Power Quality Estimation, Analysis and Improvement for Uninterrupted Power Supply

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Abstract **– With increasing use of power electronics, the amount of harmonics and other power quality problems are increasing in the system. Because of this power quality has been an important topic in the area of research. There are a number of reliability and economic issues with respect to electronic equipment. In such a scenario it is important to study the causes, effects and mitigation technologies for power quality. This problem can be approached by using a DAQ system to gather data on the system and then analyse the collected data. Once power quality analysis is completed appropriate mitigation technique is simulated then implemented. Results from this work demonstrates how to estimate the power quality of a given system and the steps involved in mitigating those issues. The conclusion can be drawn from this work that each mitigation technique has its limitation and they must be kept in mind when designing a system to mitigate power quality issues.**

Keywords **– power quality issues, DAQ system, mitigation technique**

I. INTRODUCTION

Power Quality (PQ) states to the unfailing delivery of electrical energy in a form which enables electrical equipment to perform properly. Since the distortion of electrical power is much more extensive at the load level, it is important to monitor and analyse at the terminals of end users in distribution systems. Typically, some power quality problems are at the point of common coupling (PCC) where several different types of loads are connected. The type of Power quality problems are harmonics, surges, spikes, notches, flickers and so on. These problems exist due to the presence of various disturbances in the system or due to the connection of various non-linear loads such as furnaces, uninterruptable power supplies (UPS) and adjustable speed drives (ASDs). With these in mind the aim of our work to monitor and analyse power quality of uninterrupted power supply.

Power quality issues leads to failure in capacitor banks, increased losses in distribution system and electrical machine, noise, vibrations, over voltages and high currents due to harmonic resonance, flow of -ve sequence currents in generators and motor, specifically rotor heating and derating of wires [1], [2]. Unfortunately, the modern energy-efficient electronically controlled commercial, industrial loads are sensitive to power quality problems and they themselves contribute a large amount of power quality problems due to the presence of solid-state switch controllers within them. In medium and low power rating systems, passive filters are used because of their low cost and simplicity [3], [4].

Power quality is a global problem, and keeping required standards up to date is a continuous process. One of the important developments in the power quality arena is the increased emphasis on coordinating IEEE standards with international standards developed by the International Electro-technical Committee (IEC). Also there are several papers being published in this area [5-7]. Details on how to setup a monitoring system based on lab view to do real time monitoring [1-2]. Another source which helped us greatly is the power quality problems and mitigation techniques and it gives details into design and simulation of different types of filters that can be implemented [4].

II. CIRCUIT ANALYSIS AND METHODOLOGY

PQ monitoring systems consists of both hardware and software components. It has current and voltage sensors. The UPS is connected to load which is 10 computers. Power quality analysis is done with the help of a DAQ system, which collects real time data on the system. Then the data is analysed with the help of national instruments LabVIEW. Once analysis was completed appropriate filter was selected and then simulated with MATLAB/Simulink. Then the simulated filter is implemented. The Fig. 1.1. shows the detailed block diagram of power quality monitoring system.

A PC- based power quality analyser, including a set of instruments in one hardware system, capable of running all instruments in parallel that could easily extended in the future. Measurement and data processing algorithms considered according to the latest IEC and EN standards and had a remote controlled instruments via Ethernet designed rendering to SPIPI standard. Developing a software application using the national instruments LabVIEW graphical development environment to act as the instrument firmware. The current sensor is connected in series with input and voltage sensor is connected in parallel with supply and UPS. This work combines monitoring of power quality of single phase UPS. The data analysis was done on personal computer using national instruments LabVIEW. The input data is 24 bit sampled at 50kS/s.

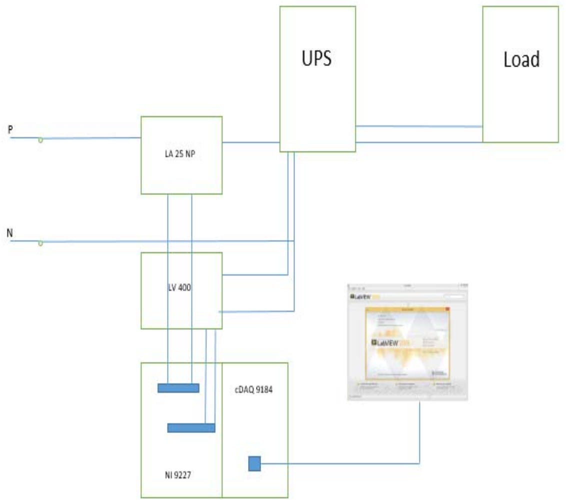

Fig. 1.1. Power Quality Monitoring block diagram

III. SOFTWARE IMPLEMENTATION

LabVIEW 2015 32-bit version along with electrical power suite add-on is used to process and display the data collected from the sensors. The Fig. 1.2. shows the front panel of power quality monitoring VI. As it can have been seen it displays current and voltage waveforms in real time from data collected by sensors. It also has indicators to indicate THD_i, IHD_1, IHD_3, IHD_5, IHD_7, IHD_9, distorted power factor, active power, FFT spectrum of current waveform. It also indicates RMS values of current and voltage with the help of gauges and numeric indicators.

The Fig. 1.2. shows block diagram of the VI used in power quality monitoring. Data from DAQ assistant contains data from all the connected sensors. Therefore, it is split and each signal is multiplied with its corresponding multiplication factor. After that RMS from electrical power suite is used to get RMS waveforms of current and voltage to be used in calculation of active, reactive and apparent power flowing through the system. Amplitude and measurement block is used to determine the RMS values of current and voltage. Spectral measurements block is used for FFT analysis of current waveform. FFT analysis of voltage waveform is not done because voltage waveform appears perfectly sinusoidal without any deviations. Calculation of IHD_n, distortion power factor is explained below.

Once all the required variables are calculated the data is to be stored in an excel sheet. Write to measurement file block only the latest value of input variables. IHD_n calculation is done in a sub VI. IHD value up to 9^{th} harmonic component is calculated. Distortion measurement block is used to calculate specific harmonic current value for each component. Then the specific harmonic current value is divided with specific harmonic current of fundamental to get IHD value.

Initial power quality studies were done on a 1 KVA UPS. Filter was designed for this UPS by including the output transformer of the UPS in the filter circuit in order to mitigate the harmonics in the UPS.

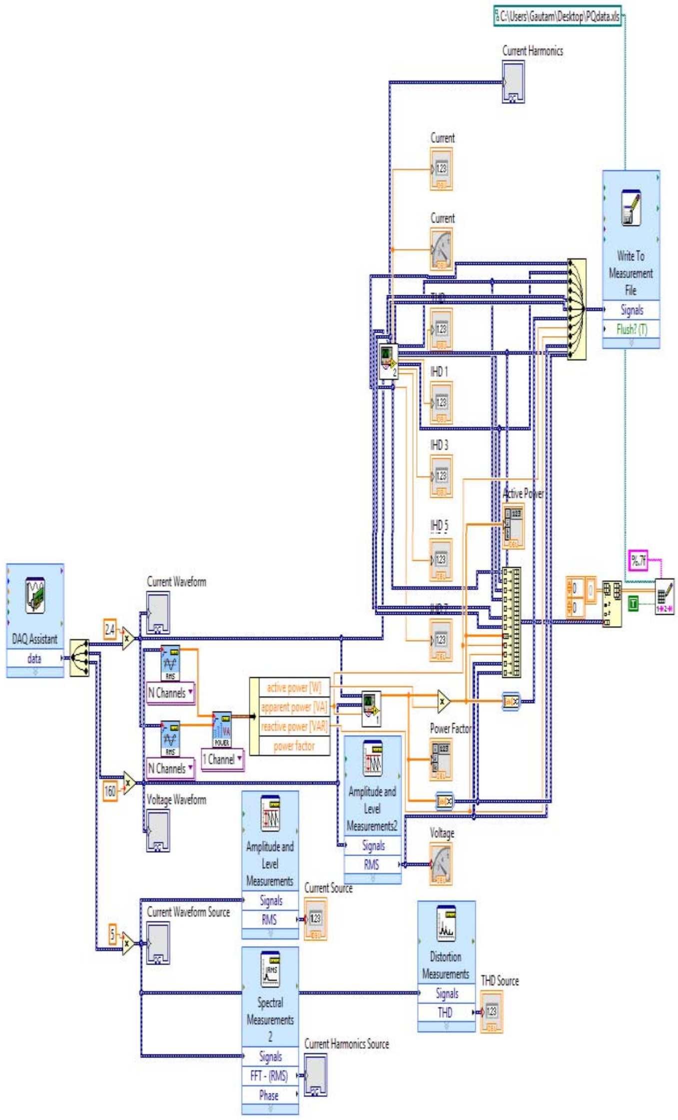

Fig. 1.2. Power Quality monitoring VI block diagram

IV. RESULT ANALYSIS AND DISCUSSIONS

This chapter gives a detailed picture of the power quality analysis carried out on the UPS along with the filter simulation results. When the simulated filter was implemented the power quality study was carried out again. Results of this study are also given below. The power quality monitoring of the load is done in steps of two PC at a time. At each step power quality analysis indices are calculated and monitored.

Figs. 1.3, 1.4, 1.5 shows the current waveform, FFT analysis and voltage waveform with load as 2 systems.

Load: 2 Systems:

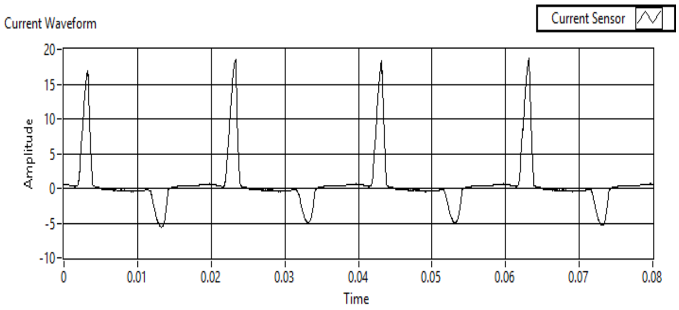

Fig. 1.3. Current Waveform with load as 2 systems.

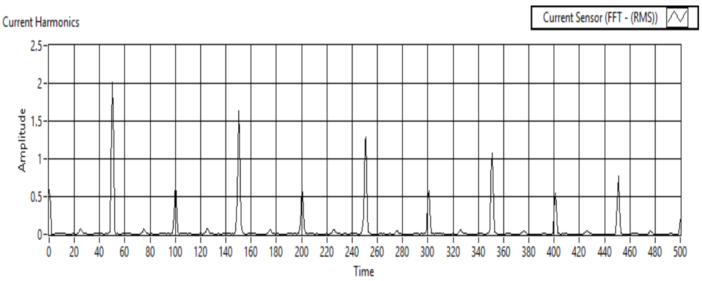

Fig. 1.4. FFT analysis of Harmonic spectrum.

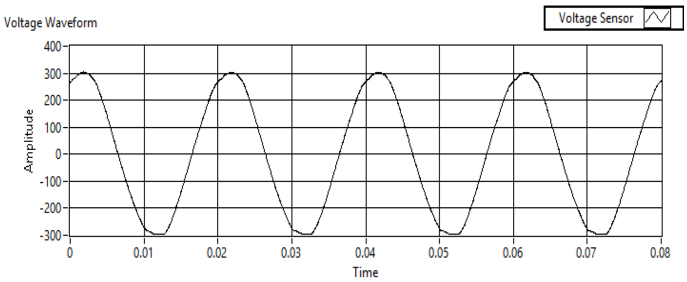

Fig. 1.5. Voltage waveform with load as 2 systems.

Figs. 1.6, 1.7, 1.8 shows the current waveform, FFT analysis and voltage waveform with load as 4 systems.

Load: 4 Systems:

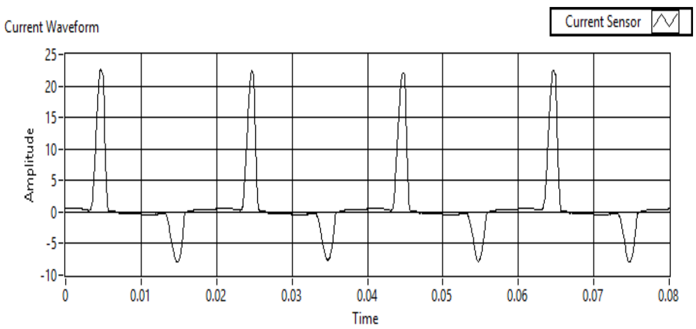

Fig. 1.6. Current waveform with load as 4 systems.

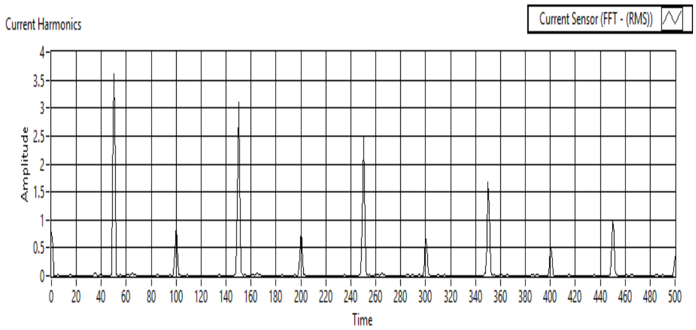

Fig. 1.7. FFT analysis of Harmonic spectrum.

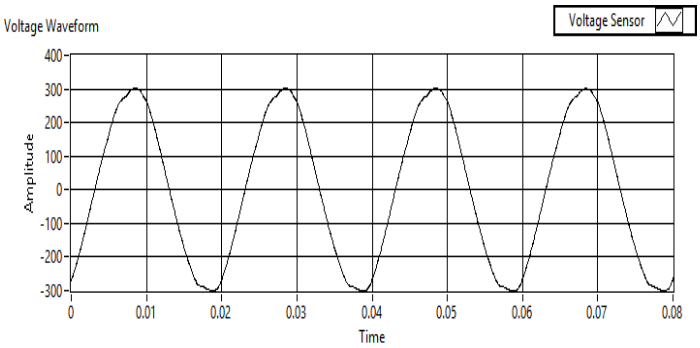

Fig. 1.8. Voltage waveform with load as 4 systems.

Figs. 1.9, 1.10, 1.11 shows the current waveform, FFT analysis and voltage waveform with load as 6 systems.

Load: 6 Systems:

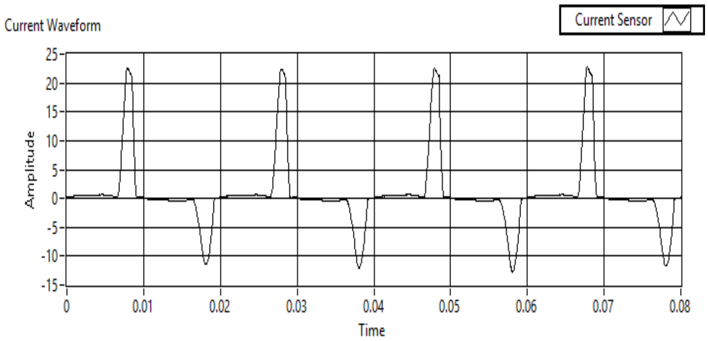

Fig. 1.9. Current Waveform with load as 6 systems.

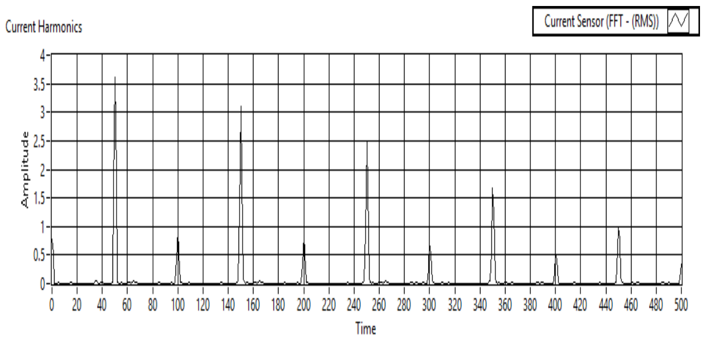

Fig. 1.10. FFT analysis of Harmonic spectrum

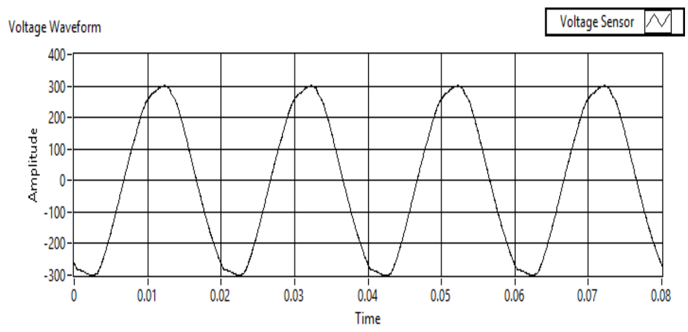

Fig. 1.11. Voltage waveform with load as 6 systems.

Figs. 1.12, 1.13, 1.14 shows the current waveform, FFT analysis and voltage waveform with load as 9 systems.

Load: 9 Systems:

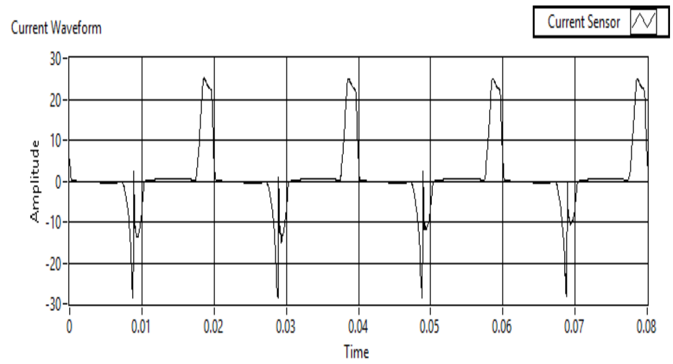

Fig. 1.12. Current Waveform with load as 9 systems.

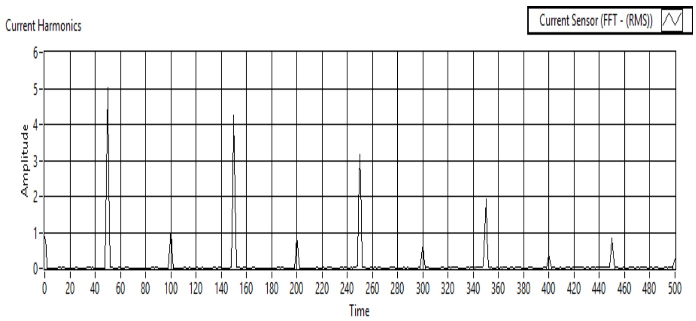

Fig. 1.13. FFT analysis of Harmonic spectrum

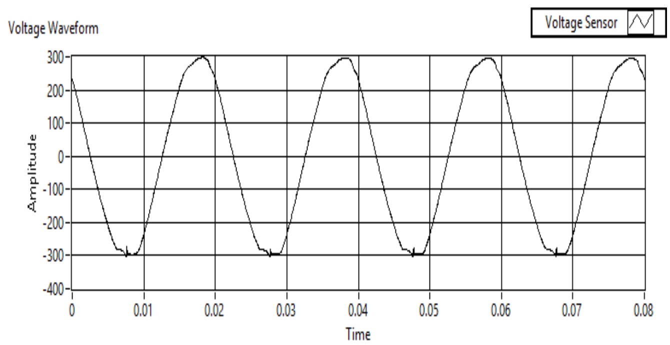

Fig. 1.14. Voltage waveform with load as 9 systems.

Fig. 1.15. shows the variation of IHD3 and IHD5 as the load increases is given below.

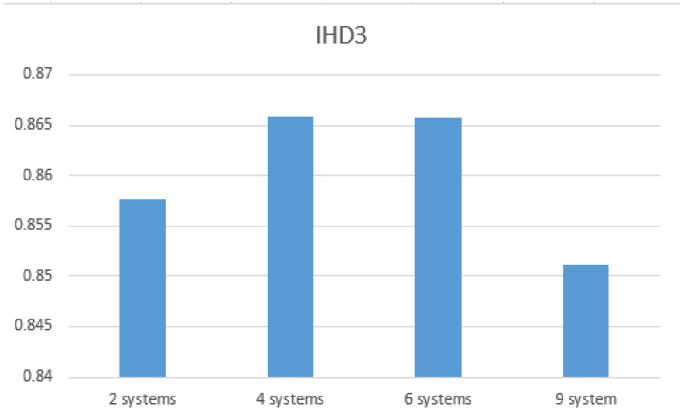

Fig. 1.15. IHD3 variation

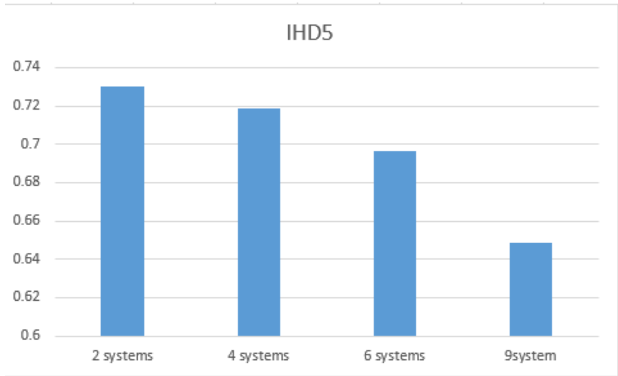

Fig. 1.16. IHD5 variation

V. FILTER IMPLEMENTATION SIMULATION

The Designed filter was simulated using MATLAB/Simulink. Filter used was shunt RLC passive filter.

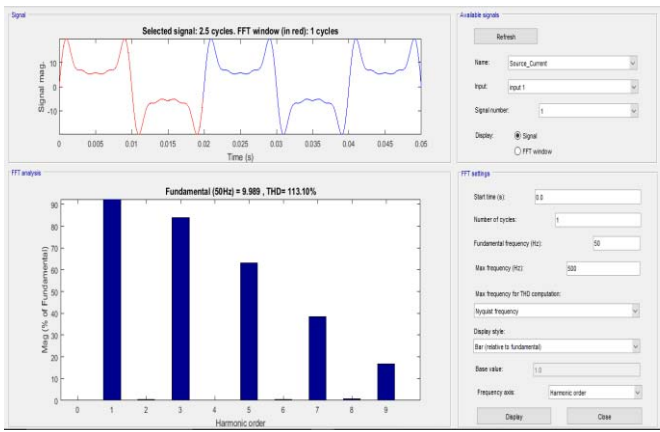

Fig. 1.17. FFT analysis in Matlab

Fig. 1.17. shows the FFT analysis of the system without filter. Dominant harmonics are 3rd and 5th harmonics. THD is at 113.10 %.

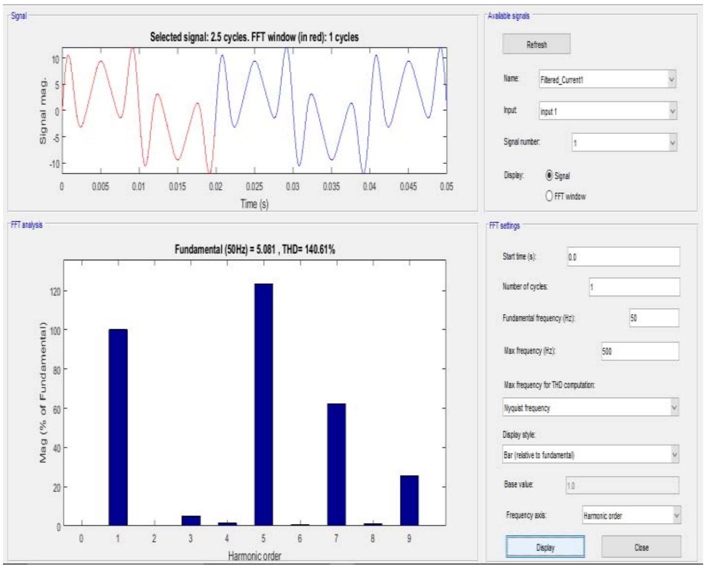

Fig. 1.18. FFT analysis in Matlab with STF for 3rd Harmonic Component.

Fig. 1.18. shows the FFT analysis of the system with single tuned filter for 3rd harmonic component. THD is at 140.61 %. The rise in THD of current is because current is measured in between 3rd and 5th filter branches. The single tuned filter for 5th harmonic component effected the value of THD.

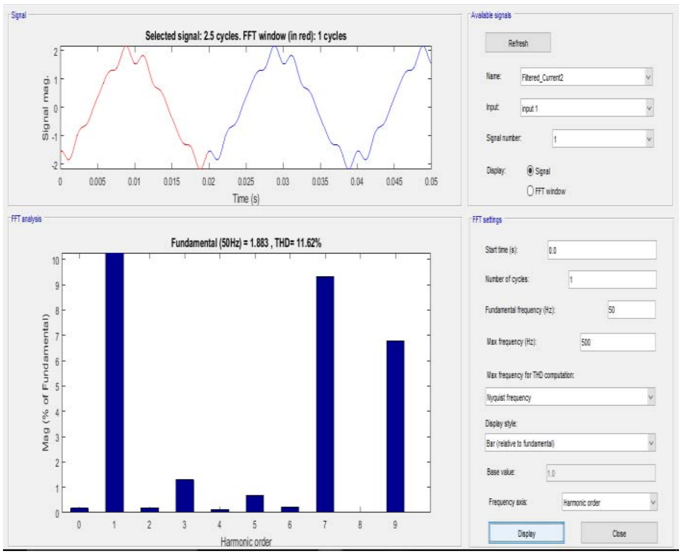

Fig. 1.19. FFT analysis in Matlab with STF for 3rd and 5th Harmonic component.

Fig. 1.19. shows the FFT analysis of the system with single tuned for 3rd harmonic and 5th harmonic components. THD is at 11.62%.

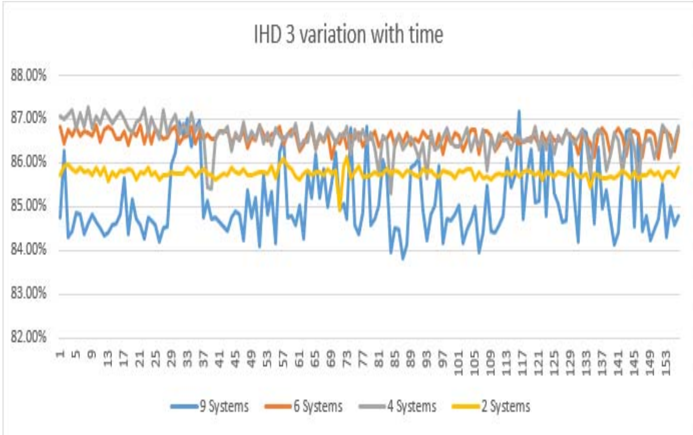

Fig. 1.20. IHD 3 variation with time

Fig. 1.20. shows that when load is small IHD 3 varies very little when compared to system at full load. At full load variation of IHD 3 is by 3 %.

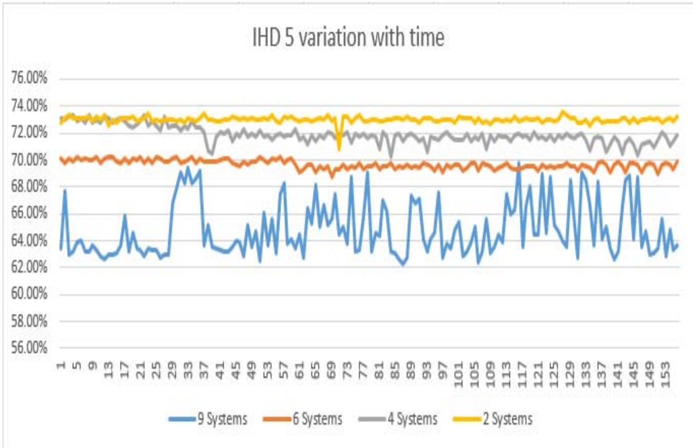

Fig. 1.21. IHD 5 variation with time

Fig. 1.21. shows that when load is small IHD 5 varies very little when compared to system at full load. At full load variation of IHD 5 is by 6 %.

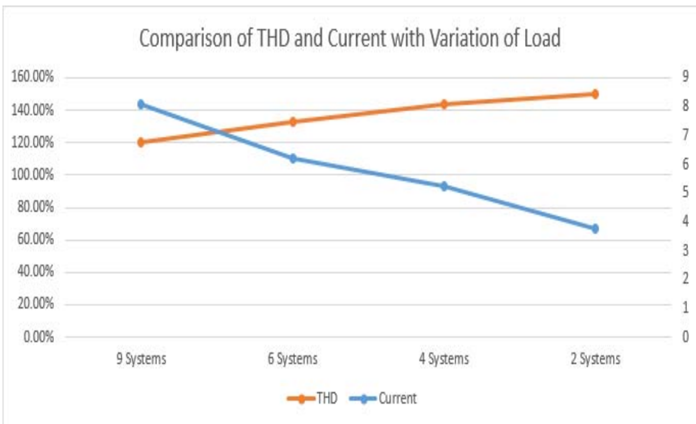

Fig. 1.22. Comparison of THD and Current for different loads

Fig. 1.22. shows comparison of THD and current for different loads as it can be observed from the graph THD value and current are inversely proportional. When the system is at full load current is at maximum and THD is its minimum.

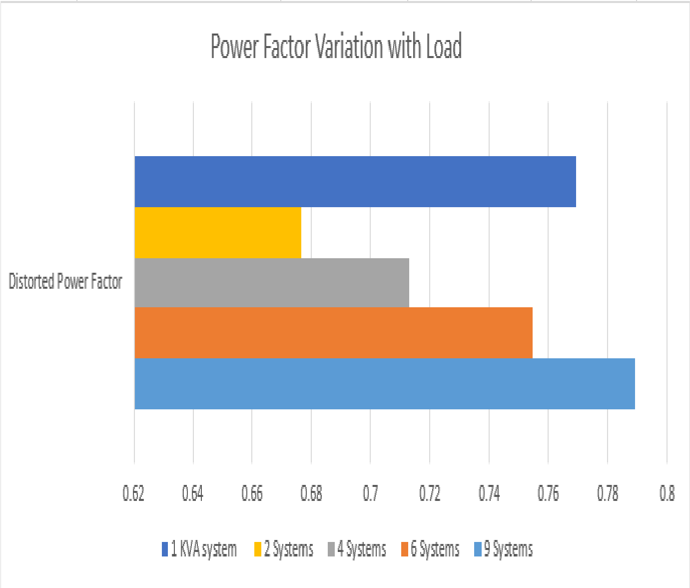

Fig. 1.23. Distorted power factor for different systems.

Fig. 1.23. shows the Power factor variation for different systems can be observed from above graph. As it can be observed even for low 1 KVA system though THD value is lower power factor value for uncompensated system is at same value.

VI. CONCLUSIONS

Power quality analysis on the system is carried out and mitigation techniques required are studied and appropriate method was chosen. Mitigation technique chosen was passive filter. This filter was simulated. Because of the problems that arose during the implementation of mitigation technique a new method of implementation of filter circuit was explored. Filter implementation using output transformer of the UPS was carried out. Limitation of such method is the power rating of the filter. Since the amount of power that can flow through the transformer is fixed during the design of UPS. Additional circuits increase the power flowing through the transformer to exceed its limit. When this limit is exceeding the transformer core starts to vibrate and starts producing noise. This limits the amount of harmonic components or harmonic content that can be removed using this procedure.

Future scope of this work can be implementation of active filters or unified power quality compensators or shunt active compensators. Although this work focuses on low powered system the same principles and methods can be extended to high powered systems and also to 3 phase systems.

REFERENCES

[1] Long-Hua; Qing Fu; Chang-Shu Liu, “Modelling and Control Analysis of a Hybrid Unified”, Power and Energy Engineering Conference, 2009. APPEEC 2009. Asia-Pacific.

[2] Xiyu Liu, “Grounding system of an uninterruptible power system (UPS)”, Telecommunications Energy Conference, 2008. INTELEC 2008. IEEE 30th International

[3] Han Shihong; Liang Jie; Jia Qingquan; Bo Zhiqian,” Development of network based power quality monitoring system”, Advanced Power System Automation and Protection (APAP), 2011 International Conference on (Volume:2)

[4] Bhim Singh, “Power Quality Problems and mitigation techniques”, Wiley, ISBN: 9781118922057.

[5] C. Sankaran, Power Quality, crc press 2001

[6] Dugan, Electrical Power Quality Second edition, Tata McGraw-Hill, 2012

[7] D.A. Paice, Power electronics converter harmonics, IEEE press, 1996