  
```

Figure 4.15.For loop function

*For i = 1: s(1,1)*

*c(i) = 0;*

*end*

Where, i is the corresponding loop variable,

And,  $s(1,1)$  is the length of sixth approximation.

The approximation and detail signals are stored in the coefficient variable  $c$  as an array in the order  $[ap6, dt6, dt5, dt4, dt3, dt2, dt1, dt0]$  in decomposed form. The corresponding bookkeeping is done and stored in variable  $s$  which keeps the record of the lengths of corresponding approximation and details of various levels stored in coefficient array,  $c$ . The length of sixth approximation,  $ap6$  is stored in the first element of the bookmark array,  $s$  that can exactly be referred as,  $s(1,1)$ . To eliminate flicker we will make this  $ap6$  as zero, so that we get 220 V supply free from flicker. Thus  $ap6$  is made zero in the corresponding for loop by making the coefficients zero corresponding to its length; which are saved first in the order of decomposed coefficients. The signal is now reconstructed from these coefficients. Hence, by performing this operation we get the pure sinusoid 220 V sine wave signal X2 free from flicker as shown in figure 4.16. This also inversely proves that the flicker is contained in the Sixth Approximation of the decomposed signal.

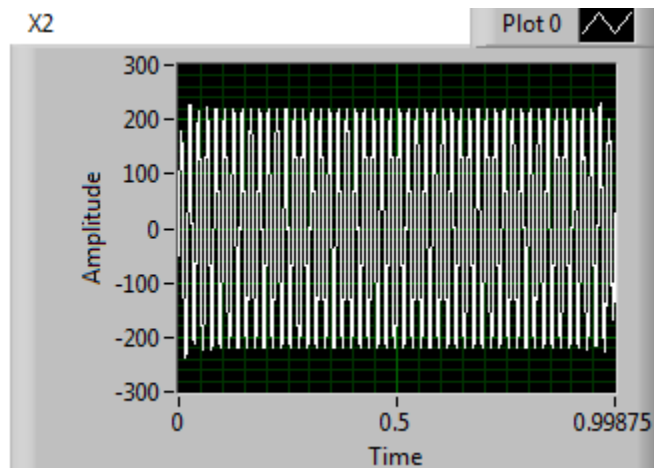


Figure 4.16.X2 signal, free from flicker

# CHAPTER 5

## CONCLUSION AND FUTURE WORK

**5.1 Conclusion:** Till now many software and hardware tools has developed to analyze flicker in the voltage, but still they do not have 100% accuracy. It was difficult to monitor the flicker in this 21 century even in the presence of SCADA (SUPERVISORY CONTROL and DATA ACQUISITION). It was too difficult to monitor the amplitude and frequency of the flicker, occurred in the power system. Therefore, researchers work very deeply on this problem and find number of solutions to overcome from the affect of flicker. But still this problem is not solved out because the time instant at which flicker occurs is unknown to us as there is variation in flicker value according to the type of load used. In case of non resistive loads it increases with a very fast rate otherwise there are no problems of flicker. So it is difficult to remove the flicker from the power system completely. In this thesis, we have addressed this important point in a systematic manner.

We have been carried out a detailed evaluation of the various flicker monitoring techniques that have been proposed in literature in terms of their efficiency and robustness. Firstly we studied the impact of the different flicker monitoring techniques on the performance of multimodal system consists of amplitude, frequency and time instant at which flicker occurs. Our analysis shows that ALEXBERG method is efficient but with in a particular small spectrum of frequency. GUAN studies the relationship between the voltage flicker problems and harmonic power variation for the power system with an electric arc furnace only. In the above two cases the limitation is that both are unable to explain the instant at which voltage flicker occurs. HUANG methods tell the time and frequency information of a waveform integrally presented, thereby enhancing the monitoring of voltage flicker-generated signals at different time intervals, unable to tell amplitude of the waveform.

One of the major contributions of this thesis has been the development of a GUI based system to monitor the flicker. This block diagram is able to explain the amplitude, frequency as well as the

instant at which voltage flicker occurs. We conclude that from all the five wavelets only DB-4 wavelet can monitor the flicker voltage very accurately even in the presence of variation of frequency. Secondly, by knowing the instant of flicker we can remove it completely by using a for loop function as discussed in chapter 4. By following this method we can totally free our power system from the flicker.

**5.2 Future Work:** In this work we have tried to deal with the problem of flicker present in power systems. Still we feel that there is a need to work in the area of flicker monitoring and removal.

1. There is a need to develop rules that would allow the practitioner to increase the frequency spectrum to monitor flicker.
2. More analysis is required to be done on the developed system by using the historical data of a substation.
3. Some techniques must be used in the power system, that when the flicker exceeds a certain value in a supply connection of an industry or general service connection, the system of light to that connection must be shut down, so that corrections can be done.

## REFERENCES

- [1] Tom Short, "Electric Power Distribution Handbook", CRC Press, Vol. 143, no.1, Jan 2004.
- [2] H.Lee Willis, "Power Distribution Planning Reference Book", Marcel Dekker Press, 01-Mar 2004.
- [3] John Wiles, "Voltage Drop after NEC Requirements", Heinemann, London, vol. 6, no. 3, pp. 19 –22,1998.
- [4] Keithley "Low Level Measurement Handbook", Ryburn Publishing, Keele University Press, 1995.
- [5] J. C Gu, C. J. Wu, and J. C. Chiang, "Effects of High Voltage Side Voltage Sources on Low Voltage Side Customers," Power Research Institute, Taiwan Power Company, 1994.
- [6] S. Tennakoon, S. Perera, D. Robinson and S. Elphick, "Attenuation of Flicker by Induction Motor Loads: A Laboratory Investigation", in the proceedings of the 12<sup>th</sup> international conference on harmonics and quality of power, Cascais, Portugal, October 1-5, 2006.
- [7] M. Kratz, "Comparative study of disturbance generated by AC and DC arc furnaces", Technical report 95NR00064, EDF (Engineering data file), France, 1994.
- [8] S. Dhandapani, M. Bridges, E. Kannatey-Asibu, Jr., "Nonlinear electrical modeling for the resistance spot welding process" In the proceedings of the American Control Conference, pp.182-186, vol.1, 1992.
- [9] G. Morison, B. Gao, P. Kundur, "Voltage stability analysis using static and dynamic approaches", IEEE Transactions on Power System, vol.8, no.3, pp.1159-1171, August 1993.
- [10] C. W. Taylor, Power System Voltage Stability, McGraw-Hill, AGBH Press, Vol. 3, no.2 ,1994.
- [11] "Voltage Stability Assessment: Concepts, Practices and Tools," IEEE Catalog Number SP101PSS, August, 2002.
- [12] P. Kundur, "Power System Stability and Control", McGraw-Hill, Charleo Press, Vol. 2, no.1 1994.
- [13] A. B. Nassif, E. E. Nino, W. Xu,"A V-I slope-based method for flicker source detection", in the Proceedings of the 37th Annual North American Power Symposium, 23-25 Oct. 2005.

- [14] D. Zhang, W. Xu, A. Nassif, "Flicker source identification by inter harmonic power direction", In the proceedings of Canadian Conference on Electrical and Computer Engineering, 1-4, May 2005.
- [15] I. Jefferies, D. Atkinso, G. Hope," Flicker Prediction Techniques for Sawmills", Proceedings of the fourth Annual Cape Technikon Electrical Engineering Department B.Tech Conference. pp 49-52, 26 October 2000.
- [16] Y. Y. Hong, L. H. Lee, "Stochastic voltage-flicker power flow", Power Delivery, vol. 15, no. 1, pp. 407-411, Jan 2000.
- [17] A. Hernandez, J.G. Mayordomo, R.Asensi, L.F.Beites, "A method based on inter harmonics for flicker propagation applied to arc furnaces" IEEE Transactions on Power Delivery, vol.20, no. 3, pp. 2334-2342, July 2005.
- [18] Electromagnetic Compatibility, Limitation of voltage fluctuations and flicker for equipment connected to medium and high voltage supply systems – Technical report (IEE - publication) 1995.
- [19] Mostert, H.S. and Manin, M.V, "Report On Research into the Establishment of Flicker Emission Prediction Techniques for Flicker Emitted from Crusher Plants". Proceedings of the 8th International Power Quality Applications Conference (Cape Town South Africa), 9-11 November 1998.
- [20] G. Kaiser, " A Friendly Guide to Wavelets", Birkhauser, Boston, pp. 44-45, 1994.
- [21] M.A. Cody, "The Wavelet Packet Transform," *Dr. Dobb's Journal*, Vol 19, pp. 44-46, 50-54. Apr. 1994.
- [22] B. Vidakovic and P. Muller, "Wavelets for Kids," unpublished. Part One, and Part Two, 1994.
- [23] Chui, K.Charles (An Introduction to Wavelets. San Diego: Academic Press, Vol 12, pp. 14-16, 1992.
- [24] M. Vetterli and C. Herley, "Wavelets and Filter Banks: Theory and Design," *IEEE Transactions on Signal Processing*, Vol. 40, pp. 2207-2232, 1992.
- [25] I. Daubechies, "Orthonormal Bases of Compactly Supported Wavelets," *Comm. Pure Appl. Math.*, Vol 41, pp. 906-966, 1988.

- [26] Y. Meyer, *Wavelets: Algorithms and Applications*, Society for Industrial and Applied Mathematics, Philadelphia, pp. 13-31, 101-105, 1993.
- [27] Pillay and Bhattacharjee, "Application of wavelets to model short-term power system disturbances. Presented at IEEE PES Winter Meeting, Baltimore, MD, 96-WM-284-0-PWRS, Jan 1996.
- [28] W. A. Wilkinson and M. D. Cox," Discrete wavelet analysis of power system transients. Presented at IEEE PES, Summer Meeting, Baltimore, MD, 96-SM-286-5-PWRS, Jan 1996.
- [29] P. F.Ribeiro," Wavelet transform: An advanced tool for analyzing non-stationary harmonic distortions in power systems, International Conference on Harmonics in Power Systems, Bologna, Italy, Sept. 1994.
- [30] G.Strang and Nguyen," Wavelets and Filter Banks. Boston, Wellesley-Cambridge Press, 1996.
- [31] From Wikipedia article on Lab VIEW (retrieved May 25, 2010). <http://en.wikipedia.org/wiki/LabVIEW>.
- [32] N. J. Cox, "Using the LabVIEW Run-Time Engine". National Instruments, vol. 6, no. 3, pp. 19 –22,1998.
- .
- [33] Jeffrey Travis, Jim Kring: LabVIEW for Everyone, "Graphical Programming Made Easy and Fun" 3rd Edition, Prentice Hall, 2006.
- [34] John Wiley & Sons, C .B. Moler," MATLAB: An introduction with Applications", 2<sup>nd</sup> Edition, 2004.
- [35] D. J. Higham and N. J. Higham. "MATLAB Guide". Second edition, Vol 10, pp. 4-6, 2005.
- [36] K. R. Coombes, B. R. Hunt, R. L. Lipsman, J. E. Osborn, and G. J. Stuck, "Differential Equations with MATLAB", 2000.
- [37] A. Gilat. MATLAB: An introduction with Applications. John Wiley and Sons, Vol 9, pp. 34-36, 2004.
- [38] PETER AXELEBERG: Department of Electrical Power Engineering, "Measurement Methods for Calculating of the Direction to a Flicker Source", CHALMERS UNIVERSITY OF TECHNOLOGY Goteborg, Sweden, 2003.
- [39] Shane Sidebottom, "Effects of Illumination and Viewing Angle on the Modeling of Flicker Perception in CRT Displays". Virginia Polytechnic Institute and State University, April 1997.

- [40] J. E. Farrell, "An analytical method for predicting perceived flicker", *Journal of Behavior and Information Technology*, 1986.
- [41] J. E. Farrell, "Predicting flicker thresholds for video display terminals, In *Proceedings of the Society for Information Display, Digest*, pp. 18-21, 1987.
- [42] Deborah Goren, "Understanding the mechanisms of flicker defined form processing University of Waterloo" Ontario, Canada, 2008.
- [43] J. M. McCune, B. Parno, A. Perrig, M. K. Reiter, and A. Seshadri, "Minimal TCB code execution (extended abstract)". In the *Proceedings of the IEEE Symposium on Security and Privacy*, May 2007.
- [44] J. L. Guan, J. C. Gu, and C. J. Wu, "Real-time Measurement Approach for Tracking the Actual Coefficient of  $\Delta V / \Delta V_{10}$  of Electric Arc Furnaces," *IEEE Trans. on Power Delivery*, vol. 19, no. 1, Jan. 2004.
- [45] Mohamed I. Mahmoud, Moawad I. M. Dessouky, Salah Deyab, and Fatma H. Elfouly, "Comparison between Haar and Daubechies Wavelet Transformations on FPGA Technology" *World Academy of Science, Engineering and Technology*, 2007.
- [46] Huang, S.J., Huang, C. L., and Hsieh, C. T, Application of Gabor transform technique to supervise power system transients. *IEE Proceedings –C: Generation, Transmission and Distribution*, 143, 5 Sept. 1996.
- [47] Huang, S. J., and Hsieh, C. T. High impedance fault detection using a Morlet wavelet transform approach. Presented at *IEEE PES Summer Meeting*, San Diego, CA, SM 98-SM-122, July 1998.
- [48] J. Sousa, M.T. Correia de Barros, M. Covas A. Simoes, "Harmonics and Flicker Analysis in Arc Furnaces Power Systems", IST- Technical University of Lisbon.
- [49] M. K. Hudson, R. B. Shanks, D. H. Snider, D. M. Lindquist, and C. B. Luchini, "UV Visible, and Infrared Spectral Emissions in Hybrid Rocket Plumes", *International Journal of Turbo and Jet Engines*, Vol. 15. [3] IEC Publication 868: Flicker-Meter, functional and design specification, 1986.
- [50] Yair Kuszpet<sup>1</sup>, Dimitry Kletsel<sup>1</sup>, Yair Moshel, Avi Levy Signal and Image processing Lab, Department of Electrical Engineering, Technion – IIT 2 Intel Corporation.

- [51] Xavier Yang, “Methodology and Simulation Tool for Flicker Propagation Analysis,” Joint Conference: Power Quality and Applications, Advanced Distribution Automation, EPRI Atlanta, USA, July 24 - 26, 2006.
- [52] Paul Turner, “Critical Flicker Frequency and centrally acting Drugs”. St. Bartholomew’s Hospital, London, 1965.
- [53] Turner, P.Beckett, A.H. Rowland “Flicker reduction and analysis”, Technical college of Ottawa, 1965.
- [54] <http://en.wikipedia.org/wiki/LabVIEW>.
- [55] <http://en.wikipedia.org/wiki/MATLAB>.
- [56] Michel Misiti, Yves Misiti, Georges Oppenheim, Jean-Michel Poggi, Wavelet Toolbox™ 4, Getting Started Guide © COPYRIGHT by The MathWorks, Inc, 1997–2010.
- [57] Michel Misiti, Yves Misiti, Georges Oppenheim, Jean-Michel Poggi, Wavelet Toolbox™ 4, User Guide S© COPYRIGHT by the MathWorks, Inc, 1997–2010.

