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POWER QUALITY MEASUREMENTS TECHNIQUES AND IMPROVEMENT

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ABSTRACT

This Review Paper gives basic idea about the recent trends and innovation in power quality measurement. Power Quality (PQ) is becoming an important issue as the increase in electricity use continues. The PQ of a power signal is generally regarded as the relative deviations from an acceptable signal in terms of voltage, current and frequency. Degradation in quality of electric power is normally caused by power-line disturbances such as voltage sag, swell, momentary interruption, harmonic distortion, flicker, notch, spike and transients, causing problems such as malfunctions, instabilities, short lifetime, failure of electrical equipments and so on. Thus, there is a definite power quality problem, which needs to be solved to reduce the losses to industry and consumers. Power quality is a significant tool of an electrical power system network. Now a day's equipment are more sensitive to power quality. In power system there may be fluctuation in power quality at the sensitive load due to faults and switching operation of breakers. This disturbance may result in failure of the equipment. So there is a improvement required in power quality measurement techniques. Recent development in power electronic devices helps us to mitigate such problem

KEYWORDS: Power Quality, Harmonic Distortion, Spike, Electrical Power System, Power System Enginering, Power Electronics

Power quality is the value of the voltage (and other electrical parameters) as a percent of nominal at the meter. Power quality is a combination of voltage profile, frequency profile, harmonics contain and reliability of power supply. Electrical power is perhaps the most essential raw material used by commerce and industry today. It is an unusual commodity because it is required as a continuous flow. The power quality is defined as the degree to which the power supply approaches the ideal case of stable, uninterrupted, zero distortion and disturbance free supply. Power Quality Monitoring (PQM) has many benefits, such as improving performance and quality. A PQM System will gather, analyze, and interpret raw electricity measurement data into useful information. Also, today's customers understand the consequences of power fluctuations and expect a higher level of service.

The quality of electrical power is an important contributing factor to the development of any country and this can be achieved through continuous power quality monitoring which helps detect, record and prevent power quality problem. Power Reliability is the presence of sufficient voltage at the meter. Power Quality is the value of the voltage (and other electrical parameters) as a percent of nominal at the meter

POWER SYSTEM ENGINEERING

Power system engineering is the subject of generation, transmission and distribution of electricity. Power engineering, also called power systems engineering, is a subfield of electrical engineering that deals with the generation, transmission, distribution and utilization of electric power, and the electrical apparatus connected to such systems. The electrical power system consists of three major components: generation, a high voltage transmission grid, and a distribution system.

Electric utilities include investor owned, publicly owned, cooperatives, and nationalized entities. They may be engaged in all or only some aspects of the industry. Electricity markets are also considered electric utilities—these entities buy and sell electricity, acting as brokers, but usually do not own or operate generation, transmission, or distribution facilities. Utilities are regulated by local and national authorities.

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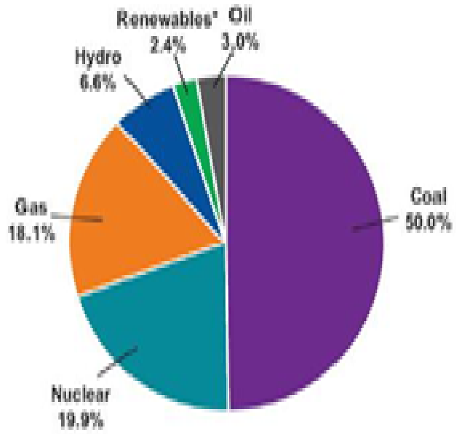

Figure 1: Electric Utility Energy Sources

Power Distribution Systems

The high voltage transmission system links the generators to substations, which supply power to the user through the distribution system. The generation of electricity in different stations such as thermal stations, Hydro electric stations, Nuclear power station, Diesel electric station, Gas turbine plants etc.

The electricity that power plants generate is delivered to customers over transmission and distribution power lines. High-voltage transmission lines, such as those that hang between tall metal towers, carry electricity over long distances to where consumers need it. Electric power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers.

POWER QUALITY STANDARDS

The most important newely recent trends in power quality are power quality standards. Electric power quality, or simply power quality, involves voltage, frequency, and waveform. Good power quality can be defined as a steady supply voltage that stays within the prescribed range, steady a.c. .Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. Power quality is a worldwide issue and keeping related standards. The quality of electrical power may be described as a set of values of parameters, such as:

- Continuity of service (Whether the electrical power is subject to voltage drops or overages below or above a threshold level thereby causing blackouts or brownouts
- Variation in voltage magnitude
- Transient voltages and currents
- Harmonic content in the waveforms for AC power

The power quality standard are described as follows:

Table 1: Brief description about various power quality standards

Standards	Short Description of Standards
IEEE 644	Standard procedure for measurement of power frequency electric and magnetic fields from A.C. power lines.
IEEE C63.12	Recommended practice for electromagnetic compatibility limits
IEEE 518	Guide for the installation of electrical equipment to minimize electrical noise inputs to controllers from external sources
IEEE 519	Recommended practices and requirements for harmonic control in electrical power systems
IEEE 1100	Recommended practice for powering and grounding sensitive electronic equipment
IEE 1159	Recommended practice for monitoring electric power quality.
IEEE 141	Recommended practice for electric power distribution for industrial plants.
IEEE 142	Recommended practice for grounding of industrial and commercial power systems
IEEE 241	Recommended practice for electric power systems in commercial buildings.
IEEE 602	Recommended practice for electric systems in health care facilities.
IEEE 902	Guide for maintenance, operation and safety of industrial and commercial

	power systems
IEEE C57.110	Recommended practice for establishing transformer capability when supplying Non-sinusoidal load.
IEEE P1433	Power quality definitions
IEEE P1453	Voltage flicker
IEEE P1564	Voltage sag indices
IEEE/TR3 61000-2-1	Electromagnetic compatibility – environment
IEC/TR3 61000-3-6	Electromagnetic compatibility – limits
IEC61000-4-7	Electromagnetic compatibility- testing and measurement technology-general guides on harmonics and inter harmonics measurements and instrumentation.
IEC 61462	Industrial A.C. networks affected by harmonics – application of filters and shunt capacitors
IEC SC77A	Low frequency EMC phenomena
IEC TC77/WG1	Terminology
IEC SC77A/WG1	Harmonics and other low frequency disturbances
IEC SC77A/WG6	Low frequency immunity tests
IEC SC77A/WG2	Voltage fluctuations and other low frequency disturbances
IEC SC77A/WG8	Electromagnetic interference related to the network frequency
IEC SC77A/WG9	Power quality measurement methods

POWER QUALITY ISSUE

Power supply quality issues and resulting problems are consequences of the increasing use of solid state switching devices, non linear and power electronically switched loads, electronic type loads. A recent survey of Power Quality experts indicates that 50% of all Power Quality problems are related to grounding, ground bonds, and neutral to ground voltages, ground loops, ground current or other ground associated issues.

One of the most frequently occurring power quality problems in transmission network is voltage sag/swell. Such problems can cause heavy flow of current reduces the life time of the equipment or can cause over voltage affecting the insulation level of the equipment.

Power quality issues

↓

Events **steady state deviations**

Events	**steady state deviations**
(1) Transients	**(1) Voltage unbalance**
(2) Voltage sags	**(2) Harmonics**
(3) Voltage swell	**(3) Inter harmonics**
(4) Interruption	**(4) Flicker**
(5) DG offset	**(5) Notching**
(6) Electrical noise	

Figure 2: Power quality issues

Power Quality & Reliability is an important issue for future Smart Grid research in general and the operation and planning of distribution system in particular. Power quality is a measurement of deviation in voltage, current or frequency that can result in faulty operation or failure of your equipment.

Reliability is our ability to meet your power demand and minimize the number and duration of unplanned interruptions you experience.

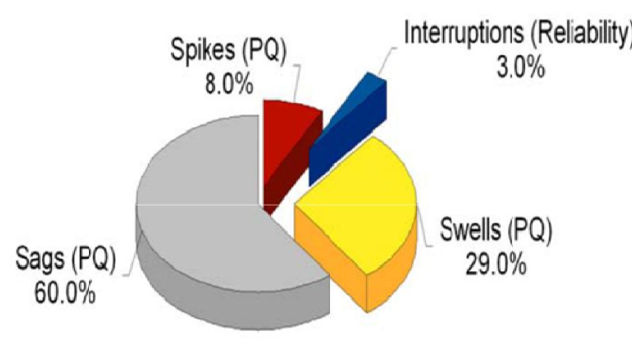

Figure 3: Power Quality & Reliability

Table 2: Power quality, issues

Category	Causes	Impacts
Voltage dips	Local and remote faults inductive loading switch on of large loads	Tripping of sensitive equipment resetting of control systems motor stalling/tripping
Voltage surges	Capacitor switching switch off of large loads phase faults	Tripping of sensitive equipment damage to insulation and windings damage to power supplies for electronic equipment
Overloading	Load switching capacitor switching system voltage regulation	Problems with equipment that requires constant steady state voltage
Harmonics	Industrial furnaces non-linear loads transformers/generators rectifier equipment	Mal operation of sensitive equipment and relays capacitors fuse or capacitor failures telephone interference
Power frequency variations	Loss of generation extreme loading conditions	Negligible most of time motors run slower detuning of harmonic filters
Voltage fluctuation	A.C. motor drives inter harmonic current components welding and arc furnaces	Flicker in : fluorescent lamps incandescent lamps
Rapid voltage change	Motor starting transformer tap changing	Light flicker tripping of equipment
Voltage imbalance	Unbalanced loads unbalanced impedances	Overheating in motors/ generators interruption of 3-phase operation
Short and long voltage interruptions	Power system faults equipment failures control malfunctions CB tripping	Loss of supply to customer equipment computer shutdowns motor tripping
Undervoltage	Heavy network loading loss of generation poor power factor lack of var support	All equipment without backup supply facilities
Transients	Lightning capacitive switching Non-linear switching loads system voltage regulaion	Control system resetting damage to sensitive electronic components damage to insulation

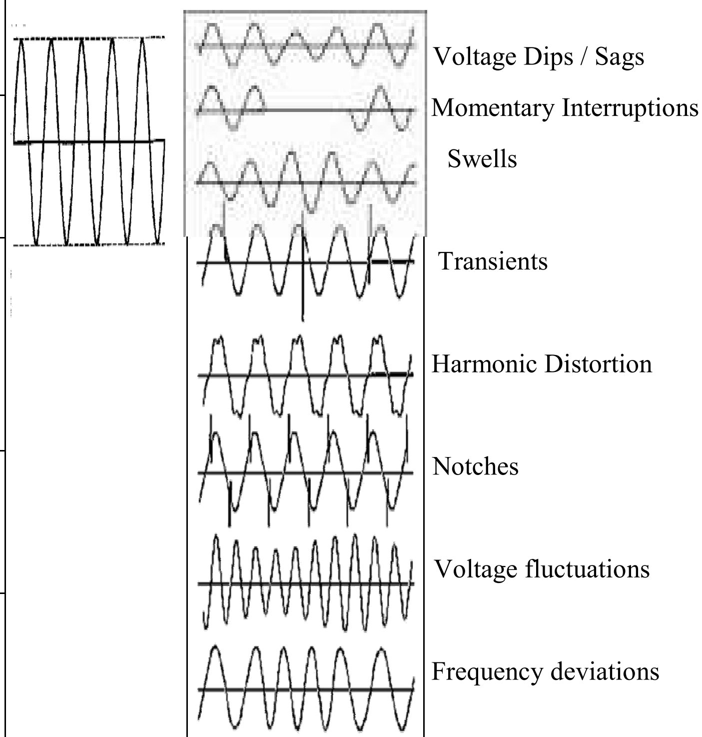

Figure 4: Power Quality/Voltage Disturbances

POWER QUALITY PROBLEMS AND SOLUTIONS

The power quality problems can be viewed as the difference between the quality of power supplied and the quality of power required for reliable operation of the load equipment. From this view, the problems can be resolved according to the following ways:

1. Design equipment and electrical systems to prevent electrical disturbances from causing equipment or systems to malfunction.

2. Analyze the symptoms of a power quality problem to determine its cause and solution.
3. Identify the medium that is transmitting the electrical disturbance and reduce or eliminate the effect of that medium.
4. Treat the symptoms of the power quality problem by the use of power conditioning equipment. Power conditioning equipment mitigates a power quality problem when it occurs.

Power factor is another main factor which affects the electrical power quality. Power factors can be improved by using these methods.(a) Power factor correction by static capacitors (b) Power factor in three phase systems (c) Power factor correction by synchronous motors. Low power factor causes several problems like overheating of motors and poor lightening. ... Power factor improvement, with use of capacitors, results in a reduction of electric bills.

POWER QUALITY SOLUTIONS

Besides energy storage systems and , some other devices may be used to solve PQ problems. Using proper interface devices, one can isolate the loads from disturbances deriving from the grid.

POWER CONDITIONING EQUIPMENT

The following devices play a crucial role in developing an effective power quality strategy.

Transient Voltage Surge Suppressors (TVSS)

It provides the simplest and least expensive way to condition power. These units clamp transient impulses (spikes) to a level that is safe for the electronic load. Employing an entire facility protection strategy will safeguard the electrical system against most transients. Multi-stage protection entails using TVSS at the service entrance, sub-panel a at the point of use. This co-ordination of devices provides the lowest possible let through voltage to the equipment. Transient voltage surge suppressors are used as interface between the power source and sensitive loads, so that the transient voltage is clamped by the TVSS before it reaches the load.

Filters

Noise Filters

Noise filters are used to avoid unwanted frequency current or voltage signals (noise) from reaching sensitive equipment. This can be accomplished by using a combination of capacitors and inductances that creates a low impedance path to the fundamental frequency and high impedance to higher frequencies, that is, a low-pass filter. They should be used when noise with frequency in the kHz range is considerable.

Harmonic Filters

Harmonic filters are used to reduce undesirable harmonics. They can be divided in two groups: passive filters and active filters. Passive filters consist in a low impedance path to the frequencies of the harmonics to be attenuated using passive components (inductors, capacitors and resistors). Several passive filters connected in parallel may be necessary to eliminate several harmonic components. If the system varies (change of harmonic components), passive filters may become ineffective and cause resonance.

Isolation Transformers

Isolation transformers are used to isolate sensitive loads from transients and noise deriving from the mains. In some cases (Delta-Wye connection) isolation transformers keep harmonic currents generated by loads from getting upstream the transformer. The particularity of isolation transformers is a grounded shield made of nonmagnetic foil located between the primary and the secondary.

Voltage Regulators

Voltage regulators maintain output voltage at nominal voltage under all but the most severe input voltage variations. Voltage regulators are normally installed where the input voltage fluctuates, but total loss of power is uncommon. There are three basic types of regulators:

Tap Changers: Designed to adjust for varying input voltages by automatically transferring taps on a power transformer. The main advantage of tap changes over other voltage regulation technology is high efficiency. Other advantages are wide input range, high overload current capability and good noise isolation. Disadvantages are noise created when changing taps and no waveform correction.

Buck Boost: Utilize similar technology to the tap changers except the transformer is not isolated. Advantages are the units withstand high in-rush currents and have high efficiency. Disadvantages are noise created when changing taps, poor noise isolation and no waveform correction.

Constant Voltage Transformer (CVT): Also known as ferroresonant transformers. The CVT is a completely static regulator that maintains a nearly constant output voltage during large variations in input voltage. Advantages are superior noise isolation, very precise output voltage and current limiting for overload protection. The lack of moving parts mean the transformer requires little or no maintenance. Disadvantages are large size, audible noise and low efficiency.

Dynamic Voltage Restorer

A dynamic voltage restorer (DVR) acts like a voltage source connected in series with the load. The output voltage of the DVR is kept approximately constant voltage at the load terminals by using a step-up transformer and/or stored energy to inject active and reactive power in the output supply trough a voltage converter.

Uninterruptible Power Supply (UPS)

UPS systems provide protection in the case of a complete power interruption (blackout). They should be applied where "down time" resulting from any loss of power is unacceptable. UPS are designed to provide continuous power to the load in the event of momentary interruptions. They also provide varying degrees of protection from surges, sags, noise or brownouts depending on the technology used. There are three major UPS topologies each providing different levels of protection:

Off-Line UPS (also called Standby)

Low cost solution for small, less critical, stand-alone applications such as programmable logic controllers, personal computers and peripherals. Off-line UPS systems supply the load directly from the electrical utility with a limited conditioning. The unit provides power to the load from the battery during sags, swells and power interruptions. They of fer some noise suppression through a filter/surge suppressor module. Advantages of off-line UPS are high efficiency, low cost and high reliability. The main disadvantage is that protection from high and low voltages is limited by the battery capacity. Other disadvantages are poor output voltage regulation and noticeable transfer time. To keep unit cost low, most off-line units utilize step-sine wave outputs when on battery power.

Line-Interactive UPS

Line-Interactive UPS provides highly effective power conditioning plus battery back-up. These units are ideal in areas where voltage fluctuations are frequent. The defining characteristic of line-interactive models is they can regulate output voltage without depleting the battery. Advantages are good voltage regulation and high efficiency. Disadvantages are noticeable transfer time and difficulty in comparing competing units. The output waveform can be either a sine wave or step-sine wave depending on the manufacturer and model.

True On-Line UPS

True On-Line UPS provides the highest level of power protection, conditioning and power availability. True on-line technology, also called double conversion is unique in that the power is converted from AC utility to DC for battery charging and to power the inverter. The DC is then converted back to AC to power the critical load. Advantages of the online UPS include the elimination of any transfer time and superior protection from voltage fluctuations. Voltage regulation is achieved by continuously regenerating a clean sine wave. Disadvantages are lower efficiency and higher audible noise.

Motor-Generators Set

Generators are machines that convert mechanical energy into electrical energy. They are usually used as a backup power source for a facility's critical systems such as elevators and emergency lighting in case of blackout. However, they do not offer protection against utility power problems such as over voltages and frequency fluctuations, and although most can be equipped with automatic switching mechanisms, the electrical supply is interrupted before switching is completed, so it cannot protect against the damage that blackouts can cause to expensive equipment and machinery. Motor generators are consists of an electric motor driving a generator with coupling through a mechanical shaft. This solution provides complete decoupling from incoming disturbances such as voltage transients, surges and sags. Motor-Generators ride through short periods of power loss, but will not protect against sustained outages without the addition of an additional motor powered by an alternate fuel source (such as diesel or propane).

Static Var Compensators (SVCS)

Static VAR compensators (SVR) use a combination of capacitors and reactors to regulate the voltage quickly. Solid-state switches control the insertion of the capacitors and reactors at the right magnitude to prevent the voltage from fluctuating. The main application of SVR is the voltage regulation in high voltage and the elimination of flicker caused by large loads (such as induction furnaces). It is normally applied to transmission networks to counter voltage dips/surges during faults and enhance power transmission capacity on long.

Thyristor-Based Static Switch

The static switch is a versatile device for switching a new element into the circuit when voltage support is needed. To correct quickly for voltage spikes, sags, or interruptions, the static switch can be used to switch in one of the following: Capacitor, Filter, Alternate power line, Energy storage system. The static switch can be used in the alternate power line application. This scheme requires two independent power lines from the utility. It protects against 85% of the interruptions and voltage sags.

Unified Power Quality Conditioner (UPQC)

The unified power quality conditioner (UPQC) is a custom power device, which mitigates voltage and current-related PQ issues in the power distribution systems. The UPQC employs two voltage source inverters (VSIs) that is connected to a dc. energy storage capacitor .A UPQC, combines the operations of a Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Regulator (DVR) together. This combination allows a simultaneous compensation of the load currents and the supply voltages, so that compensated current drawn from the network and the compensated supply voltage delivered to the load are sinusoidal and balanced.

POWER QUALITY IMPROVEMENT TECHNIQUES

Improve Power Quality

Grounding & Bonding Integrity

Computer based industrial system performance is directly related to the quality of the equipment grounding and bonding. If the grounding and bonding is incorrectly configured, poor system performance is the result. Grounding is one of the most important and misunderstood aspects of the electrical system. It is essential to differentiate the functions of the grounded conductor (neutral) from the equipment grounding system (safety ground). The safety ground protects the electrical system and equipment from super-imposed voltages caused by lightning or accidental contact with higher voltage systems. It also prevents static charges build-up. The safety ground establishes a “zero-voltage” reference point for the system. The safety ground must be a low impedance path from the equipment to the bonding point to the grounding electrode at the service entrance.

Proper Wiring

An overall equipment inspection is crucial to ensure proper wiring within a facility. The entire electrical system should be checked for loose, missing or improper connections at panels, receptacles and equipment. Article 300 of the National Electrical Code cover wiring methods and should be followed to ensure safe and reliable operation. There are many types of commonly available circuit testers that can be used to check for improper conditions such as reversed polarity, open neutral or floating grounds. Make certain to isolate panels feeding sensitive electronic loads from heavy inductive loads, or other electrically noisy equipment such as air compressors or refrigeration equipment. Also check neutral and ground conductors to make sure they are not shared between branch circuits.

Power Disturbances

Voltage fluctuations and noise are common power disturbances present in any electrical environment that directly affect electronic equipment. These disturbances exist in numerous forms including transients, sags, swells, over voltages, under voltages, harmonics, outages, frequency variations and high frequency noise. Harmonic distortion has emerged as significant problem due to the increased use of electronic equipment. This electronic equipment draws current that is not linear to the voltage waveform. This non-linear current can cause high neutral current, overheated neutral conductors, overheated transformers, voltage distortion and breaker tripping. Loads such as solid-state controls for adjustable speed motors, computers and switched mode power supplies are sources of non-linear currents.

Three Phase Shunt Filter Power Quality Improvement

It solves the problem of harmonic current in power system. It also compensate reactive power and balances load on three phase (if load is unbalanced). it calculates compensating current by inverse-Clarke transformation. The compensating current is injected to the network via three phase inverter using hysteresis band current control (HBCC) method. In this way, harmonic and reactive compnent of load is supplied by this shunt active power filter.Also, compensating p0 means balancing load on three phase.

SAPFs are widely used in the power system to compensate reactive power and current harmonics. It can also play the role of static VAR generator in the power system for improving and stabilizing the voltage profile. Shunt active power filter compensate current harmonic by injecting complementary current that of produced by non-linear load. Shunt active power filter acts as a current source by introducing the harmonic components created by the load but phase shift by 180.Consequently, the current harmonic component present in the load current got cancelled and the source current remain sinusoidal and in phase with the respective phase to neutral voltage. By the use of proper control scheme, APF can also improve system power factor. Thus, by the effect of active power filter, voltage sources see the nonlinear load simply as resistor. However the performances of SAPF largely depend on the control strategy which is responsible for generating complementary harmonic current to cancel out the current harmonics present in the load current.

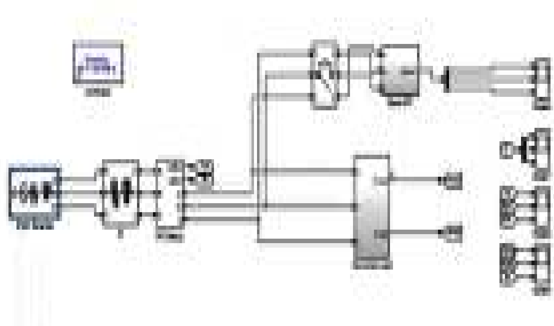

Figure 5: Three phase shunt filter

CONCLUSION

The power quality is affected by various factors of the electrical network. Power quality problems such as voltage and frequency variation, harmonic contents affect the performance of electrical utility and shorten its life time. Such problem has to be compensated to ensure the quality supply. It is important in the modern world because of two things: the ability to use any source of power for any application and to do so efficiently. The last point is very important and there is a lot of research ongoing to increase the efficiency of power converters using different topologies and devices. The demand for quality power has become a challenging issue for industrial area and consumers. Among them voltage unbalance is considered as the major affecting problem leads to degradation in performance of electrical equipments. FACTS devices used for compensation are the best method to overcome such problem. Among them DVR considered the most efficient and cost effective.

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