

Chapter 5

Flicker Measurement

5.0. Introduction

Any phenomena in voltage or current signals that deviate from ideal conditions can be denoted as an Electrical Power Quality problem. Among them, voltage fluctuation is pointed out as an important matter because it has an intermittent and/or steady state behavior, and can propagate throughout the electric system, reaching many consumers. This phenomena can be defined as voltage magnitude variations in RMS or peak value, in the range of 0.9 to 1.1 pu and frequencies up to 35Hz. It may be caused by variable demanding loads, such as electric arc furnaces, welders, rolling mills, large fluctuating motor loads etc.

Since, incandescent lamps are extremely sensitive to voltage oscillations, flicker is historically the most well known outcome caused by voltage fluctuation. In the sense, it is defined as the sensation experienced by human visual system when subjected to luminance variations. Even today flicker is used to evaluate the disturbance in the voltage.

Flicker is basically caused by fluctuations of the electrical power that may occur at any time under the influence of variations of any of the three components of the network: the load, which is switched on and off according to specific operational needs, the generator, which follows or anticipates the load variations in order to maintain an equilibrium between the generation and utilization ends, the power network (mains), whose topology varies whenever switching occurs, and which may be affected by failures. Each of

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these elements produces a contribution to voltage variations that in turn can produce light flicker.

Voltage fluctuations up to 30Hz may produce annoyance even if considering small relative amplitudes such as 0.25% at the critical modulation frequency of 8.8Hz.

This very sensitive relation between voltage fluctuations and flicker occurrence imposes severe restrictions on variable load operation such as: arc furnaces, steel mills, air compressors, electric welders and transport machinery.

From a utility application point of view, voltage fluctuations have usually been of interest, perhaps because voltage changes are easily measured with existing instrumentation. Historically, these voltage changes have been used in conjunction with "flicker curves" such as those shown in Fig. 5.1. These curves, derived from controlled experiments, offer thresholds of perception and/or irritability when periodic rectangular voltage fluctuations occur continuously (only threshold of irritability curves are shown here).

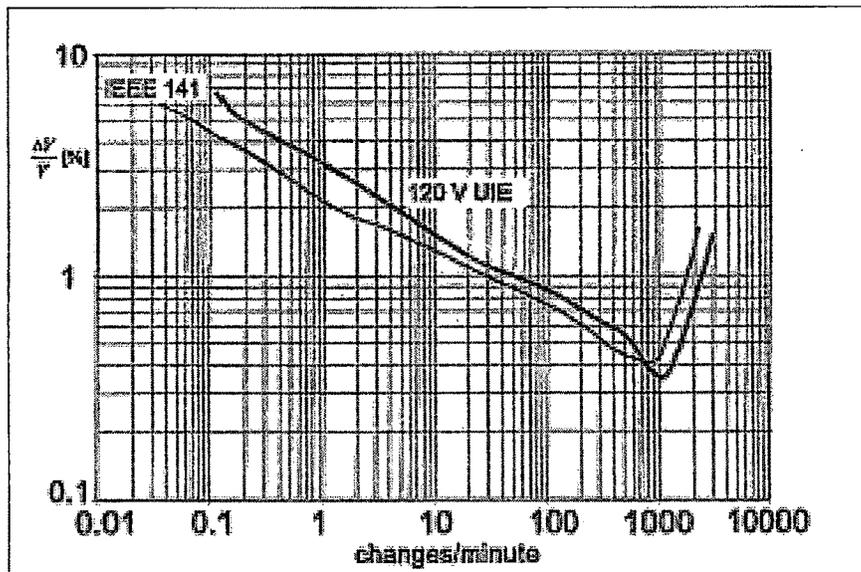


Fig. 5.1 Historical Flicker Curve

It is thus becoming important to monitor the actual flicker level present at the electrical network due to several reasons such as high-quality services, annoyance "to the eye". Due to the increasing use of electro heat (arc furnaces) and due to the high priority of power quality the importance of the flicker annoyance has increased tremendously. Flicker assessment in electrical power networks may be difficult, because its evaluation requires long computation times and special procedures. In general, the flicker severity level will depend upon the magnitude and shape of the change as well as their repetition rate. There are two flicker severity indicators defined in the IEC Standard [47] to determine the levels of flicker.

Short term flicker indicator: P_{ST} -The flicker severity evaluated over a short period (minutes).

Long term flicker indicator: P_{LT} - The flicker severity evaluated over a long period (hours) using successive P_{ST} values.

5.1. Various Methods For Flicker Estimation:

5.1.1. British Method

This method is based on 50 Hz voltage supply modulation V_{50} , so that, the instantaneous value is modulated by a random signal called fluctuation voltage V_f . The fluctuation voltage rms value, in this way, is represented by a variable defined as V_f . Generally, the V_f rms value is expressed in percentage of 50Hz reference voltage supply. Through several experiments, it was verified that V_f is between 0.20 - 0.25% results in a perceptible visual disturbance, although tolerable. For values equal or greater than 0.30%, the visual disturbance is intolerable. This fluctuation limits are not sufficient to evaluate flicker effects, since they have a random behavior. Therefore, statistical description should be a more realistic way to describe the phenomena. A combination of the recorded voltage fluctuation and an appropriated statistical description provides means to obtain the accumulated probability function - FPC, and the corresponding Complemented Accumulated

Probability Function - FPCC. Table 5.1 gives the conditions for flicker evaluation by British Method.

British Method Acceptable Limits		
Rated Voltage	≤138kV	>138kV
Voltage Drop-delta V_f	≤2%	≤1.6%
Gauge Point Voltage V_{fg}	≤0.25%	≤0.2%

Table 5.1 British Method Acceptable Limits

5.1.2. French Method

This method uses a strategy based on the variation of the fluctuation voltage values. The idea is to transform any voltage oscillation with frequency in the range of 1 and 25Hz, to an equivalent oscillation with a frequency of 10Hz [48]. To provide this, the method proposes the use of a Frequency Ponderation Curve. From the ponderation curve, the equivalent voltage is obtained in accordance with Eq. 5.1

$$a_{10} = \sqrt{\sum_{f_i=0.5}^{25} a_i^2 g_{f_i}^2} \quad (5.1)$$

Where

a_{10} = Equivalent voltage magnitude at 10Hz frequency,

a_i = Fluctuation voltage magnitude at f_i frequency

g_{f_i} = Ponderation coefficient corresponding to f_i

To quantify the luminous flux variation, the French method uses what is called the Unitary Dose of Scintillation. This concept is expressed by Eq.

5.2

$$Du_i = \int_0^{t=1\text{min}} (a_{10})^2 \cdot dt \quad \% \quad \text{min} \quad (5.2)$$

Where

Du_i = Unitary Dose of Scintillation.

a_{10} = Scintillation Instantaneous Level.

By computing this level of voltage fluctuation along the period of one minute, the value of $0.09 (\%)^2 \times \text{min}$ could be understood as the limit for the Unitary

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Dose of Scintillation. Regarding the acceptable level of flicker, it is recommended that the analysis should be carried out during 15 consecutive minutes. This results in another variable which is called by Flicker Accumulated Dose –G(t), as given by Eq. 5.3

$$G(t) = \sum_{i=1}^{15} Du_i \leq 15 \times 0.09\%^2 \text{ min} = 1.35 \%^2 \times \text{min} \quad (5.3)$$

Where:

G(t) = Flicker Accumulated Dose;

Du_i = Unitary Dose.

The table summarizes the limits to be used by the French Method.

French Method Acceptable Limits		
Tolerance Limit	Unitary Dose (1 min)	Accumulated Dose (15 min)
	$\leq 0.09 (\%)^2 \times \text{min}$	$\leq 1.35 (\%)^2 \times \text{min}$

Table 5-2 French Method Acceptable Limits

5.1.3. IEC 61000-4-15 (Testing And Measurement Techniques – Flickermeter –Functional And Design Specifications):

In the beginning of the 1980th UIE (Union Internationale D'Electrothermie) defined an analog model to estimate the level of flicker in a power network. The input signal to the model is voltage waveform data. The model describes how the chain lamp-eye-brain reacts on voltage fluctuations. The outputs of the model are the flicker parameters I_{FL}, P_{ST}, P_{LT}. Based on the model from UIE, the flicker standard IEC 61000-4-15 [47] has been developed. Fig. 5.1.3-1 shows a functional diagram of a flicker meter designed according to the IEC 61000-4-15. Since the model is defined as an analog one it was difficult to implement the model, the chapter propose a digital method for flicker measurement, using the perceptible limits as described in the standard.

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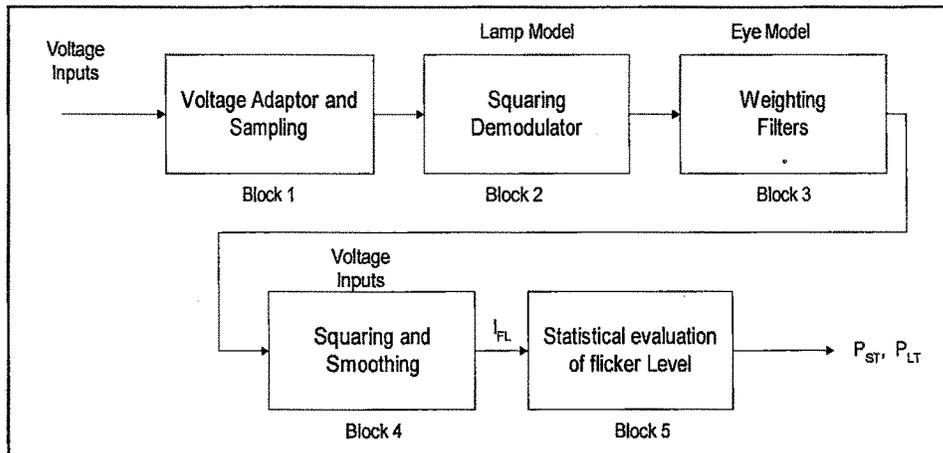


Fig. 5.1.3-1 Block diagram as per IEC 61000-4-15

In block 1, the input signal is scaled, anti-alias filtered and sampled. Block 2 is a squaring demodulator separating the modulating signals from the carrier and the low frequency variations are moved to the baseband of 0-30Hz. Block 3 consists of two band pass filters in cascade. The first one eliminates the DC and double mains frequency ripple component. The second one has a centre frequency of 8.8Hz and simulates the frequency response to sinusoidal voltage fluctuations of a coiled filament lamp (60W-230V) combined with the human visual system. Block 4 is composed of a squaring multiplier and a first order low-pass filter. The human flicker sensation is simulated by block 2, 3 and 4. The output of block 4 is the instantaneous flicker value I_{FL} . If the 60W/230V lamp is connected to a voltage with $I_{FL}=1.0$, statistically 50% of the people in a reference group will experience annoying flicker from the lamp [12]. In block 5, a statistical analysis is performed of the data giving the flicker parameters P_{ST} and P_{LT} . Accordingly to EN 50160 the 95% value of the P_{LT} shall not exceed 1.

I_{FL} values are recorded continuously during 10 minutes and the values are sorted in duration diagram. The P_{ST} value is calculated from the formula as given by Eq. 5.4:

$$P_{ST} = \sqrt{0.0314IFL_{0.1} + 0.0175IFL_{0.7} + 0.0175IFL_1 + 0.0219IFL_{2.2} + 0.0219IFL_3 + 0.0219IFL_4 + 0.056IFL_6 + 0.056IFL_8 + 0.056IFL_{13} + 0.056IFL_{17} + 0.0267IFL_{30} + 0.0267IFL_{50} + 0.0267IFL_{80}}$$

(5.4)

Where IFL_n are the IFL value exceeded 1.0 value for $n\%$ of the 10 min period.

The P_{LT} value is normally based on an observation time of 2 hours and takes into account the effect of several disturbing loads operating randomly. The formula for P_{LT} is given by Eq 5.5

$$P_{LT} = \sqrt[3]{\frac{\sum_{t=1}^N P_{STt}^3}{N}}$$

(5.5)

Where P_{STt} are consecutive 10 minute P_{ST} values and $N=12$ for an observation time of 2 hours

Also there are other methods described in various papers, such as flicker meter based on analog (which uses a four pole analog filter) and a digital implementation of the flicker meter can be found in [3]. The applicability of the analog filtering approach is limited because of the need to restart the analysis procedure every time the weighting curve changes. In [4], a method was proposed for digital computation of the flicker meter using the Fast Fourier Transform (FFT) along with a running technique to reduce the computational burden of the FFT. In [49], a method using a weighting filter along with a technique to design the filter was proposed to enable the direct computation of flicker severity index.

5.2. Modified Algorithm for Flicker Measurement

As shown in Fig 5.2-1 block diagram of digital flicker meter which is similar to the structure in IEC [47], with the exception that the statistical analysis and the weighting flicker block has been replaced by the new method. The steps involved in the calculation of the flicker index P_{ST} are explained below.

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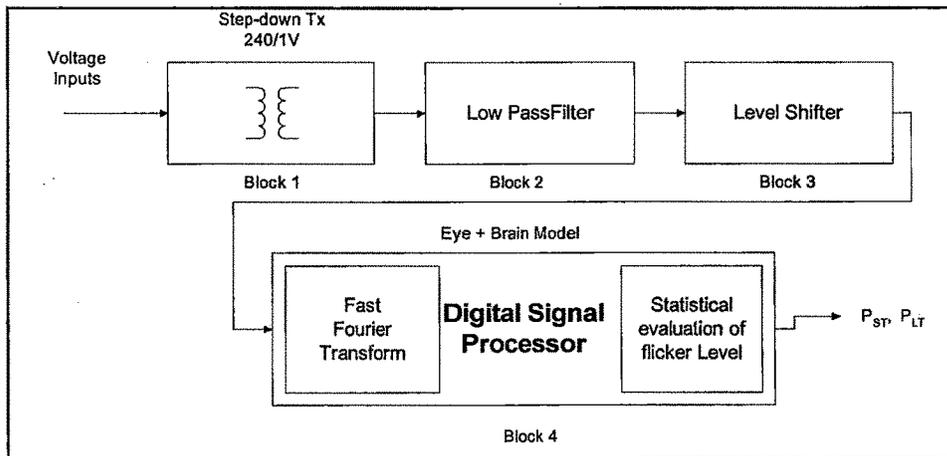


Fig. 5.2-1 Block diagram of Flicker Meter

1. The input signal is scaled to the voltage required by the DSP by using a Potential Transformer (P.T) (240/1V). The output signal from the P.T is filtered by the low pass filter with a cut-off frequency of 200Hz. The output of the filter is a bipolar signal which is converted to unipolar using a level shifter circuits.
2. The instantaneous voltage signal (after sampling) is fed as input to the DSP. The instantaneous values are then split in various window of different resolution. The reason for splitting the span of 10 minutes in various windows is to estimate the perceptible level in various resolutions.
 - 2.1 Calculation of 0.1%
Sampling Freq= 100Hz, Record Length = 0.6 sec,
frequency resolution=1.6Hz.
 - 2.2 Calculation of 1%
Sampling Freq= 100Hz, Record Length = 6 sec,
frequency resolution =0.16Hz.
 - 2.3 Calculation of 3%
Sampling Freq= 100Hz, Record Length = 18 sec,
frequency resolution=0.016Hz.

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2.4. Calculation of 10%

Sampling Freq= 100Hz, Record Length = 60 sec,
frequency resolution=0.0016Hz.

2.5. Calculation of 100%

Sampling Freq= 100Hz, Record Length = 600 sec,
frequency resolution =0.0016Hz.

Each window performs the FFT calculation and computes the magnitude of the various frequencies as mentioned in [47] using the Eq.5.6

$$\begin{aligned} H\left(\frac{n}{NT}\right) &= \sum_{k=0}^{N-1} h(kT) e^{-j2\pi nk/N} \\ &= \sum_{k=0}^{N-1} h(n) e^{-j2\pi nk/N} \end{aligned} \quad (5.6)$$

Where

$h(f)$ = a function of frequency

$h(t)$ = a function of time

$h(kT)$ or $h(n)$ are its samples

N is number of samples in the window

$N = 0, 1, \dots, N-1$

3. After computing the magnitude of the various frequency components. These magnitudes are compared with the reference magnitudes provided in the IEC 61000-4-15.
4. The P_x value for each of the frequency is calculated. The P_x value indicates the measure of severity of a particular flicker frequency for a particular period

$$P_x = \text{Record length} / \text{Flicker frequency} \quad (5.7)$$

Record Length = 0.6, 6, 18, 60, 300 sec.

Where P_x represent $P_{0.1}$, P_1 , P_3 , P_{10} , P_{50} .

These record lengths represent 0.1%, 1%, 3%, 10% and 50% of the total period. For e.g the total period required to calculate flicker is

10 minute, then record lengths values are 0.6, 6, 18, 60, 300 seconds respectively.

The magnitude of individual flicker frequency is computed for five different periods since the frequency resolution is different in each period. After calculating the magnitude of the flicker frequency, P_x value is calculated for that particular flicker frequency using Eq. 5.7. For a single flicker frequency we have five different values of flicker magnitude and five different value of P_x .

If the magnitude of the flicker frequency computed for 0.6 second period is greater than the magnitude specified value in the IEC 61000-4-15 then $P_{0.1}$ is equal to P_x (calculated for 0.6sec) otherwise $P_{0.1}$ is zero.

The above step is repeated for 6, 18, 60 and 300 seconds. In this way for a particular flicker frequency $P_{0.1}$, P_1 , P_3 , P_{10} and P_{50} values are calculated.

5. After calculating the $P_{0.1}$, P_1 , P_3 , P_{10} , P_{50} values the P_{ST} value is calculated as given by Eq. 5.8. If the value P_{ST} is greater than one then it indicates the flicker is present and vice versa.

$$P_{ST} = 0.1 * \sqrt{[3.14 * P_{0.1} + 3.14 * P_1 + 3.14 * P_3 + 3.14 * P_{10} + 3.14 * P_{50}]} \quad (5.8)$$

6. Additionally on the basis of 12 consecutive P_{ST} values over a 2-h interval, the long term flicker severity P_{LT} can be determined using the Eq. 5.9.

$$P_{Lt} = \sqrt[3]{\frac{\sum_{i=1}^N P_{St}^3}{N}} \quad (5.9)$$

Where N is 12

5.2.1. Measurement System Architecture

Flicker is difficult to assess, because the most important parameter to define its severity are P_{ST} and P_{LT} values which requires long-term measurements. Therefore, for flicker monitoring to be effective in long-term analysis, a sufficient data storage medium, continuous real-time computing architecture, a wide range and a high data throughput is required. To perform field measurements, in a noisy environment, a rugged, portable system is preferred. To fulfill these requirements a flexible, modular, stand-alone measurement system developed in-house containing a powerful DSP (TI TMS320F2806) is used.

I. Block Diagram

This section presents a brief functional description of the proposed flicker meter. The basic architecture of the flicker meter has three blocks, as shown in the simplified diagram of Fig 5.2.1-1.

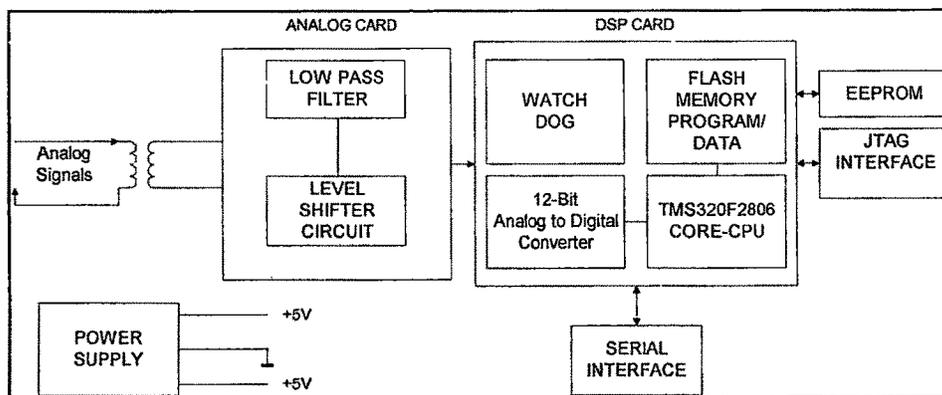


Fig. 5.2.1-1 Main blocks of the Flicker Meter.

In the following, the blocks of the flicker meter are described.

Block 1 :

In this block the input signal is scaled to the nominal value of 1V using Potential transformer. The signal is filtered using a low pass filter with a cut-

off frequency of 200Hz. The bipolar signal is then converted to unipolar using the level shifter circuit since the DSP accepts only the unipolar signal.

Block 2:

In this block the DSP samples the input signal for a period of 10min at a sampling frequency of 80Hz. The DSP calculated the instantaneous values of the signal and stored in memory continuously. After the sampling process, FFT calculation is performed for various record length i.e for 0.6, 6, 18, 60 and 300 seconds. After the FFT process the magnitude of the various interharmonic frequencies as per [47] is calculated. The P_x values are calculated using the Eq. 5.7. Using the P_x values the P_{ST} values are calculated using the Eq. 5.8. After calculating the P_{ST} value P_{LT} is calculated.

Where $P_{0.1}$, P_1 , P_3 , P_{10} and P_{50} are the flicker level that have been exceeded for 0.1%, 1%, 2%, 10% and 50% of observation period. These percentiles are obtained from the statistical analysis. The suffix "s" indicated that smoothed values are used.

Moreover, IEC recommends at least 1,008 short intervals, Corresponding to seven days of continuous flicker measurement and 84 P_{LT} values, when considering 10 minutes interval. The P_{ST} and P_{LT} measured values are then analyzed and representative indexes can be compared to the limits established by standards.

In order to design a multiprocessor system for real time measurement of power quality parameters. The system is connected to the master processor using the SPI interface. The DSP card for flicker measurement works as a slave and performs the measurement of the P_{ST} and P_{LT} continuously. As the master DSP requests the slave for the P_{ST} and P_{LT} values the values are given to the master processor by the slave unit using the SPI interface. These values are then further displayed on the PC using RS232 communication.

5.3. Simulation

The simulation is carried out in MATLAB for flicker measurement for different cases. The software is developed using the GUIDE feature of MATLAB and interfacing it with M-file.

As shown in the Fig 5.3-1 the voltage signal consists of a fundamental component and inter-harmonic frequency of 8.8Hz.

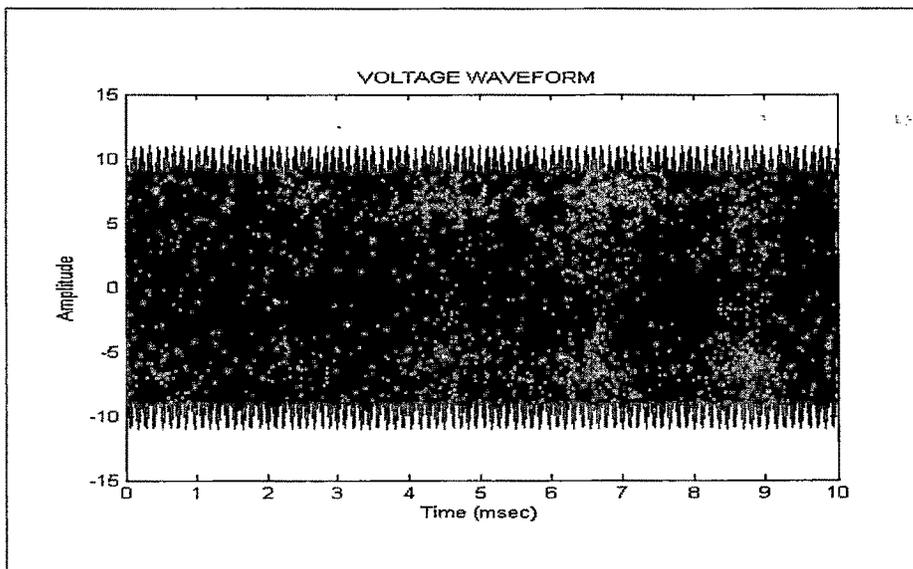


Fig. 5.3-1 Voltage signal with 8.8 Hz component

The FFT algorithm computes the magnitude of various flicker frequencies present in each window at various resolution levels as mentioned in [47]. After computing the flicker magnitude by FFT algorithm in each window the flicker magnitude is then given to the statistical block.

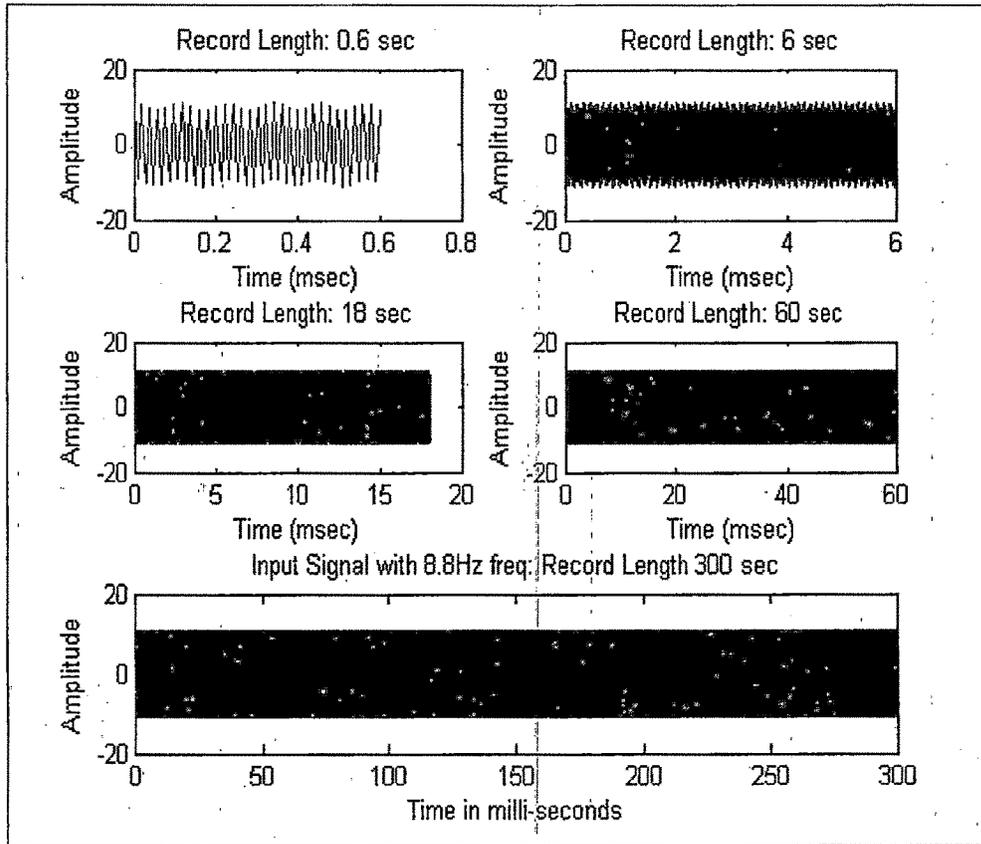


Fig. 5.3-2 FFT windows at various record lengths.

The statistical block mentioned in this thesis is unique and it differs from the IEC 61000-4-15 in such a way that it calculates the P_x values, which indicates the measure of severity of a particular flicker frequency for a particular period. The algorithm uses this technique to determining the number of time the flicker frequencies has repeated in a given record length.

The proposed method is initially mathematically validated and is also checked by simulation on MATLAB software under various conditions. The proposed method is simpler and is technically feasible to develop hardware using present day DSP chips. Waveforms of different case are given with x-axis represent time and y-axis represents amplitude.

CASE-1 Fundamental signal

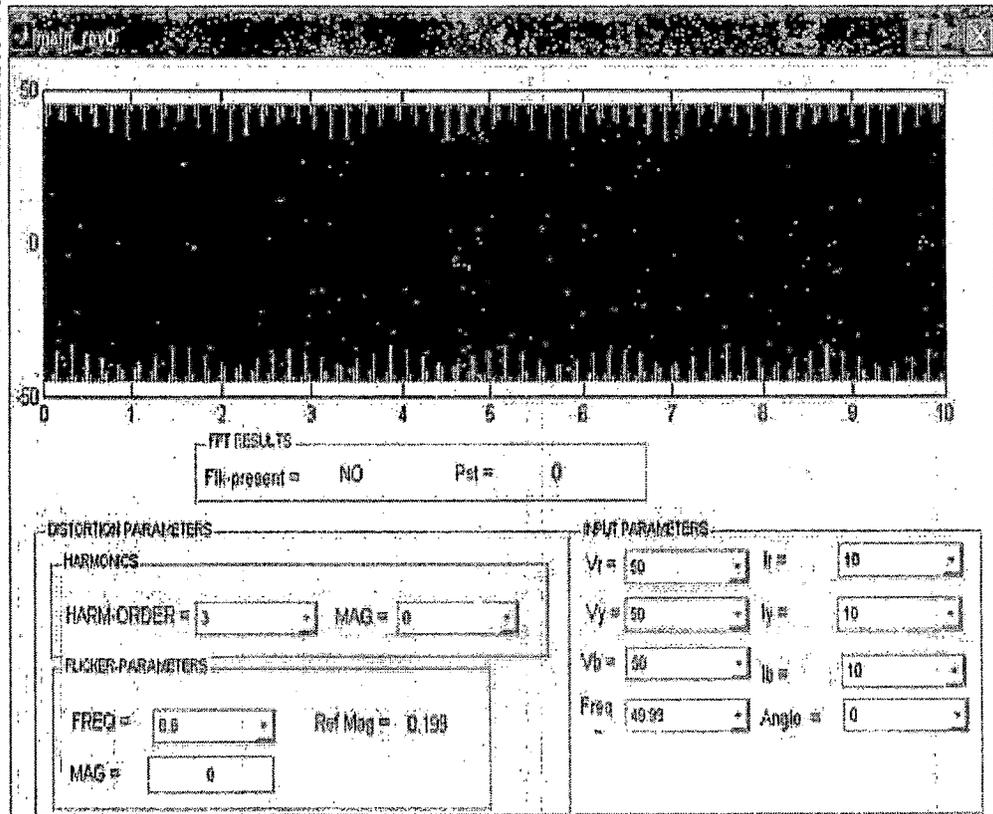


Fig. 5.3-3 GUI Plot of Simulated fundamental signal

In case 1 only fundamental signal is considered and no flicker magnitude is added to it. The P_{st} value computed is also zero, which indicate that there is no flicker being present in the input signal.

As shown in Fig 5.3-4 fundamental signal along with harmonic is simulated and no flicker magnitude is added to it. The P_{st} value computed is also zero, which indicate that there is no flicker being present in the input signal. The algorithm clearly differentiates the flicker and the harmonic signal and support mathematical results.

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As shown in Fig 5.3-5 fundamental signal with harmonic and flicker magnitude less than the reference magnitude is simulated. The P_{st} value computed is also zero, which indicate that there is no flicker being present in the input signal. The algorithm clearly differentiates the magnitude of the flicker as defined in IEC 61000-4-15.

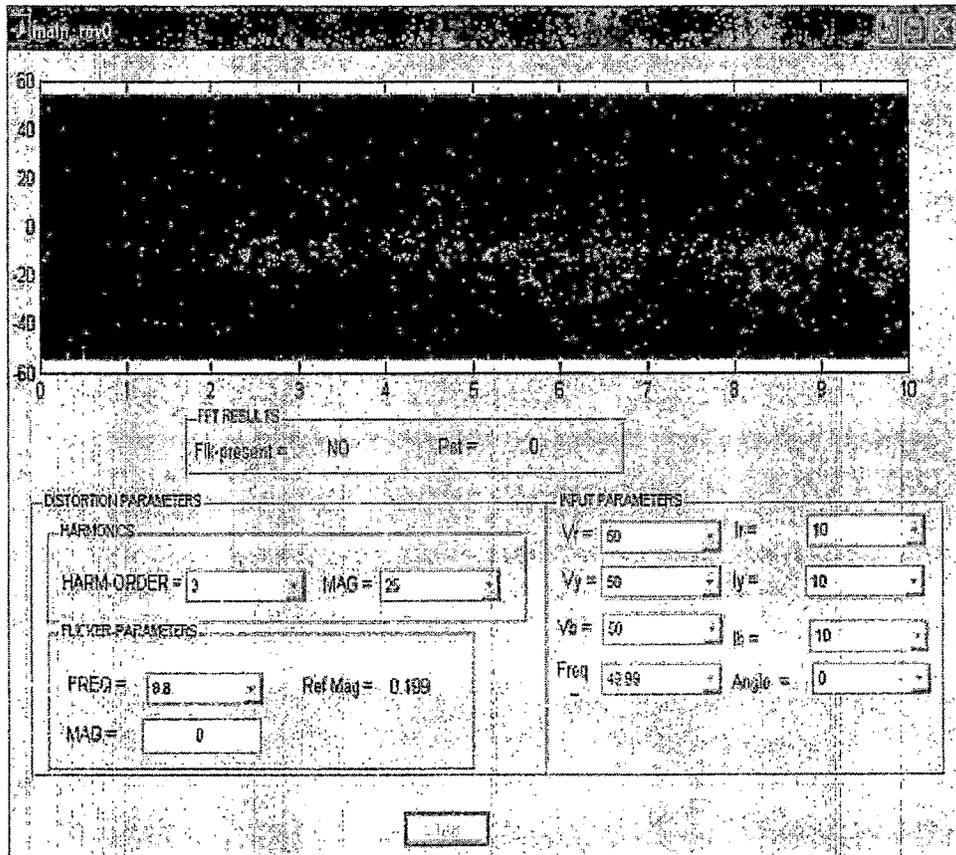


Fig. 5.3-4 GUI plot of Harmonic signal

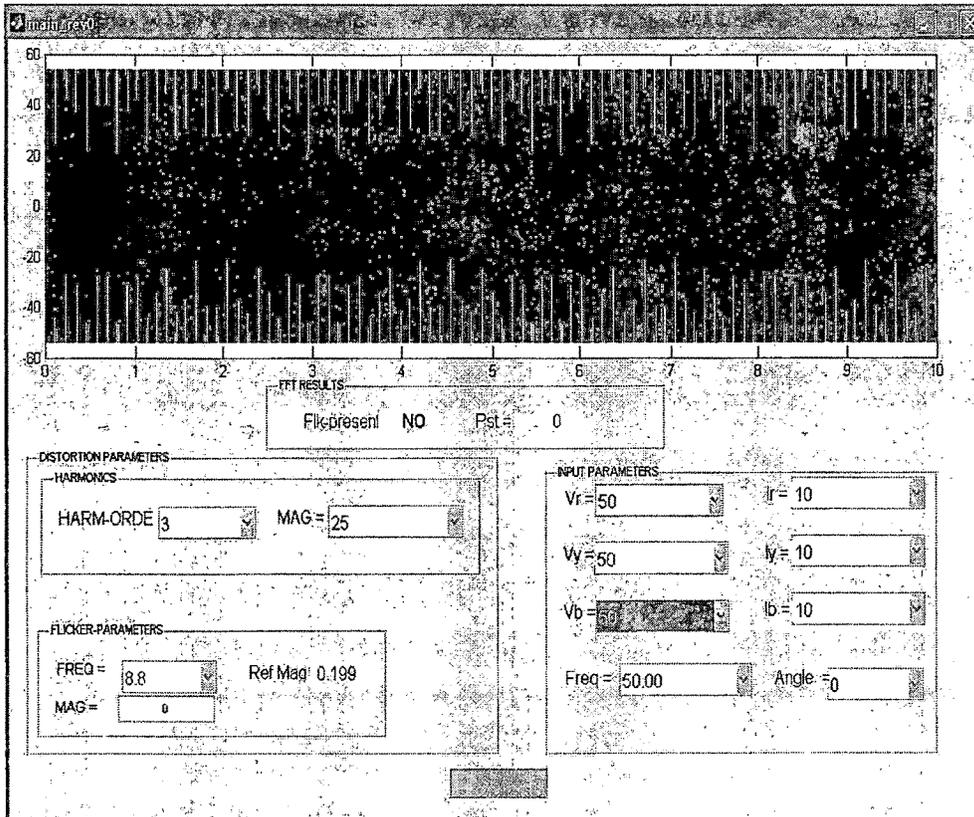


Fig. 5.3-5 GUI plot of harmonic and flicker signal

In case 2 the software is simulating with other order of harmonics and signal at different frequency. In the case of healthy condition the P_{ST} value calculated is 0.0 which holds good.

CASE-2 Fundamental signal with harmonic

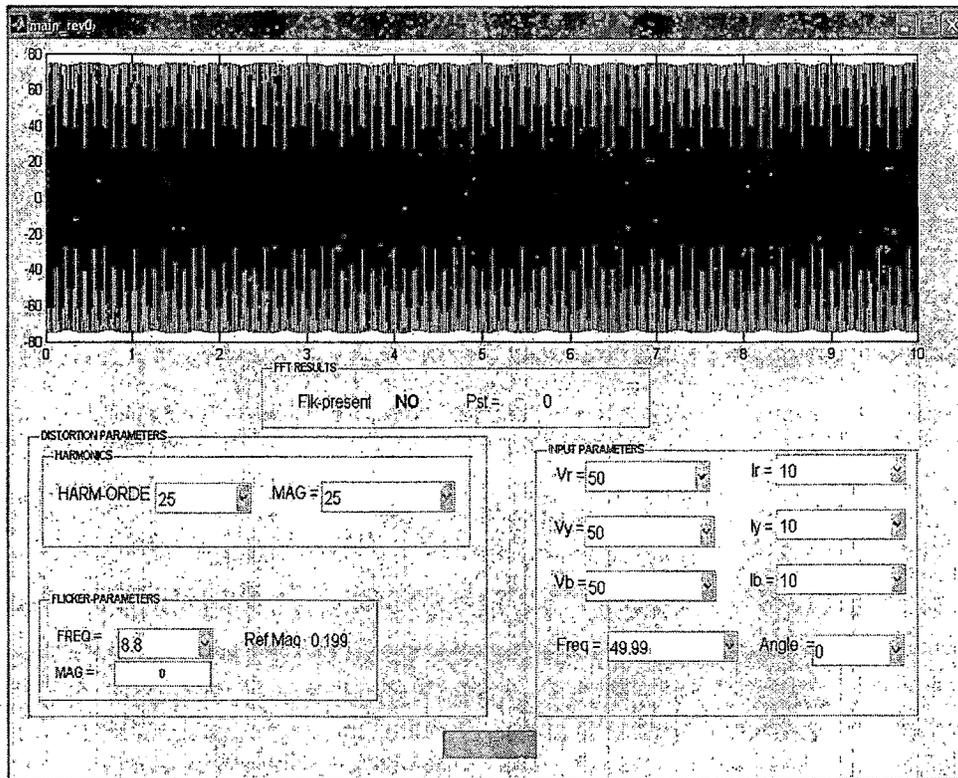


Fig. 5.3-6 Simulation with Harmonic Signal

In this case the software is simulating with fundamental and harmonic like 3rd and 25th order harmonic with 50% magnitude of the fundamental signal. In the case of the healthy condition the P_{ST} value calculated is 0.0.

CASE-3 Fundamental signal with inter-harmonic and magnitude less than the reference magnitude specified in the IEC 61000-4-15 [47]

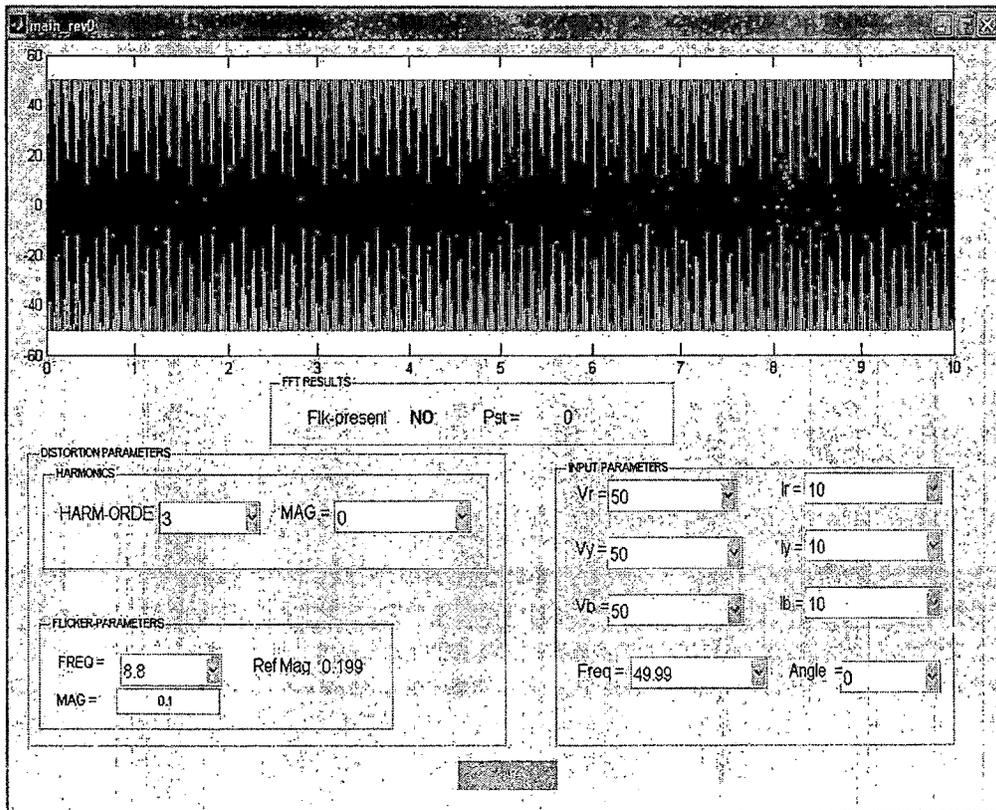


Fig. 5.3-7 Fundamental signal and flicker signal with less magnitude

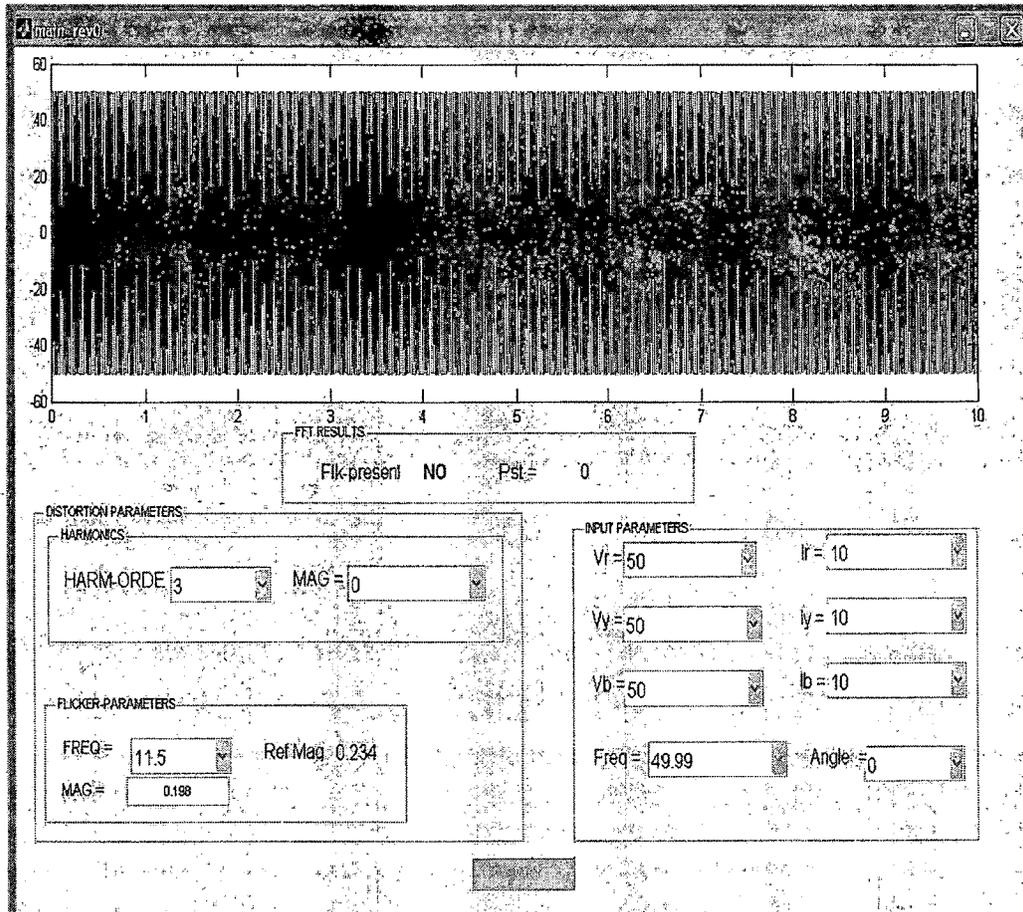


Fig. 5.3-8 Fundamental signal and flicker signal with more magnitude

In this case the software is simulating the signal (fundamental + inter-harmonics) like 8.8Hz and 11.5Hz with magnitude less than the reference signal. In the case of the healthy condition the P_{ST} value calculated is less than 1.0.

CASE-4 Fundamental signal with inter-harmonic and magnitude more than reference magnitude specified in the IEC 61000-4-15 [1]

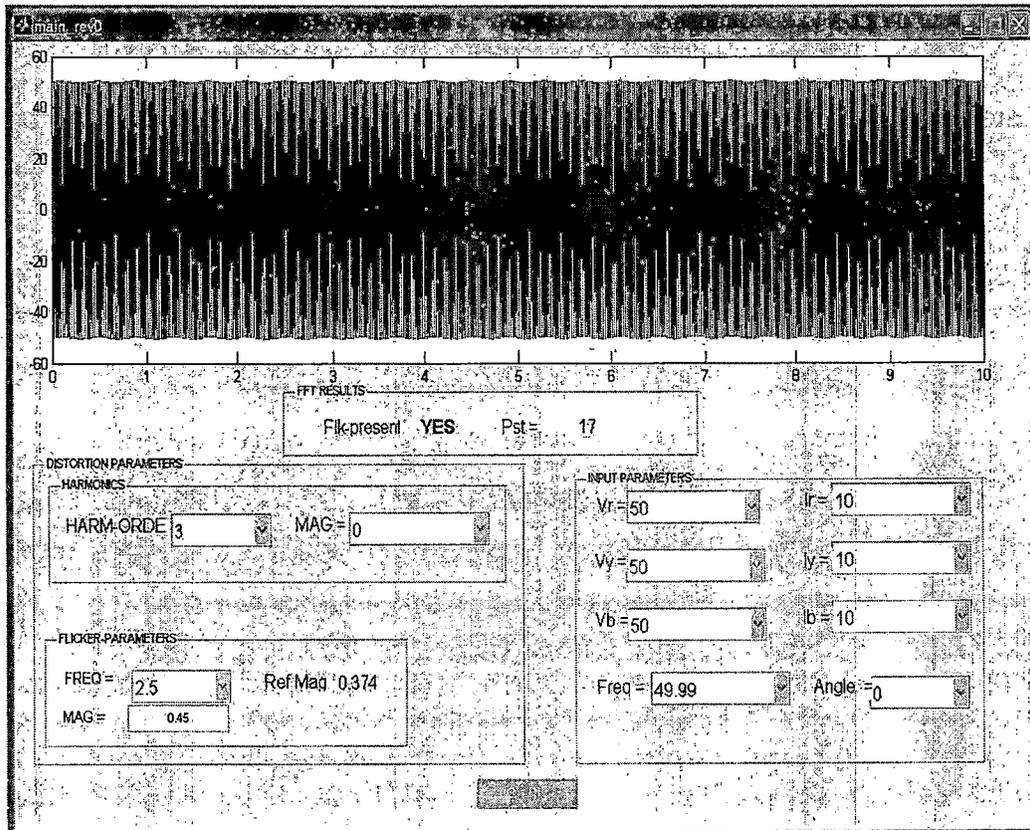


Fig. 5.3-9 Fundamental signal and inter harmonic signal with more magnitude

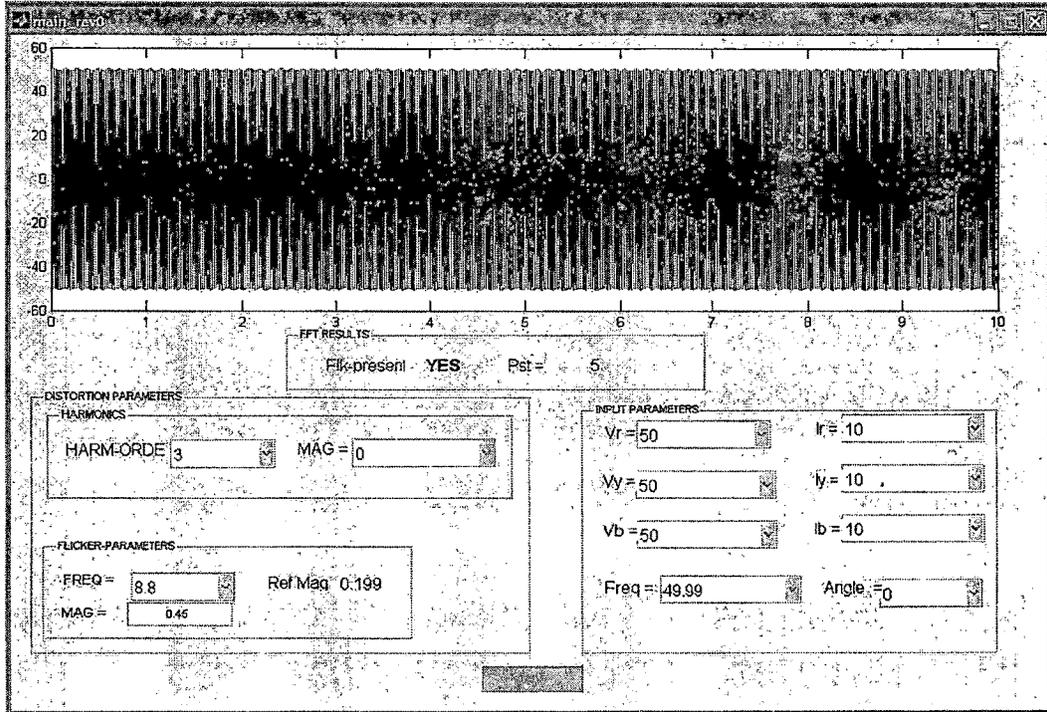


Fig. 5.3-10 Fundamental signal and inter harmonics

In this case the software is simulating the signal (fundamental + inter-harmonics) like 2.5Hz and 8.8Hz with magnitude more than the reference signal. In this case the P_{ST} value calculated is more than 1.0 and hence flicker is present. The Table 5.3-1 shows the results of the various P_{ST} values with different inter-harmonic frequency and with variable magnitude.

Sr.No	Inter-harmonic Freq (Hz)	Magnitude (Volts)	P_{ST}
1	2.5	0.375	17
2	4.5	0.45	9
3	8.8	0.45	9
4	10.5	0.312	4
5	15.0	0.412	3
6	21.0	0.823	2
7	24.0	0.743	2

Table 5.3-1

CASE-4 Fundamental signal with harmonic and inter harmonic and magnitude more than the reference magnitude specified in the IEC 61000-4-15

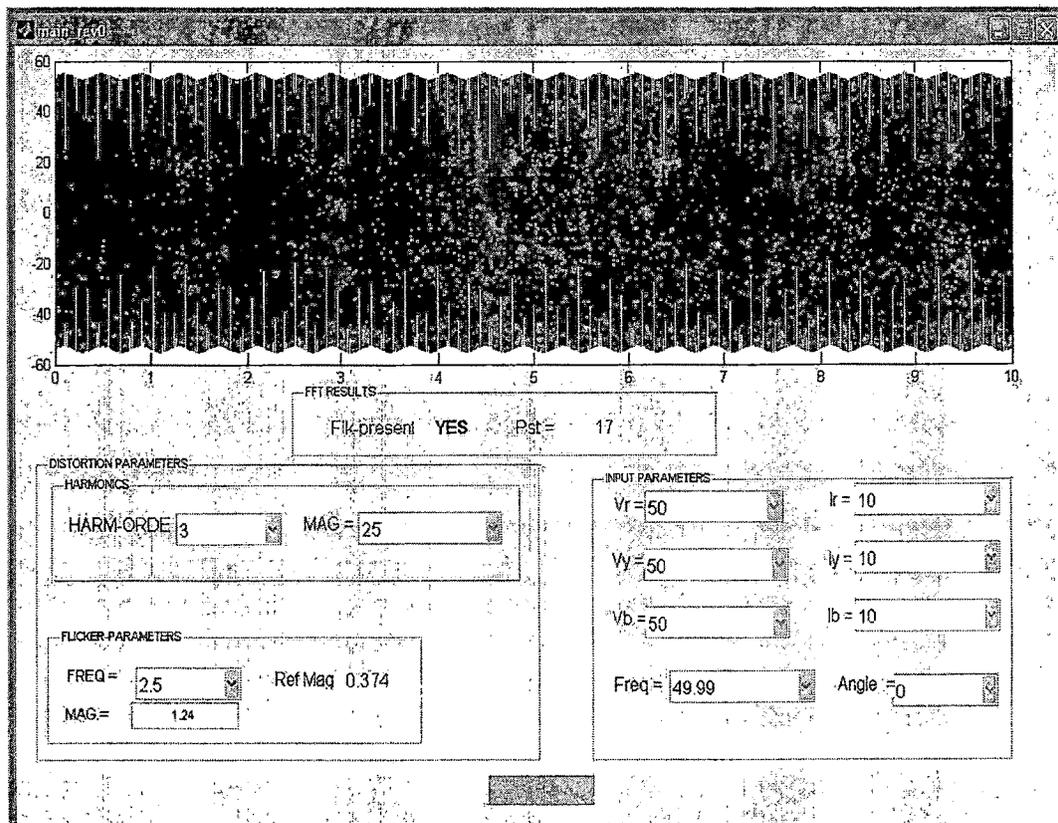


Fig. 5.3-11 Fundamental signal with harmonics and inter harmonics-case-1

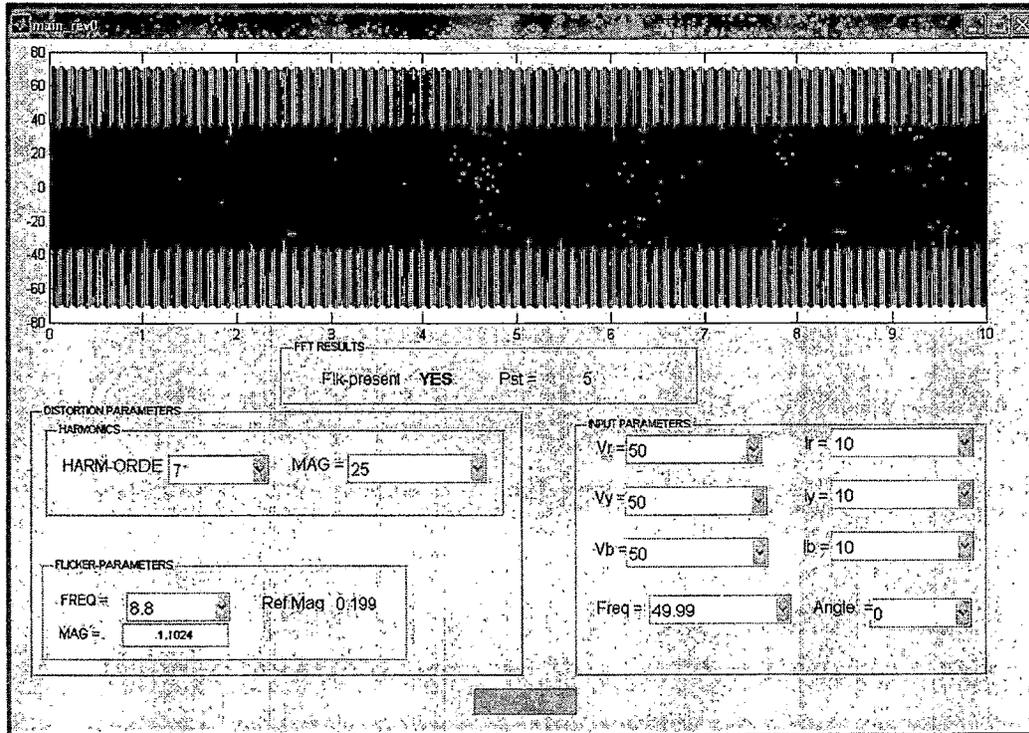


Fig. 5.3-12 Fundamental signal with harmonics and inter harmonics-case-2

In this case the software is simulating the signal (fundamental + harmonic + inter-harmonics) like 2.5Hz and 8.8Hz with magnitude more than the reference signal. In this case the P_{ST} value calculated is more than 1.0 and hence flicker is present. The Table 5.3-2 shows the results of the various P_{ST} values with different inter-harmonic frequency and with variable magnitude.

Sr.No	Harmonics		Inter-harmonic		P_{ST}
	Freq	Magnitude	Freq	Magnitude	
1.	150	25	2.5	1.24	17
2.	250	25	4.5	2.43	9
3.	350	25	8.8	1.10	5
4.	550	13	10.5	0.5	4
5.	850	9	14	0.41	3
6.	1150	9	23	7.12	2
7.	1250	25	40	8.12	2

Table 5.3-2 Reference Values of the Harmonics and Inter-harmonics

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According to the IEC 61000-4-15, every flicker meter should be validated against standard waveforms provided in the IEC standards [47]. The standard provides the amplitudes and frequencies of the six regular series of rectangular voltage changes for which the flicker severity index (P_{ST}) should be 1.00 ± 0.05 .

In Table 1, the flicker indices obtained using the FFT (P_{ST} , f) for the six test signals are summarized. As the results indicate, the flicker indices P_{ST} are within the acceptable range of $1 \pm 5\%$ for each of the test signals. It is also observed that using the FFT approach does not lead to appreciable deviations in the computation of the flicker indices. This is evident from the entries in Table 5.3-3.

Change/minute	Voltage Changes/Minute	P_{ST}	E-time
1	2.72	1.0155	0.1054
2	2.21	1.0157	0.1078
7	1.46	1.0148	0.1082
39	0.905	1.0144	0.1102
110	0.725	1.0035	0.1145
1620	0.402	0.9991	0.1172

Table 5-3 Actual Flicker Results

Table 5.3-3 we also summarize the elapsed time (Etime) obtained in MATLAB for performing the required computations.

The change of the time function $\Delta v/\bar{v}$ are equal the changes in the r.m.s value $\Delta V/V$. For example a 50Hz waveform having a 1.0 average voltage with a relative voltage change $\Delta v/\bar{v}$ equal to 40% and with 8.8Hz rectangular modulation as shown in Fig. 5.3-13 and can be written as follows:

$$v(t) = 1 * \sin(2 * \pi * 50 * t) * \left\{ 1 + \frac{40}{100} * \frac{1}{2} * \text{signum}[\sin(2 * \pi * 8.8 * t)] \right\} \quad (5.10)$$

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The corresponding waveform is shown in Fig. 5.3-13. The change in r.m.s values $\Delta V/V$ are essentially equal to the 40% $\Delta v/\bar{v}$ time function changes. The rectangular voltage changes occur at a frequency of 8.8Hz. Each full period produces two distinct voltage changes, one with increasing magnitude and one with decreasing magnitude. Two changes per period with a frequency of 8.8Hz give rise to 17.6 changes per second.

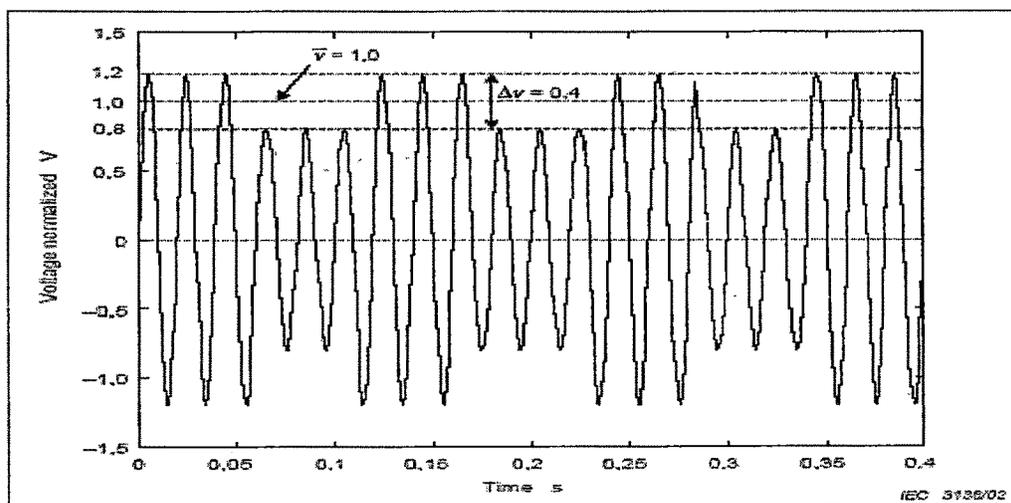


Fig. 5.3-13 Actual flicker signal

5.4. Experimental Setup And Actual Results

Since the flicker measurement required a long term measurement. Therefore sufficient data storage medium, continuous real time computing architecture is required. To fulfill these requirements a flexible, modular standalone measurement system containing DSP (TI TMS320F2806) . The overall of the system is further presented.

Hardware Set-Up

The in-house developed system features a data acquisition card and a DSP card developed for measuring Power Quality Parameters. An optional PC performs monitoring, control and other activities.



Fig. 5.4-1 Measurement System Set-up

As shown in the Fig. 5.4-1 the input signal is scaled down using potential transformer and then given to the analog signal acquisition card. The bipolar signal are scaled to unipolar signal using the signal conditioning card. The unipolar signal is then given to the ADC block of DSP (Digital Signal Processor). The DSP is programmed using the BootFlash serial utility using RS232 port. The software for computation of the P_{ST} and P_{LT} level is written in the C language and is compiled using Code Composer Studio ver 3.3. The communication from DSP to the PC is through RS232 port using MAX232. Graphical user software is developed in Visual Basic for representing the

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numeric values in a useful form. The screen shot of the VB software is shown in Fig. 5.6-3.

During algorithm development the DSP is booted so as to load the software in the flash memory. During run time the DSP boots the software from the flash memory and perform the FFT calculation and calculate the P_{ST} and P_{LT} values.

The ADC (analog to digital converter) used is of DSP only. The resolution of the ADC is 12-bit. The DSP has 16-channels of ADC with simultaneously sampling of two channels. Hence the three voltage and current channels are connected to ADCIN0 to ADCIN3 and ADCIN7 to ADCIN9. The clock frequency to the ADC channel is 100Mhz. The DSP clock frequency is 100 MHz resulting in an execution time 50ns.

Although the measurement unit and the hardware unit is designed for three phase system the system is tested for single phase only due to the limitation of the flash memory available on chip. The R-phase voltage channel is sampled at 80Hz and the samples are processed for flicker measurement.

Special attention was paid to the block related to the statistical analysis of the measured I_{FL} . As is mentioned above, IFL is recorded at a sample rate of 1000 Hz. The statistical analysis of these data over every 10-min period results in the short-time flicker value P_{ST} . In previous publications [41], [43], this statistical analysis was performed by classification of the IFL values in a number of bins, followed by an appropriate interpolation of the different percentiles in order to obtain the desired P_{ST} value. Because of the computing power available through the DSP, a slightly different approach, which leads to a more accurate P_{ST} value, is performed. After the acquisition of all the 600 000 I_{FL} values recorded over a fixed time interval of 10 min, a new statistical processing system is employed.

5.5. Software

The Software is designed on CCS 3.1 for TMS320F2806 for flicker estimation. The supply voltage signal is conditioned as per the input voltage required of the ADC and then the signal is sampled using the analog to digital converter of the DSP. The sampled values are then processed as per the flowchart shown in Fig. 5.5-1.

The FFT algorithm is implemented using the math routines in the DSP. The software is designed so that the DSP perform real time flicker measurement and whenever the flicker event occurred the DSP stores the event with time in the SD card

FLOWCHART FOR MEASUREMENT OF P_{ST} AND P_{LT} VALUES AND SENDING THE DATA TO PC.

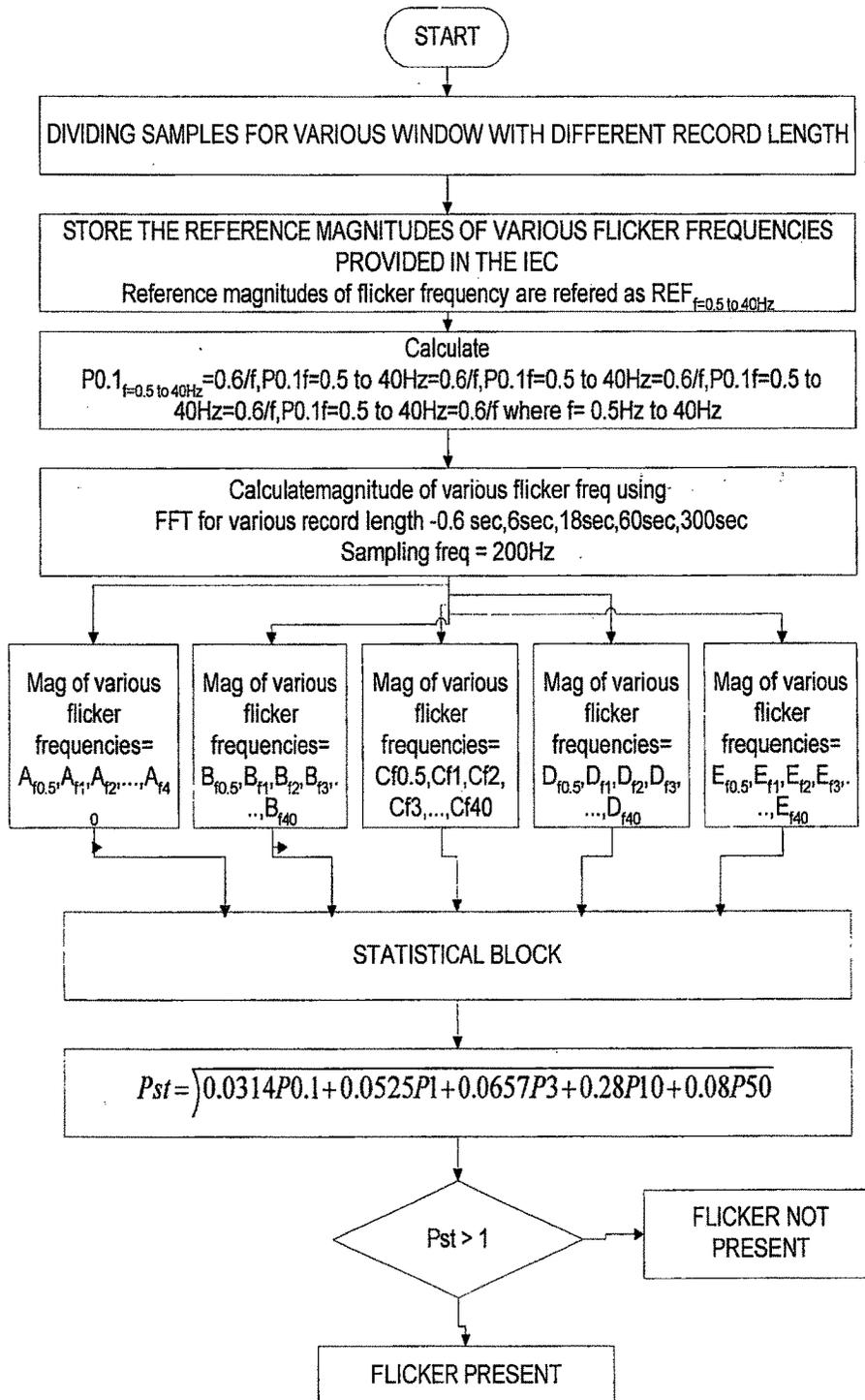


Fig. 5.5-1 Flowchart for the flicker estimation

5.6. Results:

As shown in the Fig. 5.6-1 the DSP samples the R-phase voltage channel and send the P_{ST} values for the various frequency components on the computer using the RS232 interface. All the P_{ST} values are displayed in a tabular format using a VB software.

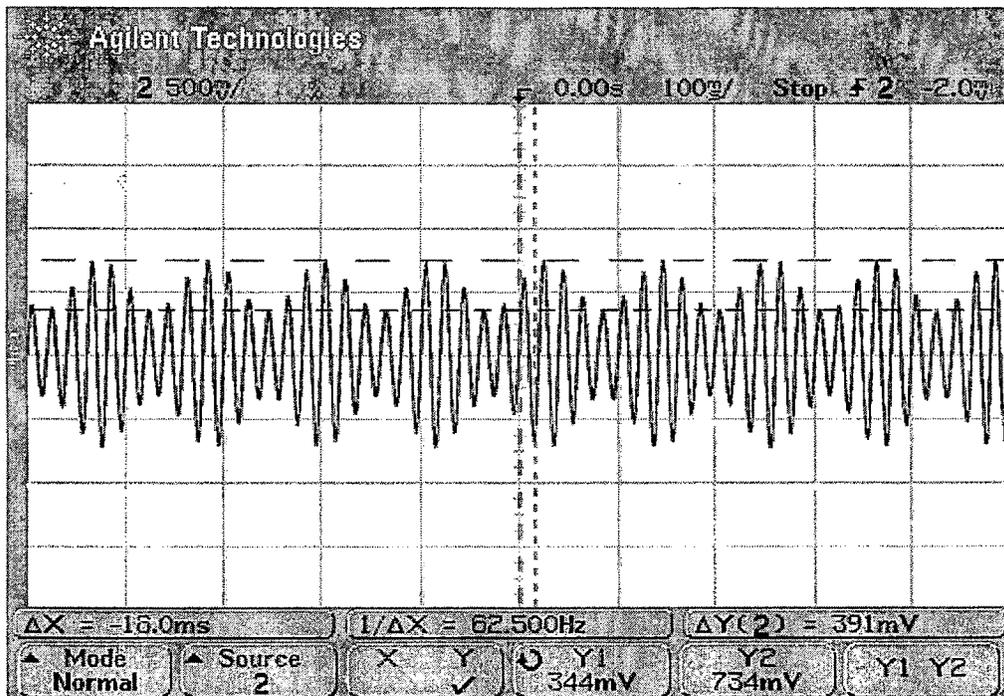


Fig. 5.6-1 Flicker signal on oscilloscope

The system is also integrated with Visual Basic (VB) based software developed in-house for real time display of various power quality parameters. The Tab feature of the software enables the user to select any of the power quality parameters such as the fundamental quantity (Three phase voltage, current, active power, reactive power, import and export of power), frequency, harmonics and flicker. A screenshot of the flicker window is shown the Fig. 5.6-1. The P_{ST} values are updated after ever 10min interval and similarly the P_{LT} values are updated at a interval of 2 hours. The magnitude of the various

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inter-harmonics as mentioned in the IEC 61000-4-12 are also transferred to the PC along with the P_{ST} and P_{LT} values. The software used RS232 port with baud rate of 115200Mbps.

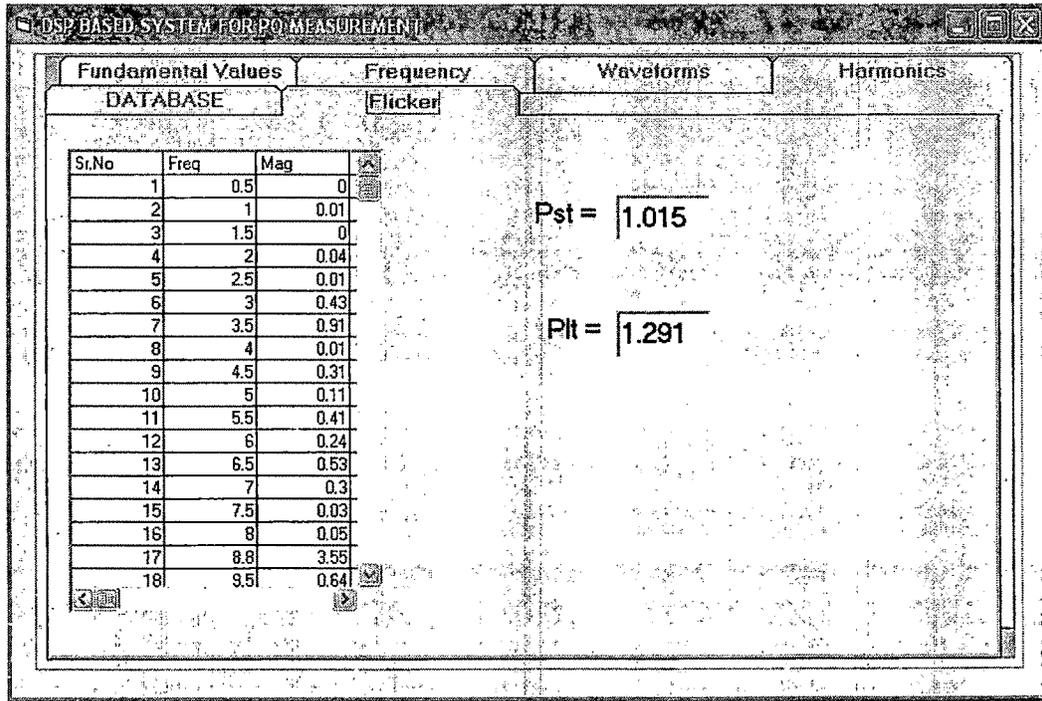
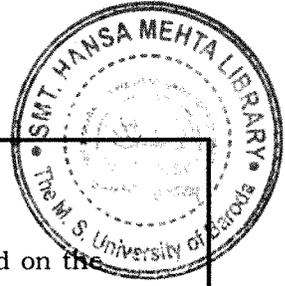


Fig. 5.6-2 Screen Shot of Flicker parameters displayed on PC

5.7. Conclusions:

In this chapter, a new digital algorithm is presented for on-line measurement of flicker. The chapter covers the various International standards available for flicker measurement and also covers various proposed techniques for flicker measurement. The chapter introduces a new digital technique for on-line measurement of flicker and also justifies the results with the International standard available for flicker measurement. The chapter validates the algorithm under various harmonic conditions to differentiate the effect of harmonics and flicker



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and also to test the validity of the measurement system. Based on the computation and findings of the proposed algorithm, following conclusions have been drawn:

- The chapter covers the importance of one of the important power quality parameter. The chapter covers the various literatures for flicker measurement and also bring out the difficulty for implementing these algorithms for on-line measurement of flicker.
- The chapter proposed a new method for measuring flicker and simulates the proposed method under various harmonic conditions. The simulation result proves the validity of the proposed method. The results obtained are then compared to the results required by IEC 61000-4-15.
- The chapter also proposes an hardware implementation of the proposed algorithm on a digital platform using TMS320F2806 DSP. A VB based software is developed to graphically represent the value.