International Journal of Electronic and Electrical Engineering.
ISSN 0974-2174 Volume 7, Number 10 (2014), pp. 1049-1056

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Power Quality Issues: Monitoring & Measurement

Arvind Dhingra [1] and Ashwani Kumar Sharma [2]

[1]NIT, Kurukshetra & AP, EED, GNDEC, Ludhiana, Punjab
[2] NIT, Kurkshetra, Haryana

Abstract

The growth of electricity market has seen a sea change in the sense consumers perceive electricity. The consumers have become more demanding. Power quality has been catching the attention of researchers worldwide. With the advent of more and more semiconductor based equipments, the power quality standards have been re written. This paper attempts to review the power quality issues including ways of monitoring power quality.

Keywords: Power Quality, Stability

I. INTRODUCTION

With utilities around the world going in for de regulation and diversification, power quality has emerged as the central issue for customers. Unbundling, use of more and more non linear equipments has added to the deterioration in the power quality. Before we examine the power quality issues, we must define what is meant by power quality. The term “Power Quality” is defined as “Set of parameters defining the properties of power quality as delivered to the user in normal operating conditions in terms of continuity of supply and characteristics of voltage (symmetry, frequency, magnitude, and waveform) in IEC [11]. In IEEE Std. 1100-1 999, “Power Quality” is defined as “The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment”. Power quality is “the provision of voltages and system design so that the user of electric power can utilize electric energy from the distribution system successfully without interference or interruption.” A broad definition of power quality borders on system reliability, dielectric selection on equipment and conductors, long-term outages, voltage unbalance in three-phase systems, power electronics and their interface with the electric power supply and many other areas. There are two different causes of deterioration of power quality. They can be classified as:

a) natural causes such as

- Faults or lighting strikes on distribution feeder.
- Falling of trees or branches on distribution feeders during stormy conditions.
- Equipment failure.

b) man-made causes:

- Transformer energization, capacitor or feeder switching.
- Power electronic loads, adjustable speed drives (ASD) etc.
- Arc furnaces and induction heating systems.
- Switching on or off of large loads.

Several aspects on power quality can be classified as shown in Table 1.

Table 1: Aspects of Power Quality [1]

Voltage Stability
Under-voltage & Over-voltage
Voltage Sag
Voltage Swell
Phase Shift
Flicker
Frequency
Continuity of Supplying Power
Momentary Interruption
Temporary Interruption
Sustained Interruption
Voltage Waveform
Transient
Three Phase Voltage Unbalance
Harmonic Voltage, Current
Notch

This classification is based on the required energy to compensate the disturbances in QCC (Quality Control Centre). The aspect of voltage stability can be compensated by use of power electronic devices, transformers, and a small energy storage device, except the frequency deviation. On the other hand, compensation of the continuity of supplying power requires larger energy storage device and/or a distributed generator. For the compensation of voltage waveform, required energy storage device is quite small.

Various schemes have been developed to monitor power quality; we shall discuss some of these in section III.

II. POWER QUALITY ISSUES: SOME DEFINITIONS

The power quality issues arise due to following:

Momentary phenomena:

Transients

A transient is that part of change in a system variable that disappears during transition from one steady-state operating condition to another. Transients can be classified into two categories:

1. Impulsive transients: an impulse transients is a sudden non-power frequency change in the steady-state condition of voltage or current that is unidirectional in polarity (primarily either positive or negative)
2. Oscillatory transients: an oscillatory transient is a sudden, non-power frequency change in the steady-state condition of voltage or current that includes both positive and negative polarity value.

Long duration voltage variations

These are defined as the rms variations in the supply voltage at fundamental frequency for periods exceeding 1 minute. These variations are classified into over-voltages, under-voltages and sustained interruptions. An over-voltage (or under-voltage) is a 10% or more increase (or decrease) in rms voltage for more than 1 minute. When the supply voltage is zero for a period of time in excess 1 minute, the long duration voltage variation is call Overvoltages

Overvoltages

An overvoltage is an increase in the rms ac voltage greater than 110 percent at the power frequency for a duration longer than 1 min. Overvoltage are usually the result of load switching and sustained interruption.

Undervoltages

An under voltage is a decrease in the rms ac voltage to less than 90 per-cent at the power frequency for a duration longer than 1 min. A load switching on or a capacitor bank switching off can cause an under voltage.

Sustained interruptions

When the supply voltage has been zero for a period of time in excess of 1 min, the long-duration voltage variation is considered a sustained interruption.

Short duration voltage variations

Any variation in the supply voltage for duration not exceeding one minute is called a short duration voltage variation. Usually such variations are caused by faults, energization of large loads that require large inrush currents and intermittent loose connection in the power wiring. Short duration variations are further classified as

Voltage sag (or dip)

A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0, 5 cycle to 1 minute. Faults on the transmission or distribution network (most of the times on parallel feeders), Faults in consumer's installation, Connection of heavy loads and start-up of large motors. Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage, Tripping of contactors and electromechanical relays, Disconnection and loss of efficiency in electric rotating machines.

Voltage swell

Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds is called voltage swell. Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours). Data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high, are the results.

Interruptions

An interruption occurs when the supply voltage or load current decreases to less than 0.1 pu for a period of time not exceeding 1 min.

Steady State Phenomena:

Waveform distortions

This is the steady-state deviation in the voltage or current waveform from an ideal sine wave. The presence of a load drawing DC current results in a DC component of the current in the secondary of a distribution transformer. This current will cause a DC bias in the sinusoidal flux of a transformer core. This increased peak value of the flux may push the transformer towards saturation. There are five primary types of waveform distortions:

- DC Offset
- Harmonics
- Interharmonics
- Notching
- Noise

Voltage Unbalance

A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle differences between them are not equal. Large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault). Unbalanced systems imply the existence of a negative sequence that is harmful to all three phase loads. The most affected loads are three-phase induction machines.

Voltage fluctuation

Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz.Arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads. Most consequences are common to under voltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.

Power Frequency Variations

Power frequency variations are defined as the deviation of the power system fundamental frequency from it specified nominal value (e.g., 50 or 60 Hz).

III. SOLUTIONS TO POWER QUALITY PROBLEMS

For the improvement of power quality there are two approaches. According to first approach the solution to the power quality problems can be done from the utility side. The first approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress the power system disturbances. In this approach the compensating device is connect to low and medium voltage distribution system in shunt or in series. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. Both schemes are implemented preferable with voltage source PWM inverters, with a dc source having a reactive element such as a capacitor. However, with the restructuring of power sector and with shifting trend towards distributed and dispersed generation, the line conditioning systems or utility side solutions will play a major role in improving the inherent supply quality.

In order to reduce the impact of power quality problems, custom power devices are being used. These devices include DVR, DSTATCOM, SVC, UPQC etc.

We shall now briefly describe some of these devices:

Distribution Static Compensator (DSTATCOM)

DSTATCOM is a Voltage source inverter (VSI) based static compensator device (STATCOM, FACTS controller) applied to maintain bus voltage sags at the required level by supplying or receiving of reactive power in the distribution system. It is connected in shunt with distribution feeder with the help of coupling transformer.

Static Series Compensator

Commercially, static series compensator is known as Dynamic Voltage Restorer (DVR). It is a high-speed switching power electronic controlling device. DVR is a series connected custom power device, designed to inject a dynamically controlled voltage in magnitude and phase in distribution line via coupling transformer to correct load voltage.

Unified Power Quality Compensator (UPQC)

It is the combination of back to back connected shunt and series compensators through a common dc bus voltage. In this dc link storage capacitor is connected between two voltage source inverters for operating as combination of shunt and series compensator. It is a most flexible device, can suppress current in shunt and voltage in series simultaneously. It can balance the terminal voltage and eliminate negative sequence current components at the same time.

IV. POWER QUALITY MONITORING SYSTEM OVER INTERNET

With the growing use of internet, power quality monitoring over internet [2] has been developed. The major features of the system are described as following:

- Provides GPS-based power quality meters (PQM) for synchronously sampling data on the remote site;
- Sets up site data manager client software that will manage the nodes that will collect, store and compress the power quality data produced by the PQMs;
- Provides the efficient and convenient methods for the different sites and data center to communicate with each other and allows the different sites to send their data through the Internet;
- Provides computer-based investigator client software that provide relatively easy and fast access to large databases and that permit the application of powerful statistical methods for analyzing and displaying those data.

A typical internet based power quality monitoring system will include: a collection of technologies including a web server, computers, communication networks, and specialized PQMs. The most common feature of a power quality monitoring system is the ability to transmit high-quality data across a communication line. Critical functions include data acquisition and downloading, data processing, and delivery of results and reports. Traditionally, separate computers have handled these functions, but new technology is enabling them to be handled either from a central station or from stations throughout a monitoring network. The PQM is an accurate electronic power meter capable of sampling voltage and current waveforms. PQM represents mechanisms for acquiring power quality data, delivering data to site data manager client software. All the PQMs are connected to the local network and by using unique time synchronization based on GPS. In this way, it was possible to monitor all the information from different location on the same graph and the same time base. For real time power quality measurement, voltages and currents of all measuring nodes must be measured simultaneously. The pulse of GPS is used as synchronization signal of the measurement system. PQMs are partitioned into two layers. The first layer is the physical device; the second layer is a software “proxy” that represents the device in another piece of hardware. In either case the device presents an established interface that “wraps” the components actually used to provide the functionality. In addition, the technologies used to deliver the requested services may be transparent.

V. Conclusions

With the growing non linear loads, it is becoming important to monitor and maintain the power quality. Only few of the methods have been discussed here. Other methods are also available. Depending upon the need and utility any one method may be suitable for a particular type of situation.

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