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Power Quality Monitoring and Control Using Virtual Instrumentation System

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This paper presents and develops a LabVIEW based mathematical model for power quality analysis and enhancement. The different types of power quality problems such as voltage sag, voltage swell, power frequency distortions, and harmonic distortions can be identified and controlled suitably. Besides standard undisturbed three-phase voltage signal waveforms, six different categories of the PQ disturbances characteristic for real-time power distribution networks can be simulated on the basis of developed virtual instruments: voltage swells, sags, interruptions, high-order voltage harmonics, swells with harmonics and sags with harmonics. Each of simulated PQ disturbances can be predefined and easily changed according to user requirements, using various combinations of the control settings implemented on the virtual instrument front panel. All computations are carried out using LabVIEW 9.0.

Keywords: *Electric power quality (PQ), Virtual instruments-LabVIEW, Harmonic distortions; Signal Processing, Active power filter (APF).*

1.0 INTRODUCTION

The development that power electronic devices have undergone during the recent years has led to a wide diffusion of nonlinear, time-variant loads both for low-power household appliances, and for industrial applications ranging from low-power, low-voltage systems to high-power, high-voltage applications.

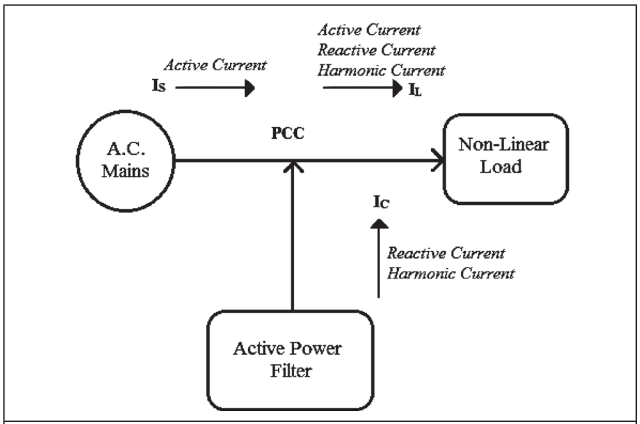

FIG. 1 SHUNT ACTIVE FILTER

The main consequence of such a great increase of this kind of load connected to the electric network is the increase of distortion and disturbances on the current and voltage signals in the electric network. The presence of current and voltage components at other frequencies than the fundamental one and, in three-phase systems, at negative and zero sequences, is harmful to the equipment of the power supply utilities and those of the other customers. All of these phenomena are responsible for the deterioration of power quality, involving both the supply and the loading quality. The active power filter has been proved to be an effective method to mitigate harmonic currents generated by nonlinear loads as well as to compensate reactive power. [Figure 1]

Ref [1] presents an algorithm which restricts the THD and SHD within the specified limits, while optimizing the PF. Ref [2] paper discusses the control strategy of the UPQC, with a focus on the flow of instantaneous active and reactive powers

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inside the UPQC. Ref [3] presents a comprehensive review on the unified power quality conditioner (UPQC) to enhance the electric power quality at distribution levels. Ref [4] introduces a new concept of optimal utilization of a unified power quality conditioner (UPQC). The series inverter of UPQC is controlled to perform simultaneous 1) voltage sag/swell compensation and 2) load reactive power sharing with the shunt inverter. Ref [5] presents a nonlinear control technique for a three-phase shunt active power filter (SAPF). The method provides compensation for reactive, unbalanced, and harmonic load current components.

Ref [6] presents a linear current control scheme for single-phase active power filters. Ref [7] provides a novel signal-processing algorithm for selective harmonic identification based on heterodyning, moving average finite-impulse response filters, and phase-locked loop (PLL). Ref [8] proposes a distributed measuring system to monitor a number of power-quality indices on every load connected to the same point of common coupling, to transmit the measured values to a master device that processes them in order to locate the sources of unbalance and harmonic distortion and to quantify the effects of such disturbances on power quality. Ref [9] describes the concept of virtual instruments used in PC based automatic high voltage measurement and gives the detail of hardware and software requirements for measuring an electrical quantity like voltage or current. Ref [10] proposed adaptive shunt active filters can compensate for harmonic currents, power factor and nonlinear load.

The aim of the present work is to develop an application in virtual instrumentation using LabVIEW to simulate and measure the voltage waveform disturbances and distortions in the form of harmonics, noise and impulsive transients etc. on front panel like computer screens.

2.0 MODELLING FOR POWER QUALITY ANALYSIS AND ENHANCEMENT

To provide a balance, distortion-free, and constant magnitude power to sensitive load and, at the same time, to restrict the harmonic, unbalance, and reactive power demanded by the load and hence to make the overall power distribution system more healthy, the unified power quality conditioner (UPQC) is one of the best solutions.

Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source.

2.1 Operation of UPQC

Step 1: obtaining balanced voltage at load terminals. The system (utility) voltage can be expressed as,

$$v_s(t) = v_{s+}(t) + v_{s-}(t) + v_{s0}(t) + \sum v_{sh}(t) \qquad ....(1)$$

Usually the voltage at the load at PCC is expected to be sinusoidal with a fixed amplitude V_l,

$$v_l(t) = V_l \sin(\omega t + f_+) \qquad ....(2)$$

Hence the series converter will need to compensate for the following components of voltage,

$$v_c(t) = v_l(t) - v_s(t)$$

$$v_c(t) = (v_l - v_{s+})\sin(\omega t + f_+) - v_{s-}(t) - v_{s0}(t) - \sum v_{sh}(t) \qquad ....(3)$$

Step 2: obtaining balanced system currents through the feeder

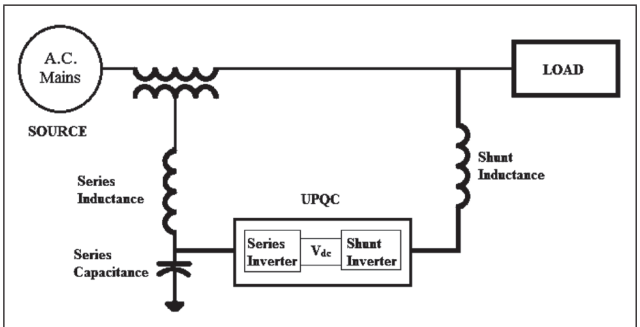

FIG. 2 BASIC CONFIGURATION OF UPQC

$$i_l(t) = i_{l+}(t) + i_{l-}(t) + i_{l0}(t) + \sum i_{lh}(t) \qquad ....(4)$$

$$
\begin{aligned}
i_{l+}(t) &= I_{l+}\sin(\omega t+\delta_{+})\\
i_{l-}(t) &= I_{l-}\sin(\omega t+\delta_{-})\\
i_{l0}(t) &= I_{l0}\sin(\omega t+\delta_{0})
\end{aligned} \quad ....(5)
$$

$$\Sigma i_{lh}(t) = \Sigma i_{lh}\sin(h\omega t+\delta_{h}) \quad ....(6)$$

$\delta_{+}, \delta_{-}, \delta_{0}, \delta_{h}$ are the phase angles of corresponding currents. The shunt converter is supposed to provide compensation of the load harmonic current to reduce current distortion. It should act as a controlled current source to nullify the magnitudes of negative, zero and harmonic components.

$$\delta_{+} = \theta_{1} + f_{+}$$

$$i_{l}(t) = I_{l+}\sin(\omega t + f_{+} + \theta_{1}) + I_{l-}\sin(\omega t+\delta_{-}) + I_{l0}\sin(\omega t+\delta_{0}) + \Sigma i_{lh}\sin(h\omega t+\delta_{h}) \quad ....(7)$$

$$
\begin{aligned}
i_{l}(t) &= I_{l+}\sin(\omega t + f_{+})\cos\theta_{1} + I_{l+}\cos(\omega t+f_{+})\sin\theta_{1}\\
&\quad + I_{l-}\sin(\omega t+\delta_{-}) + I_{l0}\sin(\omega t+\delta_{0}) + \Sigma i_{lh}\sin(h\omega t+\delta_{h})
\end{aligned} \quad ....(8)
$$

It's clear that the output of the shunt converter should be controlled and must assume the wave shape, as specified by (2) , (3) , (4) , (5) terms of equation.

$$
\begin{aligned}
i_{l}(t) &= -I_{l+}\cos(\omega t + f_{+})\sin\theta_{1} + I_{l-}\sin(\omega t+\delta_{-})\\
&\quad + I_{l0}\sin(\omega t+\delta_{0}) + \Sigma i_{lh}\sin(h\omega t+\delta_{h})
\end{aligned} \quad ....(9)
$$

$$
\begin{aligned}
i_{s}(t) &= i_{l}(t) - i_{c}(t)\\
i_{s}(t) &= I_{l+}\sin(\omega t + f_{+})\cos\theta_{1}
\end{aligned} \quad ....(10)
$$

UPQC is employed in a power distribution system, to perform the shunt and series compensation simultaneously which improve the PQ, offered for other harmonic sensitive loads at the point of common coupling (PCC).

A power distribution system may contain dc components, distortion, and unbalance both in voltages and currents. The main purpose of a UPQC is to compensate for supply voltage power quality issues, such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems, such as, harmonics, unbalance, reactive current, and neutral current by performing shunt and / or series compensation. Figure 2 shows a single-line representation of the UPQC system configuration with series and shunt APFs.

3.0 IMPLEMENTATION IN LabVIEW

LabVIEW based graphical programming environments are currently used widely for data acquisition and control. This program allows the user to interface with the digital hardware module to analyze the waveforms of voltage and current signals simultaneously.

3.1 Harmonic Analysis on LabVIEW

The harmonic simulation programming VI in the LabVIEW platform (Block Diagram) is shown in Figure 3. Distortion sine wave is generated by odd harmonic signals superposition.

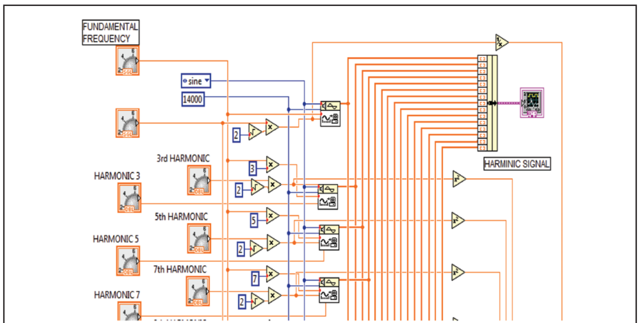

FIG. 3 BLOCK DIAGRAM OF LABVIEW SHOWING GENERATION OF VOLTAGE WAVEFORM WITH HARMONICS

3.2 Modelling of Shunt Active Filter

Shunt active power filter compensate current harmonics by injecting equal-but-opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180^{0}. The current compensation characteristic of the shunt active power filter is shown in Figure 4.

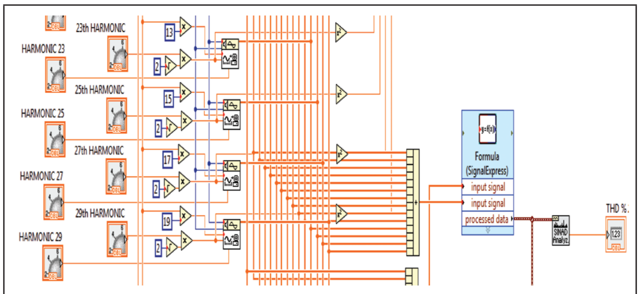

FIG. 4 BLOCK DIAGRAM OF LABVIEW SHOWING MODELLING OF SHUNT ACTIVE FILTER (UPQC)

4.0 SIMULATION RESULTS

Figure 5 displays the voltage harmonics in the system without the inclusion of UPQC in the network.

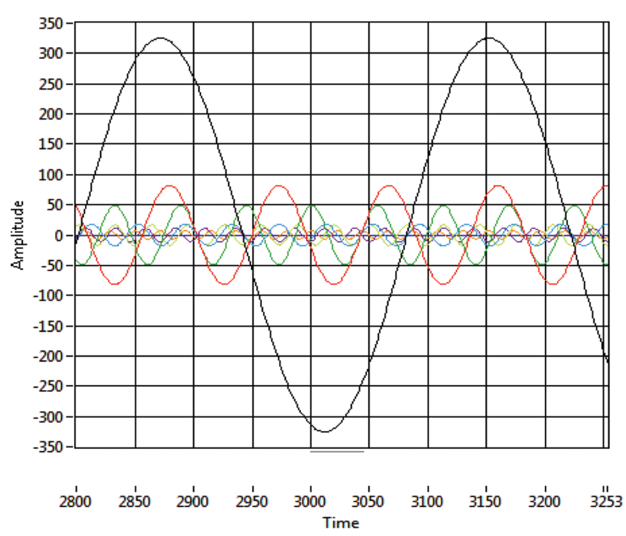

FIG. 5 FRONT PANEL OF LABVIEW SHOWING VOLTAGE HARMONICS

Figure 6 displays the voltage waveforms with and without the injection of UPQC.

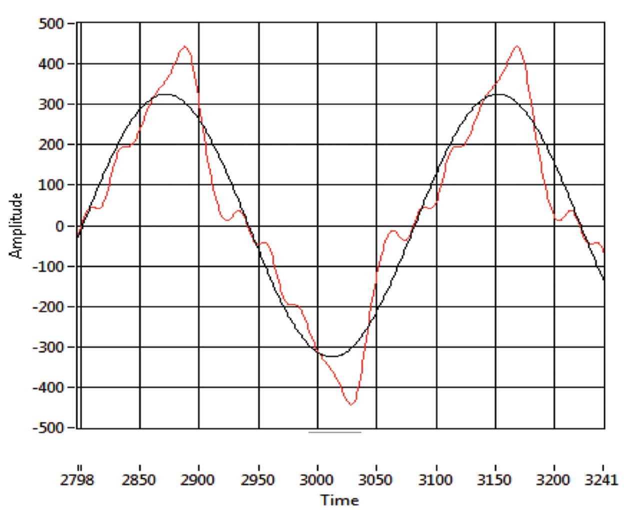

FIG. 6 FRONT PANEL OF LABVIEW SHOWING VOLTAGE WAVEFORMS WITH AND WITHOUT UPQC

Usually, voltage sources in power system are sinusoidal waveform. Nonlinear loads cause voltage waveform distortion.

To describe power quality of power system, THD (Total harmonic Distortion) is an important index widely used. It considers the contribution of every individual harmonic component on the signal. It's defined for voltage and current signal as,

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \qquad ....(11)$$

THD% content before and after the injection of voltage from UPQC is given in the Table 1.

TABLE 1		
HD% CONTENT		
THD%	without UPQC	with UPQC
	25.914	4.19661

5.0 CONCLUSION

Power quality monitoring has traditionally been used for problem solving in industrial, commercial and residential systems. It is becoming an integral part of overall system performance assessment. A basic PQ system will monitor the voltages and currents waveforms, transients, glitches, sags and swells, distortions, frequency deviations etc. in a given system. It may also monitor the voltages and currents on the neutral line if imbalanced loads or harmonics are suspected. Power quality monitoring and power metering will allow the industry to perform predictive maintenance, energy management, cost management, and quality control.

Today's instrument control using PC bus technology has revolutionized the measurement and monitoring systems. This has turned down the need of analog / digital instrumentation and monitoring in which system is monitored at various locations and analysis of gathered data is tedious and time consuming. Use of virtual instrumentation for the measurement and monitoring of power system improves the performance and reliability of the system. Virtual instrumentation can save extra cost, time and energy that are incurred while setting up of traditional instrumentation system.

In modern industries, electrical power quality problems are becoming the matter of serious concern, as modern equipments are prone to even small variations of PQ indices. In the paper, one aspect of power quality, i.e. power waveform distortions have been discussed. Also these distortions have been simulated and measured with the help of virtual instrumentation.

It is a latest measurement / monitoring technology where all types of measurements are done on front panel created on PC screen. In real situations, data can be collected with the help of digital acquisition technique and given to PC through specific interfacing devices. Then this raw data can be processed or analyzed by using VI software, LabVIEW. It is powerful VI software, which can acquire, analyze and present any electrical signal efficiently. This can be very helpful for studying, measuring, analyzing and controlling of power waveforms and to avoid their harmful effects.

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REFERENCES

[1] Sincy George, Vivek Agarwal, Optimum Control of Selective and Total Harmonic Distortion in Current and Voltage under Non-sinusoidal Conditions" IEEE Trans On Power Delivery, Vol. 23, NO. 2, pp. 937-944, 2008.

[2] Hideaki Fujita, Member, IEEE, and Hirofumi Akagi, The Unified Power Quality Conditioner: The Integration of Series- and Shunt-Active Filters, IEEE Trans On Power Electronics, Vol. 13, No. 2, pp. 315-322, 1998.

[3] Vinod Khadkikar, Enhancing Electric Power Quality Using UPQC: A Comprehensive Overview, IEEE Trans.on Power Electronics, Vol. 27, No. 5, pp. 2284-2297, 2012.

[4] Vinod Khadkikar, and Ambrish Chandra, UPQC-S, A Novel concept of Simultaneous Voltage Sag/Swell and Load Reactive Power Compensations Utilizing Series Inverter of UPQC, IEEE Trans. on Power Electronics, Vol. 26, No. 9, pp. 2414-2425, 2011.

[5] Salem Brahman, Nassar Mendalek, and Kamal Al-Haddad, Experimental Design of a Nonlinear Control Technique for Three-Phase Shunt Active Power Filter, IEEE Transactions on Industrial Electronics, Vol. 57, No. 10, pp. 3364-3375, 2010.

[6] Jaume Miret, Member, IEEE, Miguel Castilla, José Matas,Joseph M. Guerrero, Juan C. Vasquez, Selective Harmonic-Compensation Control for Single-Phase Active Power Filter with High Harmonic Rejection, IEEE Trans. on Industrial Electronics, Vol. 56, No. 8, pp. 3117-3126, 2009.

[7] Francisco D. Freijedo, Jesús Doval-Gandoy, Óscar Lopez, Pablo Fernández-Comesaña, and Carlos Martinez-Peñalver, Member, A Signal-Processing Adaptive Algorithm for Selective Current Harmonic Cancellation in Active Power Filters, IEEE Transactions on Industrial Electronics, Vol. 56, No. 8, pp. 2829-2840 , 2009.

[8] Loredana Cristaldi, Alessandro Ferrero, Simona Salicone, A Distributed System for Electric Power Quality Measurement" IEEE Trans. on Instrumentation and Measurement, Vol. 51, No. 4, pp. 776-781, 2002.

[9] C. Zang, Y. Wen, Hao wu, IEEE Transmission and Distribution Conference, pp. 2300-2304, 2002.

[10] L. H. Tey,P.L.So, Y. C. Chu, Improvement of Power Quality Using Adaptive Shunt Active Filter, IEEE Trans. on Power Delivery, Vol. 20, No. 2, pp. 1558-1568, 2005.