

MEASUREMENT AND ANALYSIS OF POWER QUALITY DISTURBANCES USING LABVIEW

L.P.SINGH S.S.DESWAL

A. P., EEE Deptt.

Maharaja Agrasen Institute of Tech., Sec-22, Rohini, Delhi, India

singh_lp73@yahoo.com

S. P. JAIN

Prof., EE Deptt.

NIT, Kurukshetra, Haryana, India

jainsp@rediffmail.com

D. K. JAIN

Prof., EE Deptt.

DCRUST, Murthal, Haryana, India

jaindk66@gmail.com

Abstract: *Maintaining and improving standards of living as well as development of industries require a constant supply of energy. This motivates creation of new kinds of measurement systems allowing evaluation of problems related to quality of electricity. One of the most important issues that need to be addressed is the electric power quality. This paper describes an implementation method of a virtual instrument, with user-friendly GUI, for generation of disturbances which affect power quality, in Lab View environment, using as hardware component a data acquisition board, for the research of these various disturbances.*

Key words: *Power Quality; Voltage Sag; LabView; Power Quality Evaluation; measurement.*

1. Introduction

The International Electrotechnical Commission's (IEC) definition of power quality is; however different, 'Characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters.

Power quality is combination of voltage quality and current quality. Voltage quality is concerned with deviations of the actual voltage from the ideal voltage. The ideal voltage is defined as sinusoidal voltage waveform with constant amplitude and frequency, equal to their nominal values. The ideal current is defined in similar way, as sinusoidal current waveform with constant amplitude and frequency. Additionally, the frequency and phase of the current waveform should be equal to the frequency and phase of voltage. Power quality disturbance, according to Bollen, is a deviation of voltage or current from ideal. It can be a voltage or a current disturbance. An important division of power quality systems, often used in power quality monitoring systems, is between variations and events. Variations are steady-state or quasi-steady-state

disturbances that require continuous measurements. Events are sudden disturbances with beginning and ending [1-3].

Modern power quality monitoring systems provide a tremendous volume of raw data, about various phenomenon's with parameters values which can vary in wide ranges, difficult to analyze [4]. For this reason are preferred automated analysis systems. The development of systems presumes an interdisciplinary research [5], it is necessary a link between power engineering, electromagnetic compatibility (power quality problems can arise from the incompatibility between power supply system and the customer equipment or the latter can produce disturbances in power supply system) and signal processing, for extraction of specific information's from raw data in a few stages: identification, classification and characterization, using various techniques in function of signal characteristics.

In Lab VIEW environment can be developed power quality monitoring systems using virtual instruments, which are in fact data acquisition systems and use various signal processing methods for extraction of desired information's about disturbances. Supplementary it can be developed a disturbances generator for their testing; this thing is the objective of the paper. The development of virtual instruments requires a shorter time and can be understood by a non-programmer. The virtual instruments are very flexible because are based on software and personal computers hardware, so are beneficiaries of new technologies performances which have an ascendant evolution and the effects are increase performances and efficiency and decrease of costs. Their functions are selected by users and can be extended or modified after user's desires, in contrast with traditional instrumentations (multimeters, oscilloscopes etc.), where the functions are vendor defined by hardware structure of the instrument and can not be changed.

2. Interest in Power Quality

In recent years, there has been an enormous increase of interest in Power Quality. According to Bollen [6-7], there are several reasons for that:

Companies become less tolerant to any production stoppages and also more aware of their right to have good quality power. At the same time the production processes have become less tolerant to incorrect operation of equipment and the equipment has become less tolerant to any voltage disturbances. Even small disturbance in electric power grid can cause high costs for a company.

There are more electronic systems used nowadays and this number still grows. Electronic frequency converters are being used in both low- and high-power equipment. These converters are known to produce harmonic distortion which becomes more visible in the power grids nowadays. It has been also noticed that the harmonic content in electric grid changes from low harmonics, like third, fifth, seventh to much higher harmonics with ranges of one-two kilohertz. This is caused by introducing new power converters with much shorter switching times. Their number grows compared to number of rectifiers, which are known to produce low frequency harmonic content and were extensively used in the past.

Deregulation of the electricity industry has resulted in increased need for power quality indicators. Consumers are no longer willing to pay for 'any' electricity. Instead, they demand more information about the product they buy. Utilities have to treat consumers as customers and electricity as a product, which has to be measured, predicted, guaranteed and constantly improved.

The increased utilization of renewable energy sources and distributed generation introduced new problems to power quality. The most common ones are voltage variations, flicker, and waveform distortion.[8-12]

3. Overview of Power Quality Phenomena

Power quality can be expressed in terms of physical characteristics and properties of electricity. It is most often described in terms of voltage, frequency and interruptions. The quality of the voltage must fulfill requirements stipulated in national and international standards. In these standards, voltage disturbances are subdivided into voltage variations, flicker, transients and harmonic distortion. Fig.1 shows different power quality phenomena. [13-16]

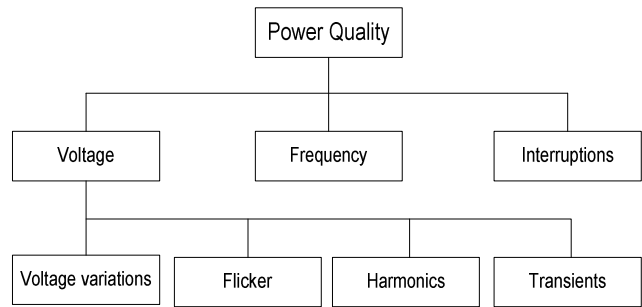


Fig 1. Different power quality phenomena.

a) Transients

Potentially the most damaging type of power disturbance, transients fall into two subcategories:

(i) Impulsive

Impulsive transients are sudden high peak events that raise the voltage and/or current levels in either a positive or a negative direction. These types of events can be categorized further by the speed at which they occur (fast, medium, and slow). Impulsive transients can be very fast events of short-term duration as shown in Fig 2

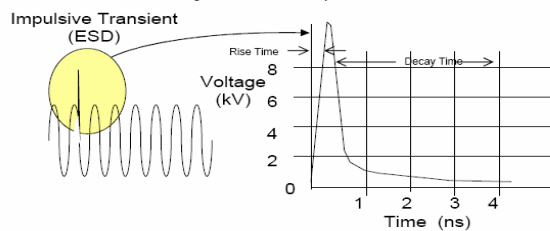


Fig 2. Impulsive Transient.

(ii) Oscillatory

An oscillatory transient is a sudden change in the steady-state condition of a signal's voltage, current, or both, at both the positive and negative signal limits; Oscillatory transients usually decay to zero within a cycle as shown in Fig 3.

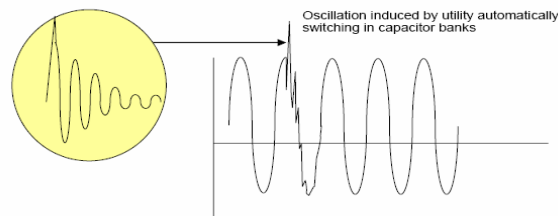


Fig 3. Power Quality Issue: Oscillatory transient

b) Interruptions

An interruption as shown in Fig. 4 is defined as the complete loss of supply voltage or load current. Depending on its duration, an interruption is

categorized as instantaneous, momentary, temporary, or sustained.

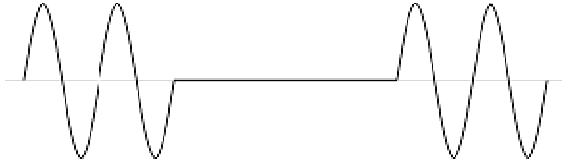


Fig 4. Power Quality Issue: Momentary Interruption

c) Voltage Sag

A voltage sag as shown in Fig 5 is a reduction of AC voltage at a given frequency for the duration of 0.5 cycles to 1 minute's time. Common causes of sags include system faults, starting large loads and remote fault clearing performed by utility equipment.



Fig 5. Power Quality Issue: Voltage Sag

d) Voltage Swell

A voltage swell as shown in Fig . 6, is the reverse form of a sag, having an increase in AC voltage for a duration of 0.5 cycles to 1 minute's time. For swells, high-impedance neutral connections, sudden load (especially large) reductions, and a single-phase fault on a three-phase system are common sources. The result can be data errors, flickering of lights, degradation of electrical contacts, semiconductor damage in electronics, and insulation degradation.

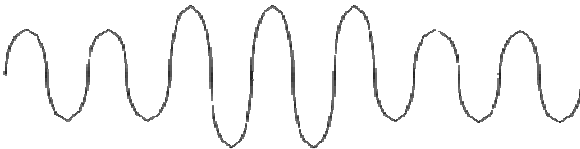


Fig 6. Power Quality Issue: VoltageSwell

e) Common Waveform Distortion

(i) DC offset

Direct current (dc) can be induced into an ac distribution system, often due to failure of rectifiers within the many ac to dc conversion technologies that have proliferated modern equipment. A dc offset is shown in Fig 7.

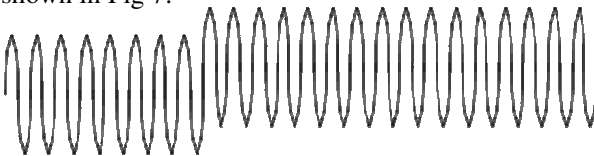


Fig 7. Power Quality Issue: DC Offset

(ii) Harmonics

Harmonic distortion as shown in Fig 8 is the corruption of the fundamental sine wave at frequencies that are multiples of the fundamental.



Fig 8. Power Quality Issue: Typical harmonic waveform distortion

(iii) Noise

Noise as shown in Fig 9 is unwanted voltage or current superimposed on the power system voltage or current waveform. Noise can be generated by power electronic devices, control circuits, arc welders, switching power supplies, radio transmitters and so on.

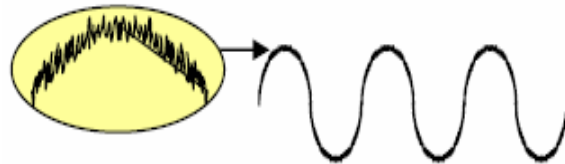


Fig 9. Power Quality Issue: Noise

f) Voltage Fluctuations

A Voltage fluctuation is as shown in Fig 10 is a systematic variation of the voltage waveform or a series of random voltage changes, of small dimensions. Any load exhibiting significant current variations can cause voltage fluctuations.



Fig 10. Power Quality Issue: Voltage fluctuations

g) Frequency Variations

Frequency variation as shown in Fig 11 is extremely rare in stable utility power systems, especially systems interconnected via a power grid.



Fig 11. Power Quality Issue: Frequency Variations

h) Voltage Unbalance

Voltage unbalance is when supplied voltages are not equal. While these problems can be caused by external utility supply, the common source of voltage unbalances is internal, and caused by facility loads.

More specifically, this is known to occur in three phase power distribution systems where one of the legs is supplying power to single phase equipment, while the system is also supplying power to three phase loads.

4. LabView environment

This section describes briefly the programming environment used for creating the measurement system. The main features of the software will be shown with their relation to the created system. LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a platform and development environment for a visual programming language from National Instruments. It is a graphical language designed for engineers and scientists and quite unique in the method by which code is constructed and saved. There is no text-based code as such, but a diagrammatic view of how the data flows through the program. It is simple and used for creating custom measurement and automation applications. A LabView program is called virtual instrument, or VI, and consists of two major components: a block diagram where the code is developed and a user interface where the objects like graphs, knobs and buttons can be used and customized. The programming is done by wiring together functional blocks. Each block has a specific function to perform, a set of inputs and outputs. The output of one block is connected to the input of another by a wire. A wire creates a path for transferring data between blocks. The order of execution is determined by the movement of data through the wires. LabView, in theory, supports parallel execution of code. The LabView environment contains pre-installed drivers for a variety of measurement devices. The configuration of devices is in most cases done without user help. LabView handles the acquisition of data automatically, based on the guidelines given by the user in dedicated software called Measurements and Automation. In this software user is able to choose and synchronize used hardware and create measurement tasks. A task is a predefined configuration setting for a specific device. The settings can also be passed to the device directly from a VI. The advantage of LabView lies not only in the graphical programming language, but mostly in the whole environment around the language, developed through recent years. LabView can be used on platforms such as Windows, Linux, Mac OS10, real-time and embedded operating systems.

Storage of measurement data

The created system measures and evaluates the voltage waveforms in terms of different disturbances and stores the data on the disk of a PC. The data can be stored in different ways, as for example in a database or in a dedicated file. Creation of a dedicated database would be time consuming and was not a part of specifications for the paper. It was therefore decided to store data in a set of files, according to the aggregation times. The advantages of that solution are the

simplicity of code and easiness of data transfer between computers.

The power quality can be divided into voltage quality and current quality and it is sometimes difficult to distinguish between voltage and current disturbances because any change in one implies the change in the other. That was the basis on which the decision was made that it is sufficient, to create the measurement system of only voltage disturbances. It is possible in the future to extend the capabilities of the system by measuring current signal and adding modules responsible for finding current disturbances. This would be relatively simple as most of the measurement methods used for finding voltage disturbances can be directly used to find corresponding current disturbances.

The system measures the voltage at three phases, shows the parameters of the waveform and evaluates the signal in terms of Unbalance, Dips, swells and interruptions

5. Measurement Methodology

The measurement system contains LabView based software used for evaluation of voltage disturbances, data aggregation and storage and a hardware used for measuring and conditioning the signal. Fig. 12 shows the system's measurement chain.

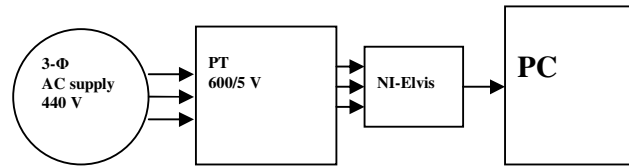


Fig 12. Three-Phase voltage measurement system.

The system is connected to low voltage grid, 440Vrms. The measurement board has input of $\pm 5V$. It is therefore needed to step down the voltage from 440Vrms to 5V. To measure the voltages, voltage transformers were used with voltage ratio:

$$Ratio = \frac{Max.Voltage\ Primary\ side\ (V)}{Max.Voltage\ Secondary\ side(V)} = \frac{600}{5}$$

The output of measurement transformers is a voltage of amplitude less than $\pm 5V$, which is then fed into the National Instrument (NI) data acquisition board, PCI6143, using I/O connector block, NI CB-68LP, and noise-rejecting shielded cable, NI SHC 68-68EP. The brief specification of the board is shown below. For full specification refer to .

- 8 differential 16-bit analog inputs
- 250 kS/s per channel analog input
- Simultaneous sampling
- 8 digital I/O lines (5 V TTL/CMOS);
- two 24-bit counter/timers
- Digital triggering
- $\pm 5 V$ analog input signal range
- Operating Systems: Windows 2000/NT/XP,

Mac OS X, Linux

The most important advantages of the board are the simultaneous sampling and the presence of timers/counters. Simultaneous sampling is done by utilization of eight separate analogue-to-digital converters. It assures that data is taken at exact the same time at all measurement channels and therefore prevents misalignment of the measured waveforms. The counters on the board were used for controlling the board's sampling rate. That allowed to dynamically adjusting the sampling rate relative to the power system frequency. The sampling rate of the board is variable and depends on power frequency and is set to 6400 samples per second for 50 Hz.

The sampling frequency should be at least two times greater then the biggest harmonic frequency to be measured. According to the standard the measurement instrument should be able to record harmonic frequencies to at least 50th, what gives the sampling rate of at least 5000Hz. Higher harmonics should be attenuated by an anti-aliasing filter.

6. Proposed Measurement System And Results

NI ELVIS and NI DAQ card is used by the investigator. But any compatible DAQ card can be used with this software. The NI ELVIS receives real time voltage and current data from voltage transformer and current transformer respectively. Then by using DAQ card this data is given to the software input (Fig. 13). Then it starts giving real time voltage component, current component, power and energy component .

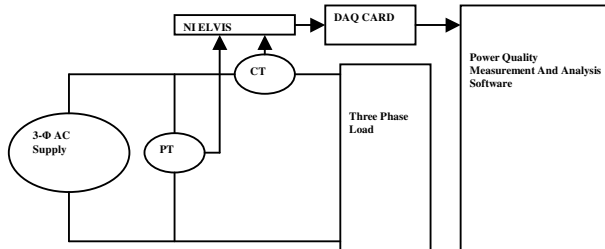


Fig 13. Proposed Mesurement Technique

The experiment have been carried out to get the traces of three-phase source voltages (V_{sry} , V_{syb} , V_{sbr}) during various power quality disturbances such as voltage sag, swell, interruption and voltage unbalance.

The steady state experimental results are shown in Fig. 14 to Fig. 18 under normal and abnormal conditions. The symmetrical fault was created using three-phase fault block wherein all the three-phases were grounded with a small fault resistance of 0.001 ohms for 28 cycles leading to symmetrical voltage sag of 60%.

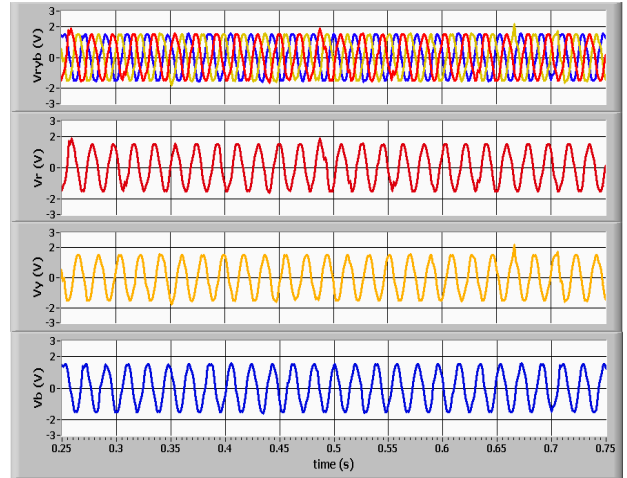


Fig 14. Experimental results showing three-phase source voltages during Normal operating condition, Voltage scale: 100 V per division.

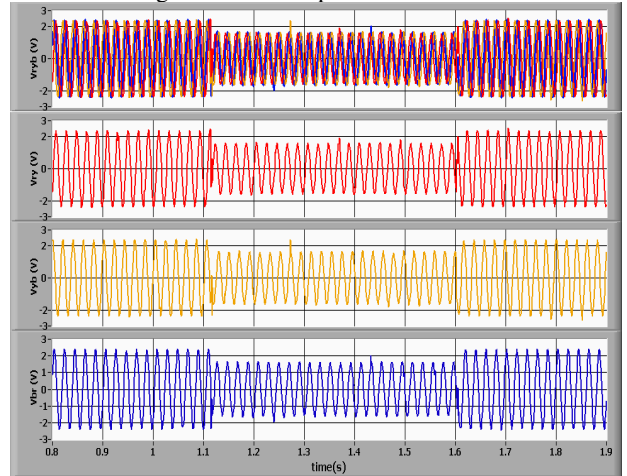


Fig 15. Experimental results showing three-phase source voltages during voltage sag condition, Voltage scale: 100 V per division.

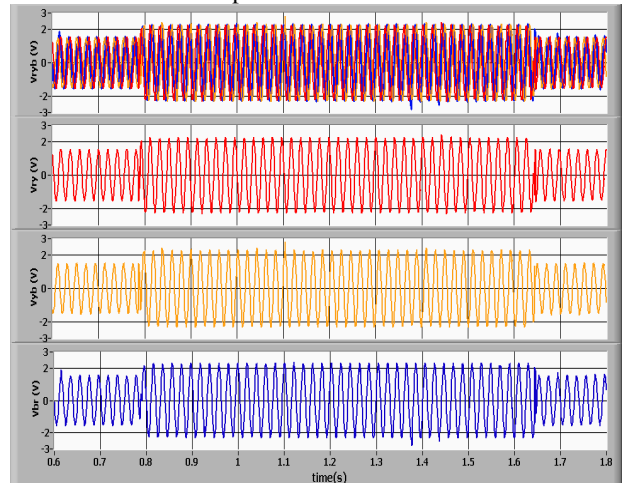


Fig 16. Experimental results showing three-phase source voltages during voltage swell condition, Voltage scale: 100 V per division

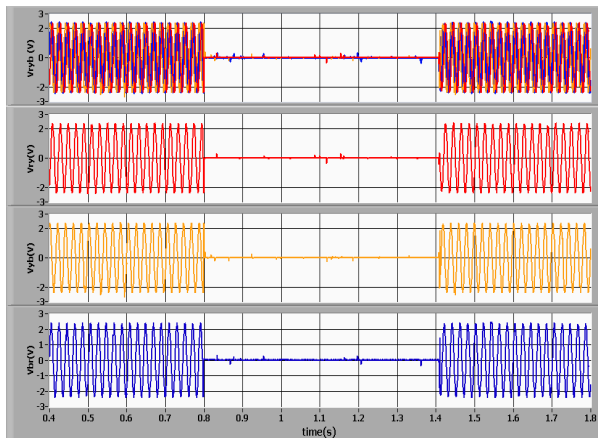


Fig 17. Experimental results showing three-phase source voltages during voltage interruption condition, Voltage scale: 100 V per division

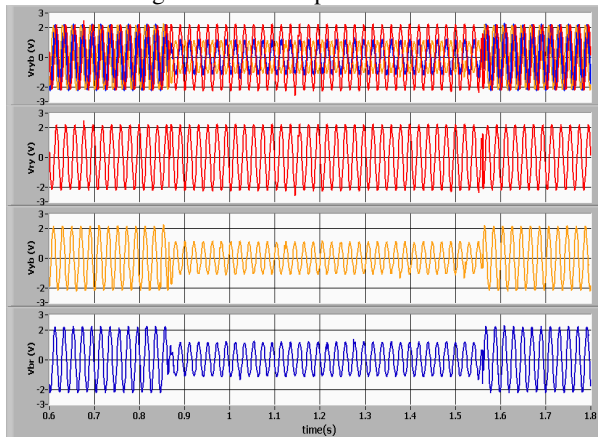


Fig 18. Experimental results showing three-phase source voltages during voltage unbalance condition, Voltage scale: 100 V per division.

7. Conclusion

Software controlled procedure for classification and generation of the typical power quality disturbances, is presented in this paper. Generation procedure is functionally based on the virtual instrumentation concept, including software application developed using graphical programming package LabVIEW and D/A data acquisition card NI PCI 6713, installed in standard PC environment. 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, Each of simulated PQ disturbances can be predefined and easily changed according to user requirements, using various combinations of the knobs and controls implemented on the virtual instrument front panel. Data acquisition 8-channel card NI 6713 provides real-time generation of the disturbances using analog output channels,

which can be applied for testing and verification of the instruments developed for measurement and processing of the basic PQ parameters.

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