Різноманітні питання, що стосуються моніторингу та аналізу проблем якості електроенергії

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Якість електроенергії – це питання, яке привертає увагу дослідників по всьому світу. Із зростанням кількості напівпровідникового базового обладнання було переглянуто якість електроенергії. Існує багато причин виникнення проблем яксоті електроенергії, короткочасне зниження/підвищення напруги, гармонічні хвилі, швидкі сигнальні імпульси, суб-циклічні імпульси, нейтральні або фонові високочастотні шуми і т.д. Деякі з цих перешкод виникають досить часто і спричиняють несправності, а інші (як наприклад 1 наносекунда або 0.5 наносекунд) трапляються рідко, або ж рідко спричиняють несправності. Важливим завданням є оцінити рівень якості електроенергії та визначити причину виникнення несправностей, які викликають порушення електричного режиму в системах електроенергії, що в свою чергу визначає відношення до цього поганої якості електроенергії. Для того, щоб проаналізувати та визначити збої та їх причини, необхідним буде моніторинг якості електроенергії, який можуть проводити як комунальні підприємства, так і користувачі. В той час, як комунальні підприємства по всьому світу займаються регулюванням та диверсифікацією, якість електроенергії постає головною проблемою для користувачів. Розмежування, зростаюче використання нелінійного обладнання, ще більш погрішили якість електроенергії. Перед тим, як розпочати вивчення питань якості електроенергії, ми повинні зрозуміти, саме поняття якості електроенергії. Як правило, нас турбує якість електроенергії при використання нелінійного навантаження. Коли системи електророзподілення/ використання пов'язані, електрона вантаження та їхній профіль, планування енергосистеми, робота допоміжної системи, включаючи ступінь навантаження не лінійності, - все це впливає на якість електроенергії. Мета системи моніторингу якості електроенергії визначає методи збору даних, функції та вид вимірювальної техніки і т.ін. Крім цього, устаткування повинно характеризуватися точністю показників, в залежності від короткочасного зниження напруги, короткочасного підвищення напруги та збоїв у системі подачі електроенергії а також від перепаду напруги. Питання якості електроенергії викликало значне занепокоєння в електроенергетичних підприємствах із збільшенням використання сенсорного електронного та комп'ютерного обладнання (напр.. персональні комп'ютери, автоматизовані робочі місця, джерела безперебійного електропостачання, факси, принтери, і т.д) та іншого нелінійного навантаження (напр.. флуоресцентне освітлення, регульовані приводи,системи регулювання освітленням та опаленням, промислові електричні вентилі, електрозварювальні апарати та ін..). Всі нелінійні нестаціонарні темпоральні електричні навантаження, поділяються на дві великі категорії, а саме на апарати з аналоговими дугами (пускові/насичувальні) та апарати з цифровим (електронним) включенням перетворювача. Також вимірювання необхідно здійснювати спеціальним чином. Як тільки було виявлено та зафіксовано збій, аналіз зафіксованої форми сигналу може надати більше інформації про причину збою. В цій роботі було зроблено спробу проаналізувати питання якості електроенергії, в тому числі способи моніторингу якості електроенергії, а також вплив гармонічних хвиль на якість електроенергії.

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Various Concerns Regarding Monitoring & Measurement of Power Quality Problems

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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. There are many causes of power quality problems, voltage sags/swells, harmonics, fast impulses or sub-cycle impulses, neutral to ground high frequency noise etc. Some of these occur very frequently and cause problems and others (such as 1 nanosecond or 0.5 nanosecond impulses) either occur very rarely or cause problems rarely. It is important to evaluate power quality level and identify the source of faults that origin electrical disturbances in electrical power systems, which determines the responsibility of a bad quality of power. In order to evaluate and identify the disturbances and its origin, power quality monitoring is the tool that utilities and customers can use. This paper attempts to review the power quality issues including ways of monitoring power quality and also the effect of harmonics on power quality.

Keywords – Power Quality, PQM, Harmonics, Power factor, THD, Voltage distortion.

I. Introduction

With utilities around the world going in for de regulation and diversification, power quality has emerged as the central issue for customers. 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). Power quality can be easily understood as shown in the fig 1.

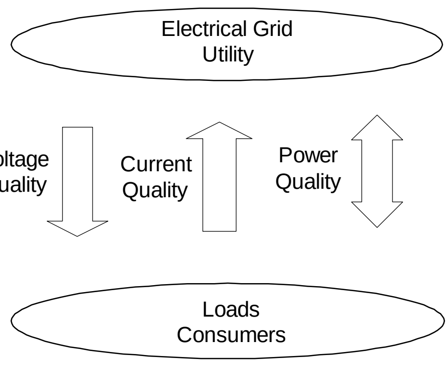

Fig. 1: Concept of power quality

Delivering a certain level of voltage stability and sinusoidal quality should be the main concern for designers of the utility electrical grid. When electrical distribution/utilization system is interconnected, electric loads and their profile, grid design, utility operation including the electric load degree of nonlinearity, all together affect and influence the power quality. The reasons behind the growing concern about power quality are:

- The characteristics of the electric loads have changed dramatically with the proliferation of new micro-electronics and sensitive computer type equipment.
- Harmonics cause equipment to fail prematurely and also decrease the efficiency of the electric distribution/utilization network.
- Electric power systems are now interconnected, integrated, and thus any system disturbance can have an extended serious economic impact particularly for large industrial type consumers due to process shutdown.
- Deregulation of the electricity market. Consumers are now much more aware of the power quality problems issues, and its effect on equipment failure and safety hazards.

II. Power Quality Monitoring

The objectives for a power quality monitoring system [2] determine the various methods for data collection, the range and type of measurement equipment etc. In addition to this, equipments must have unwavering features depending on the power quality category like harmonics, voltage sag, voltage swell, and interruption in power supply and voltage flicker etc. All nonlinear and time varying temporal type electric loads fall generally in two wide categories, namely the analog arc (inrush/saturation) type and digital converter (power electronic) switching type. Also the measurement must be done in a specific way. Once the disturbance has been detected and recorded, analysis of the captured waveforms can give more information about the disturbance. A simple classification of power quality monitoring could be:

- System monitoring: Its objective consists in determining the quality of power and the behaviour of the electrical system globally. The range of this system is broader. For example, to check that voltages in all buses are in the range indicated by legislation, that the number of sags is under the maximum allowed.
- Local monitoring: Its objective consists in determining the quality of power that is delivered to a single customer. It may be useful to identify if the utility is supplying power with the level of quality accorded by contract, identify if the source of electrical disturbances are internal or external, enhance power quality service, etc. Power quality monitoring involves several issues like classification and characterization of electrical disturbances, propagation of disturbances, measurement campaigns, i.e. optimizing the number of monitoring points.

III. Measurement of Harmonics & Its Effect on Power Factor

Nonlinear type loads contribute to the degradation in the power quality of electric supply through the generation of harmonics [3]. Harmonics interfere with sensitive-type electronic communications and networks. The increased use of nonlinear loads makes the harmonic issue (waveform distortion) a top priority for all equipment manufacturers, users and electric utilities. Lower order harmonics cause the greatest concern in the electrical distribution/utilization system. Low order triple harmonics causes hot-neutrals, grounding potential rise (GPR), light flickering, malfunction of computerized data processing equipment and computer networks and computer equipment. Another problem which harmonics cause is that they often do not cancel each other in the neutral but instead are additive causing very high currents, sometimes even higher than the line current, heating and other problems.

There are several defined measures commonly used for indicating the harmonic severity and content of a waveform. One of the most common measures is total harmonic distortion (THD) in current

$$(THD_i) = \left[\frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1} \right];$$

Where I_1: Fundamental (50Hz) Current;
n: Harmonic order and
I_n: Harmonic current.

The power factor PF for any non-sinusoidal quantities is defined by:

$$PF = \frac{V_S I_{S1} \cos f_1}{V_S I_S} = \frac{I_{S1}}{I_S} \cos f_1$$

I_{s1}= RMS value of the fundamental 50Hz component of the current. The displacement power factor (DPF, which is the same as the power factor in linear circuits with pure sinusoidal voltage and current) is defined as the cosine of the angle between the fundamental-frequency (50Hz) current and voltage waveforms) which could be written as: $DPF = \cos f_1$, therefore, the power factor PF with a non-sinusoidal current is:

$$PF = \frac{I_{S1}}{I_S} DPF$$

In terms of total harmonic current distortion, the PF and I_s (the rms value of the total current) could be written as:

$$PF = \frac{1}{\sqrt{1 + THD_i^2}} DPF$$

Where;

$$I_S = I_{S1} \sqrt{\left(1 + THD_i^2\right)}$$

Thus, we can say that the power factor value decreases with any high current harmonic content or distortion or we can also say that power quality has direct impact on the power factor. The effect of THD on voltage distortion has been shown in the following table.

Thus it has been shown that as the voltage level increases, THD value decreases. Various schemes have been developed to monitor power quality; we shall discuss some of these.

Effect of THD on Voltage distortion limit

Bus Voltage at Power Control Centre	Individual Voltage distortion (%)	THD (%)
Less than 69 kV	3	5
69-161 kV	1.5	2.5
More than 161 kV	1	1.5

IV. Power Quality Monitoring System Over Internet

With the growing use of internet, power quality monitoring over internet [4] has been developed. By inspecting and analysing, 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 who can collect, store and compress the power quality data produced by the Power Quality Meters (PQM)
- Provides the efficient and convenient methods for the different sites and data centre to communicate with each other and allows the different sites to send their data through the Internet.

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 through-out a monitoring network.

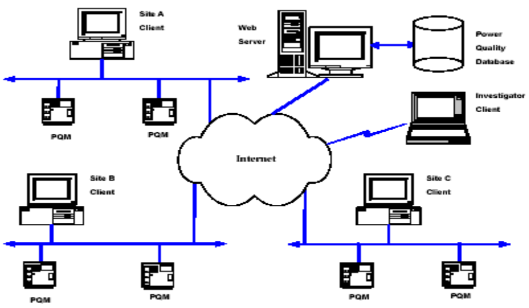

Fig. 2: An internet based power quality monitoring system

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.

V. Power Quality Measurement Using Wavelet And Fuzzy Logic

In order to devise methods for monitoring power quality using wavelet and fuzzy logic, we must define some of the quantities using fast fourier transform. Yoon and Devaney [5] proposed Wavelet based algorithms for power and rms measurements. They separated frequency into various wavelet levels by IIR filter. The most useful definition on power system components under non sinusoidal conditions can be found in the IEEE standard 1459-2000 which provides definitions used for measurement of electric power quantities under sinusoidal, non sinusoidal, balanced or unbalanced conditions. Yoon and Devaney [6] discussed the theoretical basis for the measurement of reactive power and distortion powers from the wavelet transforms. The distortion power at each wavelet sub band has been derived from real, reactive and apparent powers of the sub band, where the apparent power is the product of the voltage, current element pair's sub band rms voltage and current. Styvaktakis et al. [7] proposed an expert system for automatic classification of power quality recording. The main objective of the system was to distinguish between the different types of power system events according to their causes. Eldery [8] proposed an algorithm to determine the optimum number and location of power quality monitors while keeping the system state variables, current and bus voltages observable. Willems [9] proposed separate definitions for the generalization of the concepts of apparent power and power factor for the analysis of the efficiency of power transfer and for the oscillatory character of the instantaneous power. Morsi and Hawary [10] proposed power components definitions contained in the IEEE standard 1459-2000 for unbalanced three phase systems with non-sinusoidal situations with the help of discrete wavelet transform (DWT). Morsi and Hawary [11] reformulated the power components definitions contained in the IEEE Standard 1459-2000 which are based on frequency domain approach using Fourier Transform (FT) in wavelet domain using DWT. Morsi and Hawary [12] also proposed the power components definition for unbalanced three phase systems operating under non-sinusoidal conditions. Another method has been presented for achieving better utilization and control of active power filters dealing with harmonic and reactive current compensation. Some new indices have been proposed for disturbance based on time frequency distribution. The fundamental harmonic and total active powers are defined as

$$P_I = V_I I_I \cos\theta_I ,\ P_H = \sum_{h\neq 1} V_h I_h \cos\theta_h ,\ P = P_I + P_H$$

where V_I and I_I, are the fundamental voltage and current components, V_h and I_h, are the harmonic voltage and current components. The fundamental reactive power, Budeanu's harmonic reactive power and Budeanu's reactive power are defined as

$$Q_I = V_I I_I \sin\theta_I,\ Q_{Bh} = \sum_{h\neq 1} V_h I_h \sin\theta_h$$

and $Q_B=Q_I+Q_{BH}$. The fundamental apparent power is defined as $S_I=V_I I_I$. The current distortion power D_I and harmonic distortion power S_H are defined as

$$S_H= V_H I_H,\ D_I = V_I I_H,\ and\ S_H = V_H I_H.$$

Conclusion

For ideal electrical systems, the supplied power should have perfect current and voltage sinusoidal waveforms, being safe and reliable. But the reality is that the electric utilities controls the voltage levels and quality but are unable to control the current, since the load profile dictates the shape of the current waveform. With the growing non linear loads, it is becoming important to monitor the power quality because as shown in the paper power quality has direct impact on power factor also. There are plenty of methods available for the measurement of power quality but only few of the methods have been discussed here. Other methods are also available depending upon the need. The utility can choose any one method may be suitable for a particular type of situation. Power quality monitoring and power metering will allow plants to perform predictive maintenance, energy management, cost management, and quality control.

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