# A LabVIEW Based  Power Analyzer

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***Abstract*— Poor power quality affects the functioning of utilities, industrial units, productions, system performance, customer services and operating cost. There is an ever increasing need for power quality monitoring systems owing to the growing number of sources of disturbances in AC power systems. Thus, a real-time signal detection and harmonic analysis is of great significance to provide power quality solutions. In this paper, a power quality monitoring system is developed by designing Virtual Instruments (VIs) using LabVIEW$^{TM}$. Power quality parameters such as instantaneous power, active and reactive power, power factor and harmonics are all presented.**

***Keywords- LabVIEW, Virtual Instrument, Power Analyzer, Sensors, DAQ, power factor, sag, swell, interruption, TDMS***

## I. INTRODUCTION

The extensive use of computers in power system measurement has paved way for more research in the field of power system technology. This main interest is as a result of reduced costs of experimental laboratories and the acceleration in the speed of development. Over the years, conventional power equipment such as voltmeters, ammeters, expensive power meters, complex circuits power electronic devices and others for detecting frequency and analyzing its harmonics did not provide the ability to store data for future reference and further analysis, which were not flexible enough and thus infeasible for such systems[1]. As against this, with the use of virtual instrumentation, systems can be built with standard computers and cost-effective hardware[6]. LabVIEW$^{TM}$ is a system design platform and development environment for a visual programming language from National Instruments[4].

In this project, the visual interface offered by LabVIEW$^{TM}$ has been adopted for simplified design implementation and use of programmable measurement for system parameters. The inputs to the proposed system are single phase voltage and current and the hardware system developed, allows for measurement and analysis of the system parameters such as power (active, reactive, apparent, instantaneous), power factor, Total Harmonic Distortion (THD) (%), energy and Signal-to-noise and distortion ratio (SINAD) (in decibels) using voltage and current sensors, a data acquisition card and a PC.

## II. METHODOLOGY

This paper presents the development of a computer-based power analyzer that provides real-time monitoring of various power quality parameters, with remote monitoring feature. The system runs on a desktop computer with National Instruments (NI) 9239 Data Acquisition (DAQ) card and cDAQ 9184 Chassis. The system is implemented as a virtual instrument (VI), whereby a programming and user interface is developed using LabVIEW$^{TM}$. The main objectives of the project were to capture power quality parameters and disturbance events and the storing of this data for post-monitoring analysis and corrections.

### *A. Power Analyzer*

Current probes and Hall Effect voltage and current sensors are employed to acquire single phase voltage and current signals for proper and accurate sensing. Signal conditioning which helps to curb the loss of data and ensures accurate measurements and the analog to digital conversion of the input signals are taken care by the DAQ card NI 9239 as these functions are inherent in the card. A National Instruments Data Acquisition card is chosen to interface the analog AC signal

The components used are as follows:
1. LEM Voltage Transducer (LV 25-600)
2. LEM Current Transducer (LA 25-NP/SP14 and LA 25-NP)
3. Regulated Power Supplies for transducers: ±12V and ±15V for voltage and current transducers respectively.
4. Single phase 260V Auto-transformer
5. DAQ CARD NI 9239 and cDAQ 9184, NI USB 6008
6. Computer (LabVIEW$^{TM}$ software)

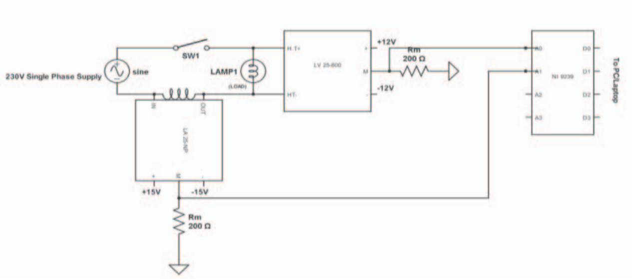


**Fig.1.** Hardware Design of the Virtual Power Analyzer

### *B. Power Quality Indices and Events*

- *Harmonics*

Harmonic distortion is the corruption of the fundamental sine wave at frequencies that are multiples of the fundamental. Waveform harmonics are usually caused by equipment which draws non-linear currents. Modern electrical equipment such as computerized equipment and telecommunication equipment often use switching power supplies to “step up” or “step down” the voltage. This introduces a non-sinusoidal load which pulls current in short pulses during every cycle.

Linear loads have very low values of THD because they have little or no harmonic current. Non-linear loads have large values of THD, and cause considerable distortion to the normal sine wave[3,5].

The THD of a current waveform is calculated as follows:

$$I_{THD} = \sqrt{\frac{I_3^2 + I_5^2 + I_7^2 + \cdots}{I_1}}$$

Where $I_3$, $I_5$, $I_7$, $I_9$ … are the currents at their respective harmonics and $I_1$ is the current at fundamental frequency[2]. Similarly, the voltage harmonics of a system can be found and the formula for voltage THD can be given as:

$$V_{THD} = \sqrt{\frac{V_3^2 + V_5^2 + V_7^2 + \cdots}{V_1}}$$

Where $V_3$, $V_5$, $V_7$… are the voltages at their respective harmonics and $V_1$ is the voltage at the fundamental frequency[2].

- *Interruption*

Table No.1. IEEE 1159 Standards for Interruptions

| Standard (IEEE 1159) | Term | Definition |
|---|---|---|
| 1. | Interruption | Voltage below 10% of nominal. |
| 2. | Momentary Interruption | 0.5 cycles to 3 seconds |
| 3. | Temporary Interruption | 3 seconds to 1 minute |
| 4. | Sustained Interruption | 1 minute and above |

- *Sag*

As per international standards (IEEE 519), if the voltage of the system is in between 0.1 p.u to 0.9 pu of the nominal voltage, i.e. between 23V and 207V of a single phase 230V AC supply, then the condition is termed as a sag[7]. Sag which lasts for a time from 0.5 cycles to 30 cycles, is termed as Instantaneous Sag[7] while that which persists for 30 cycles and up to 3 seconds is termed as Momentary Sag[7]. If it exists for a time between 3 seconds and 60 seconds, then Temporary Sag is said to have occurred. If the time duration of the event exceeds 60 seconds, then it is classified as under voltage[7].

- *Swell*

As per international standards (IEEE 519), if the voltage of the system is greater than 1.1 p.u. of the nominal voltage, i.e. 253V and above for a single phase 230V AC supply, then the condition is termed as a swell[7]. Swell which lasts for a time from 0.5 cycles to 30 cycles, is termed as Instantaneous Swell[7] while that which persists for 30 cycles and up to 3 seconds is termed as Momentary Swell[7]. If it exists for a time between 3 seconds and 60 seconds, then Temporary Swell[7] is said to have occurred. If the time duration of the event exceeds 60 seconds, then it is classified as over voltage[7].

### C. *Event Logging*

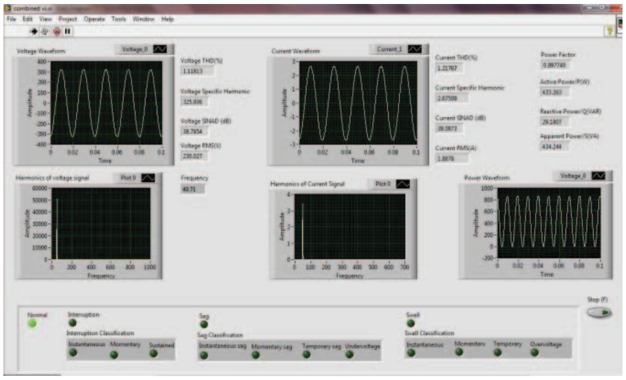
LabVIEW$^{TM}$ provides for recording of data through its Technical Data Management Streaming (TDMS) file format in the Write to Measurement File Express VI. The TDMS file format is a specific type of binary file created for National Instruments' products. It consists of two specific files –a binary file that contains data and stores properties about the data and a binary index file that provides consolidated information on all the attributes and pointers in the binary file. An MS-Excel sheet is generated for the power quality events such as interruptions, sags, swells by importing TDMS files generated while the program is executed. This document contains various parameters such as start time/date, duration for which the event occurs and the magnitude of RMS voltage at that time.

## III. RESULT ANALYSIS

Using LabVIEW$^{TM}$ internal programs, different noises or disturbances were generated to view different events of power quality on simulated signals by the developed Virtual Power Analyzer. Then, the simulation blocks were replaced by Data Acquisition palettes. The waveforms shown in Fig.2 and Fig.7 are those observed for three sets of loads –linear load (three 150W incandescent lamps) and non-linear load - namely, a laptop load (Lenovo SL 400C, 65W).

### A. *Bulb load*

#### *a)Virtual Power Analyzer using LabVIEW$^{TM}$*



Voltage THD(%) 1.11813
Voltage Specific Harmonic 325.936
Voltage SINAD (dB) 38.7854
Voltage RMS(V) 230.027
Frequency 49.71
Current THD(%) 1.21767
Current Specific Harmonic 2.67509
Current SINAD (dB) 38.0873
Current RMS(A) 1.8878
Power Factor 0.997740
Active Power/P(W) 433.263
Reactive Power/Q(VAR) 29.1807
Apparent Power/S(VA) 434.244

**Fig.2.** Front Panel and Waveforms for a Linear load (3*150W incandescent lamps)

*b)Fluke 43B Screen Shots*

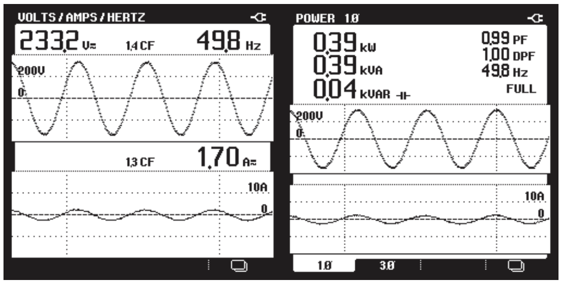


**Fig.3.** Voltage, current, power for linear load (3*150W Incandescent lamps) as observed on Fluke 43B

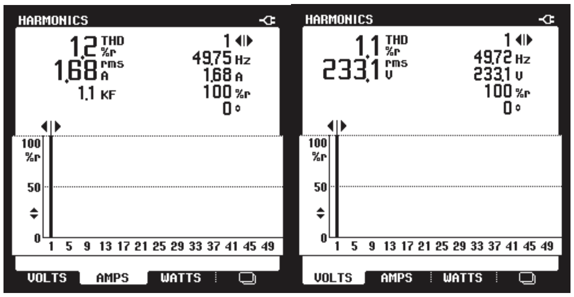
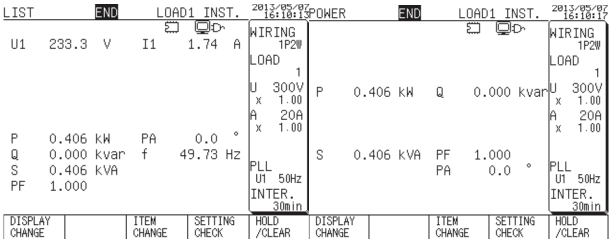


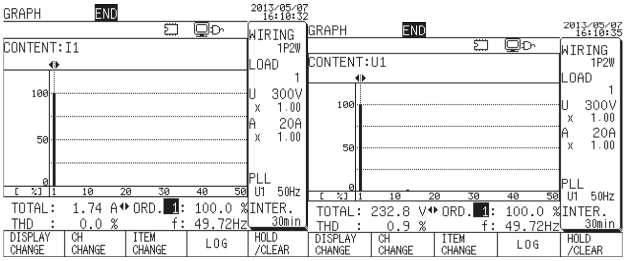
**Fig .4.** Current and voltage harmonics for linear load (3*150W Incandescent lamps) as observed on Fluke 43B

*c)Yokogawa Screen shots*



```
LIST        END      LOAD1 INST.   2013/05/07
                                     16:10:13
 U1   233.3  V    I1     1.74  A   WIRING
                                      1P2W
                                   LOAD
                                         1
                                   U   300V
                                    x  1.00
                                   A    20A
                                    x  1.00
 P    0.406 kW    PA      0.0  °
 Q    0.000 kvar  f     49.73 Hz
 S    0.406 kVA                    PLL
 PF   1.000                         U1  50Hz
                                   INTER.
                                      30min
DISPLAY |        | ITEM   | SETTING | HOLD
CHANGE  |        | CHANGE | CHECK   | /CLEAR

POWER       END      LOAD1 INST.   2013/05/07
                                     16:10:17
                                   WIRING
                                      1P2W
                                   LOAD
                                         1
 P    0.406 kW    Q     0.000 kvar U   300V
                                    x  1.00
                                   A    20A
                                    x  1.00
 S    0.406 kVA   PF    1.000
                  PA      0.0  °   PLL
                                    U1  50Hz
                                   INTER.
                                      30min
DISPLAY |        | ITEM   | SETTING | HOLD
CHANGE  |        | CHANGE | CHECK   | /CLEAR
```

**Fig .5.** Voltage, current, power for linear load (3*150W Incandescent lamps) as observed on Yokogawa CW240



```
TOTAL:  1.74 A ORD. 1: 100.0 %
THD  :   0.0 %       f: 49.72Hz

TOTAL: 232.8 V ORD. 1: 100.0 %
THD  :   0.9 %       f: 49.72Hz
```

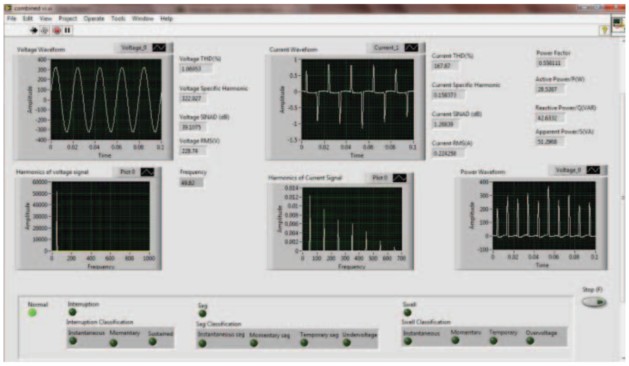
**Fig.6.** Current and voltage harmonics for linear load (3*150W Incandescent lamps) as observed on Yokogawa CW240

Table.2. Comparison Table for Linear load (3*150W Incandescent lamps)

| | **LabVIEW$^{TM}$** | **Fluke** | **Yokogawa** |
|---|---|---|---|
| $V_{RMS}$ in Volts | 230.027 | 233.2 | 233.2 |
| $I_{RMS}$ in Amps | 1.8878 | 1.70 | 1.74 |
| Power factor | 0.997740 | 0.99 | 1.000 |
| Frequency(Hz) | 49.71 | 49.8 | 49.72 |
| Apparent power(KVA) | 0.434244 | 0.39 | 0.406 |
| Active power(KW) | 0.433263 | 0.39 | 0.406 |
| Reactive power(KVAR) | 0.0291807 | 0.04 | 0.000 |
| Voltage THD (%) | 1.11813 | 1.1 | 0.9 |
| Current THD (%) | 1.21767 | 1.2 | 0.0 |

## B. Non linear load(Laptop load)

*a)Virtual Power Analyzer using LabVIEW$^{TM}$*



Voltage THD(%) 1.08953
Voltage Specific Harmonic 322.927
Voltage SINAD (dB) 39.1075
Voltage RMS(V) 228.74
Frequency 49.82
Current THD(%) 167.87
Current Specific Harmonic 0.158373
Current SINAD (dB) 1.26839
Current RMS(A) 0.224258
Power Factor 0.556111
Active Power/P(W) 28.5267
Reactive Power/Q(VAR) 42.6332
Apparent Power/S(VA) 51.2968

**Fig.7.** Front Panel and Waveforms for a Non Linear load (65W Laptop load)

*b)Fluke 43B Screen shots*

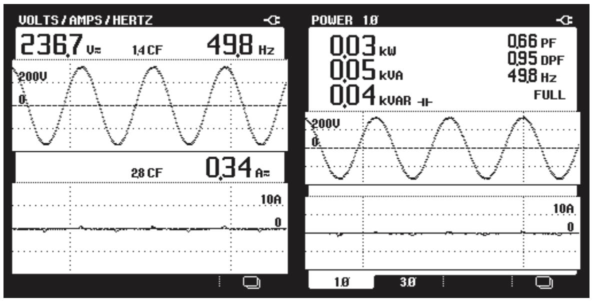


**Fig .9.** Voltage, current, power for Non Linear load (65W Laptop load) as observed on Fluke 43B

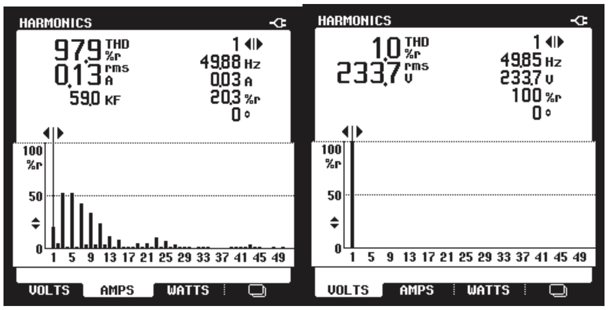
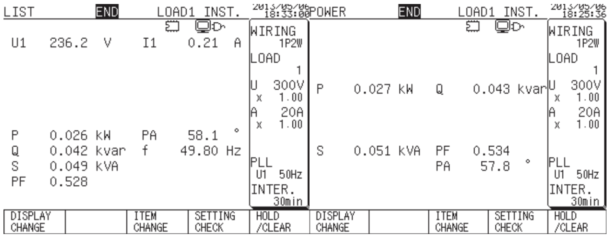


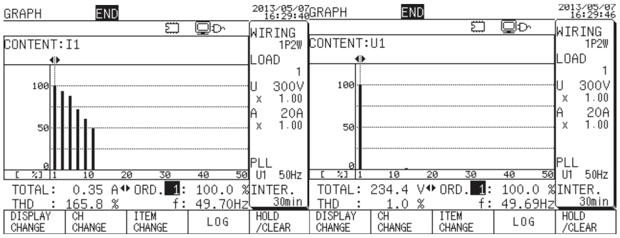
**Fig.10.** Current and voltage harmonics for Non Linear load (65W Laptop load)
as observed on Fluke 43B

*c)Yokogawa Screen shots*



```
LIST            END      LOAD1 INST.  2013/05/06    POWER           END      LOAD1 INST.  2013/05/06
                                        18:33:00                                          18:25:36
                                     WIRING                                            WIRING
 U1    236.2  V     I1     0.21  A      1P2W                                              1P2W
                                     LOAD                                              LOAD
                                           1                                                 1
                                     U   300V     P     0.027 kW    Q     0.043 kvar   U   300V
                                      x   1.00                                          x   1.00
                                     A    20A                                          A    20A
                                      x   1.00                                          x   1.00
 P     0.026 kW     PA     58.1  °
 Q     0.042 kvar   f     49.80 Hz                S     0.051 kVA   PF    0.534
 S     0.049 kVA                     PLL                            PA     57.8   °    PLL
 PF    0.528                          U1  50Hz                                          U1  50Hz
                                     INTER.                                            INTER.
                                        30min                                             30min
DISPLAY |       | ITEM   | SETTING | HOLD   | DISPLAY |       | ITEM   | SETTING | HOLD
CHANGE  |       | CHANGE | CHECK   | /CLEAR | CHANGE  |       | CHANGE | CHECK   | /CLEAR
```

**Fig.11.** Voltage, current, power for Non Linear load (65W Laptop load) as observed on Yokogawa CW240



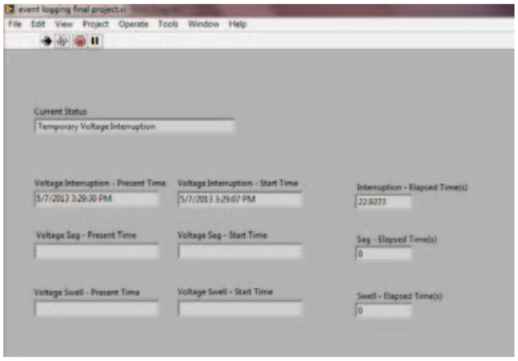
```
GRAPH           END              2013/05/07   GRAPH           END              2013/05/07
                                   16:29:40                                      16:29:46
                                 WIRING                                        WIRING
CONTENT:I1                          1P2W      CONTENT:U1                          1P2W
                                 LOAD                                          LOAD
                                       1                                             1
                                 U   300V                                      U   300V
                                  x   1.00                                      x   1.00
                                 A    20A                                      A    20A
                                  x   1.00                                      x   1.00

                                 PLL                                           PLL
[ %] 1   10   20   30   40   50   U1  50Hz    [ %] 1   10   20   30   40   50   U1  50Hz
 TOTAL:   0.35 A◂▸ORD. 1: 100.0 %INTER.        TOTAL: 234.4 V◂▸ORD. 1: 100.0 %INTER.
 THD  : 165.8 %        f: 49.70Hz  30min       THD  :   1.0 %        f: 49.69Hz  30min
DISPLAY | CH     | ITEM   | LOG | HOLD   | DISPLAY | CH     | ITEM   | LOG | HOLD
CHANGE  | CHANGE | CHANGE |     | /CLEAR | CHANGE  | CHANGE | CHANGE |     | /CLEAR
```

**Fig.12.** Current and voltage harmonics for Non Linear load (65W Laptop load) as observed on Yokogawa CW240

Table.3. Comparison Table for Non-Linear load (65W Laptop load)

| | LabVIEW$^{TM}$ | Fluke | Yokogawa |
|---|---|---|---|
| $V_{RMS}$ in Volts | 228.74 | 236.7 | 236.2 |
| $I_{RMS}$ in Amps | 0.224 | 0.34 | 0.22 |
| Power factor | 0.55611 | 0.66 | 0.534 |
| Frequency(Hz) | 49.82 | 49.8 | 49.70 |
| Apparent power(KVA) | 0.0512968 | 0.05 | 0.051 |
| Active power(KW) | 0.0285267 | 0.03 | 0.027 |
| Reactive power(KVAR) | 0.0426332 | 0.04 | 0.043 |
| Voltage THD (%) | 1.06953 | 1.0 | 1.0 |
| Current THD (%) | 167.87 | 97.9 | 165.8 |

## C) Event Logging



Current Status: Temporary Voltage Interruption

Voltage Interruption - Present Time: 5/7/2013 3:29:30 PM

Voltage Interruption - Start Time: 5/7/2013 3:29:07 PM

Interruption - Elapsed Time(s): 22.9273

Voltage Sag - Present Time:

Voltage Sag - Start Time:

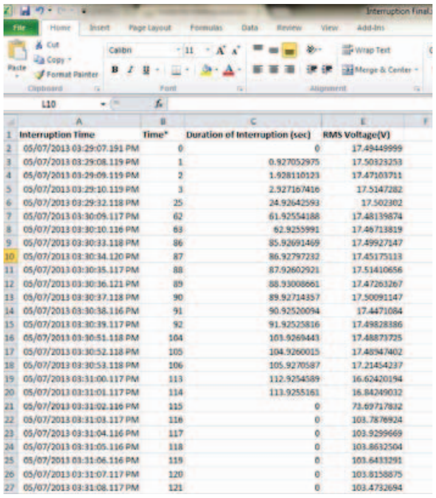
Sag - Elapsed Time(s): 0

Voltage Swell - Present Time:

Voltage Swell - Start Time:

Swell - Elapsed Time(s): 0

**Fig.13**. Temporary voltage interruption



| | A | B | C | E |
|---|---|---|---|---|
| 1 | Interruption Time | Time* | Duration of Interruption (sec) | RMS Voltage(V) |
| 2 | 05/07/2013 03:29:07.191 PM | 0 | 0 | 17.49449999 |
| 3 | 05/07/2013 03:29:08.119 PM | 1 | 0.927052975 | 17.50323253 |
| 4 | 05/07/2013 03:29:09.119 PM | 2 | 1.928110123 | 17.47103711 |
| 5 | 05/07/2013 03:29:10.119 PM | 3 | 2.927167416 | 17.5147282 |
| 6 | 05/07/2013 03:29:32.118 PM | 25 | 24.92642593 | 17.502302 |
| 7 | 05/07/2013 03:30:09.117 PM | 62 | 61.92554188 | 17.48139874 |
| 8 | 05/07/2013 03:30:10.116 PM | 63 | 62.9255991 | 17.46713819 |
| 9 | 05/07/2013 03:30:33.118 PM | 86 | 85.92691469 | 17.49927147 |
| 10 | 05/07/2013 03:30:34.120 PM | 87 | 86.92797232 | 17.45175113 |
| 11 | 05/07/2013 03:30:35.117 PM | 88 | 87.92602921 | 17.51410656 |
| 12 | 05/07/2013 03:30:36.121 PM | 89 | 88.93008661 | 17.47263267 |
| 13 | 05/07/2013 03:30:37.118 PM | 90 | 89.92714357 | 17.50091147 |
| 14 | 05/07/2013 03:30:38.116 PM | 91 | 90.92520094 | 17.4471084 |
| 15 | 05/07/2013 03:30:39.117 PM | 92 | 91.92525816 | 17.49828386 |
| 16 | 05/07/2013 03:30:51.118 PM | 104 | 103.9269443 | 17.48873725 |
| 17 | 05/07/2013 03:30:52.118 PM | 105 | 104.9260015 | 17.48947402 |
| 18 | 05/07/2013 03:30:53.118 PM | 106 | 105.9270587 | 17.21454237 |
| 19 | 05/07/2013 03:31:00.117 PM | 113 | 112.9254589 | 16.62420194 |
| 20 | 05/07/2013 03:31:01.117 PM | 114 | 113.9255161 | 16.84249032 |
| 21 | 05/07/2013 03:31:02.116 PM | 115 | 0 | 73.69717832 |
| 22 | 05/07/2013 03:31:03.117 PM | 116 | 0 | 103.7876924 |
| 23 | 05/07/2013 03:31:04.116 PM | 117 | 0 | 103.9299669 |
| 24 | 05/07/2013 03:31:05.116 PM | 118 | 0 | 103.8632504 |
| 25 | 05/07/2013 03:31:06.116 PM | 119 | 0 | 103.6433291 |
| 26 | 05/07/2013 03:31:07.117 PM | 120 | 0 | 103.8158875 |
| 27 | 05/07/2013 03:31:08.117 PM | 121 | 0 | 103.4732694 |

**Fig.14.** Interruption data logged using MS-Excel Sheet generated using TDMS file format

As can be seen from Fig.14, an interruption occurred at 03:29:07:191 PM on 05/07/2013 when the RMS value of the voltage was less than 23V and persisted for a period of 113.9255161 seconds after which it ceased to exist as the voltage crossed 23.

## IV. CONCLUSIONS

In this project, a data acquisition (DAQ) system for remote monitoring of power quality disturbances has been successfully developed using LabVIEW$^{TM}$ and tested using laboratory experimental setup. Results have been displayed on instrument like front panels on a computer screen, called virtual instruments. Some of the power quality variations such as Total Harmonic Distortion, SINAD have been monitored and also, other system parameters have been measured.

A distinction has been made between different power quality events.

The results have been verified against an existing meters like the Fluke Meter and the Yokogawa Three phase Energy Meter and the values were found to tally. One can conclude that the system is more accurate than the Fluke Meter as the sampling frequency of the analyzer is much higher (up to 50kS/s) than that of the Fluke Meter (up to 10kS).

The developed event logger exhibited accurate and precise logging of power quality events such as voltage interruptions, sags and swells. All the measuring and recording techniques have been developed according to the guidelines of the recent standards defined by IEEE and other reputed international firms.

### *A. Bulb load*

Three bulbs(Incandescent lamps) each rated at 150W have been used, resulting in a total consumption of power close to 450W and a current of nearly 1.80A being drawn from the supply. An incandescent lamp is completely linear in nature. This explains why the power factor is found to be unity or very close to unity and also, the negligible presence of harmonics is justified. The values of the current harmonics observed are very low. Apparent power (KVA) calculated is nearly equal to the active power (KW) with the reactive power (KVAR) being negligible or nearly equal to zero. The current, voltage and power waveforms are found to be perfectly sinusoidal in nature.

### *B. Non linear load(Laptop load)*

A laptop load (Lenovo SL 400c) rated at 65W has been used for analysis. It is observed that it draws a current of 0.22A and consumes power close to 43W. The current THD exceeded 160%, as a result of a high level of individual distortions introduced by the odd harmonics, predominantly 3rd, 5th and 7th as can be seen from the Fig.7. The current contains frequency components that are multiples of the supply frequency and there is a significant decrease in power factor. A change in the shape of the current waveform from a sinusoidal to distort is observed and the current waveform now has spikes. The voltage waveform is completely sinusoidal due to the absence of harmonics.

### *C. Event logging*

The event logging VI enables the user to detect and log the occurrence of different power quality events which can be crucial to the development of preventive and curative measures against the incidence of these events.

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