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Overview of Power Quality Standards, Issues and Mitigation Techniques

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Abstract— Power quality is one of the major and emerging issues in the present scenario. With the increasing use of non linear devices in electrical systems, it has become necessary to investigate the power quality issues as all electrical devices are prone to failure when feces different types of power quality problems. This paper represent overview of the power quality standards, problems, their effect and mitigating devices for its correction. Some power quality enhancement devices are also discussed. This paper will be very helpful for engineers and researchers to become familiar with power quality issues.

Index Terms— Power Quality, Harmonics, Harmonic Distortion, Power Quality Problem, Power Quality Solution.

I. INTRODUCTION

Electricity is now a day becomes a necessity and a part of our everyday life. A short interruptions and voltage fluctuation can be even harmful when the amount of computers, programmable logics etc. in industry and as well in households have increased rapidly. In modern life requirements and expectations related to power quality have become very much important because of increased requirements of power quality by electric utilities and customers. Many industrial and commercial customers have sensitive equipment to power disturbances. Therefore, it is important to understand the quality of power being supplied in a power system, faults, dynamic operations, or nonlinear loads often cause various kinds of power quality issues such as voltage sags, voltage swells, switching transients, unbalance, flickering, harmonics etc. One of the most important fact of power quality studies is the ability to perform automatic power quality detection and measurements. Generally, electric utilities install power quality meters for different power quality issues that can be recorded for further analysis. Power quality is the "concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment" according to IEEE 100 Authoritative Dictionary. Power Quality is a set of electrical boundaries that permit electrical equipment to function in its intended manner without significant loss of performance or life expectancy."

II. IMPORTANCE OF POWER QUALITY

With advancement in technology, the worldwide organization has move towards globalization and the profit margins of many activities tend to decrease. The increased sensitivity of all the devices or equipment to power quality problems tends the availability of electric power with quality a crucial factor for competitiveness in every activity sector.]. The performance of electronic devices is directly dependent to the power quality level. Power quality disturbance can be defined as the deviation of the voltage and the current level from its ideal waveform.. Faults at either the transmission or distribution level may cause voltage fluctuation in the entire system or a large part of it. Also, at heavy load conditions, a significant voltage drop may occur in the system. Voltage fluctuation can cause failure of sensitive equipment, shutdown and create a large current unbalance. These effects can cause a lot of expensive from the customer and cause equipment damage. So , in order to provide uninterrupted power supply to the service sectors as well as industry for economic growth and prevent equipment damage with varying voltage level and frequency , undoubtedly power quality improvement is most important [2].

III. POWER QUALITY INDICES

Institute of Electrical and Electronic Engineers defines power quality as "the concept of powering and grounding sensitive electronic equipment in a manner suitable for the operation of that equipment"[4]. Power quality imposes pre defined quality and reliability of supply. This pre defined quality may contains low phase voltage unbalance, no power interruptions, low flicker at the load voltage and low harmonic distortion in voltage, specified limit of magnitude and duration of over voltages and under voltages, acceptance level of fluctuations and power factor of loads without considerable effect on the terminal voltage.

The following are the factors of Power Quality problems:

- Malfunctioning of Piece of equipment.
- Tripping of circuit breakers without being overloaded.
- Failure of equipment during a thunderstorm.
- Automated systems off without reason
- Failure of electronic systems to operate on a frequent basis.

IV. POWER QUALITY STANDARDS

Power quality is a global issue now a day and its related standards [4] are being used by researchers and engineers to improve power quality are given below:

IEEE-519 provides recommended practices and requirements for harmonic control in electric power systems, established limits on harmonic currents (table 1) and voltages at the point of common coupling (PCC), or point of metering.

IEC 61000-3-2 and IEC 61000-3-4 provides specified limits for harmonic current emissions applicable to electrical and electronic equipment having an input current up to and including 16 A per phase, and beyond 16 A respectively.

IEEE Standard 142-1991 provides complete investigation of the grounding problem and the methods for solving grounding problems.

IEEE Standard 446-1987 provides guidelines for the emergency and standby power systems selection and application.

IEEE Standard 493-1997 provides guidelines for design and planning of industrial and commercial distribution systems.

IEEE Standard 1100-1999 provides information about design, installation and maintenance related issue for electrical power and grounding equipment used in commercial and industrial applications.

IEEE Standard 1159-1995 provides recommended methods of measuring power-quality issues.

IEEE Standard 1250-1995 provides guidance against momentary voltage disturbances occurring in ac power systems, their potential effects on this new, sensitive, user equipment.

IEEE Standard 1346-1998 provides technical and financial analysis of voltage sag compatibility between process equipment and electric power systems.

V. POWER QUALITY PROBLEMS AND EFFECT

There are several factors which result in power quality problems due to which an electrical device may malfunction, fail to operate. Some of the most common power supply problems and their effect on sensitive equipment [1].

A. Harmonics

Harmonics are sinusoidal voltage or current components having frequency are integer multiples of the supply frequency. Distortion means the alteration of the original shape of an object waveform or other form of information and representation. Harmonics is a type of distortion which changes the voltage and current waveform of fundamental power frequency. Various nonlinear loads, power semiconductor devices, fluorescent lamps, adjustable speed drives, personal computers etc. are generated harmonics in power system. This causes various harmful effect in power system. It can reduces the efficiency of system, plant mal-functioning of equipments , aging of installation ,overheating and failure of machines ,overloading of power factor correction capacitors and power transformers.[6]

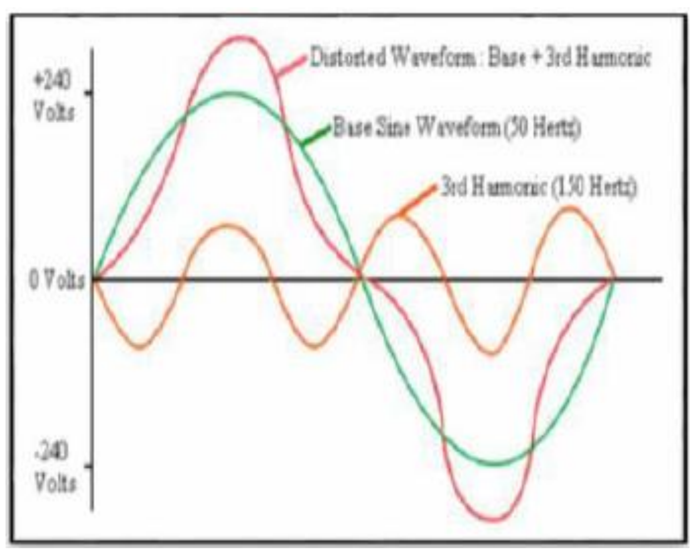

Fig: Harmonics

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B. Voltage Sag (Or Dip)

A decrease in the voltage level between 10% to 90% of the nominal rms voltage at the power frequency for durations of 0,5 cycle to 1 minute. It is due to Faults on the transmission or distribution line and consumer's installation.

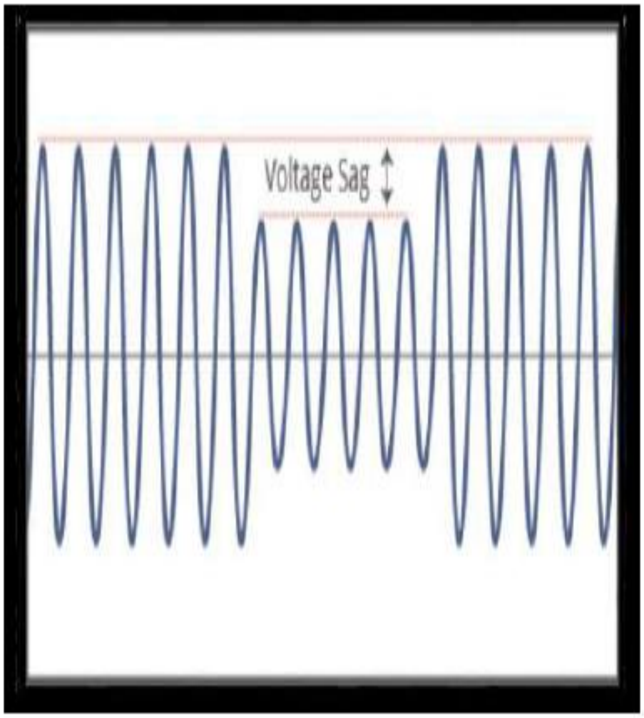

Fig: Voltage Sag.

It results in malfunction of information technology equipment like micro controller based systems (PCs, PLCs, ASDs, etc) that may lead to process discontinue. Tripping of contactors and electro mechanical relays and loss of efficiency in electric rotating machines.

C. Voltage Swell

The momentary increase in the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds. It causes start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours).

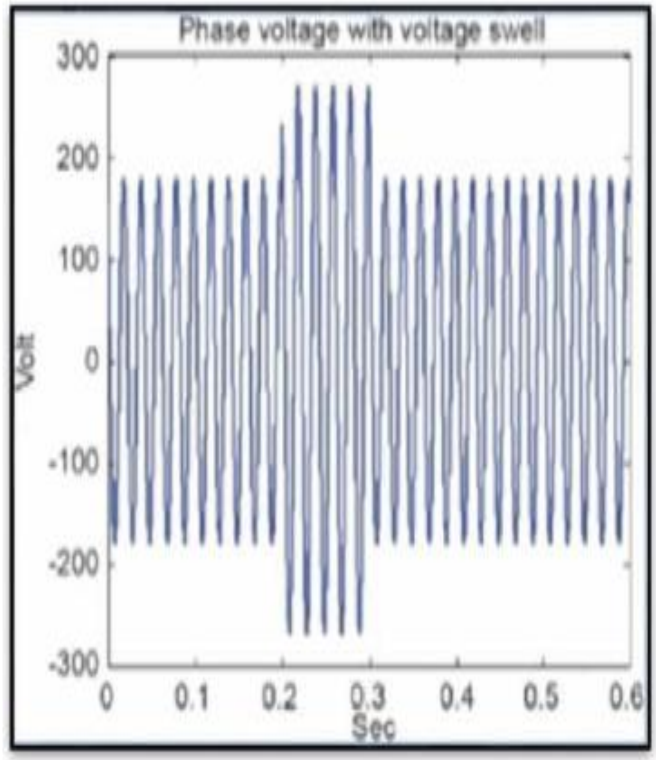

Fig: Voltage Swell.

This results data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

D. Voltage Fluctuation

Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz. It causes due to arc furnaces, frequent start/stop of electric motors, oscillating loads. This results in 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.

E. 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. It causes due to large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system .

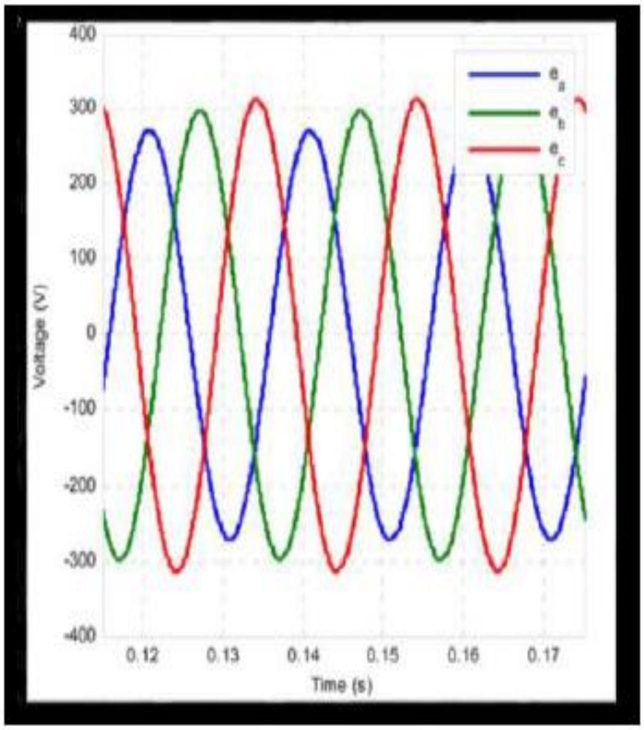

Fig: Voltage Unbalance.

This result in 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.

F. Noise

Superimposing of high frequency signals waveform on the power frequency waveform. It is due to Electromagnetic interferences provoked by Hertzian waves such as microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. Improper grounding may also be a cause. This results disturbances on sensitive electronic equipment, usually not destructive and may cause data loss and data processing errors.

G. Voltage Spikes

Sudden change in the value of voltage for aduration of several microseconds to few milliseconds. These variations may be thousands of volts to very low voltage. It is due to Lightning, switching of lines or power factor correction capacitors, disconnection of heavy loads.

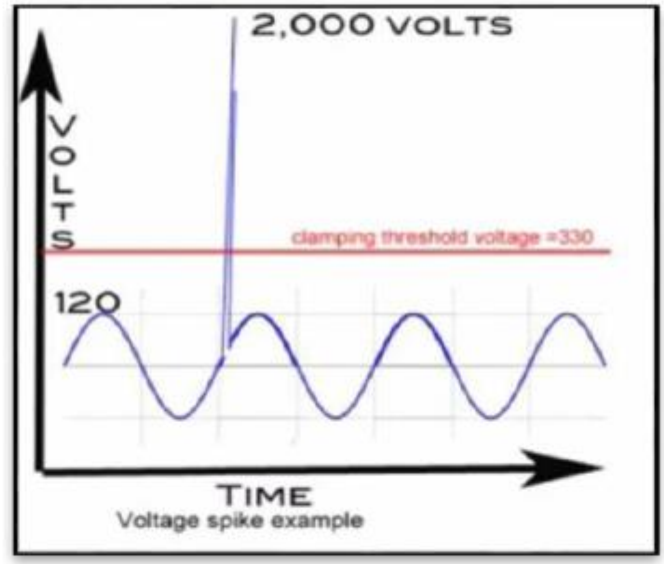

Fig: Voltage Spikes.

Destruction of components and insulation materials, data processing errors or data loss, electromagnetic interference.

VI. POWER QUALITY SOLUTIONS

The following devices play a important role in improving power quality strategy.

A. Transient Voltage Surge Suppressor (TVSS)

It provides the simplest and least expensive way to condition power. These units suppress transient impulses to a safe value for the electronic load. TVSS are used as interface between power source and sensitive loads so that the transient voltage is clamped before it reaches the load. TVSS usually a nonlinear resistance that limits excessive line voltage and conducts any excess impulse energy to ground [14].

B. Filters

Filters are categorized into noise filters, harmonic [15] filters (active and passive) etc. Noise filters are used to remove unwanted frequency components of current or voltage signals from reaching into sensitive equipment. This can be done by using a combination of capacitors and inductances that provides low impedance path to the fundamental frequency and high impedance to higher frequencies; it is a low-pass filter. Harmonic filters are used to reduce undesirable harmonics. Passive filters consist in a low impedance path to the frequencies of the harmonics to be attenuated using passive components (inductors, capacitors and resistors).

C. Isolation Transformer

Isolation transformer [16] is used to isolate sensitive loads from transients and noise generated from the mains. The main component of isolation transformer is a grounded shield made of nonmagnetic foil located between the primary and the secondary side. Any noise or transient that come from the source in transmitted through the capacitance between the primary and the shield and on to the ground and does not reach the load. Isolation transformers reduce normal and common mode noises. However, they do not compensate for voltage fluctuations and power outages [16].

D. Voltage Regulator

Voltage regulators are normally installed where the input voltage fluctuates but total power loss is not within the limit. There are three basic types of regulators:

Tap Changers- It is designed to adjust varying input voltages by automatically transferring taps on a power transformer.

Buck Boost- It uses similar technology to the tap changers except the transformer is not isolated.

Constant Voltage Transformer (CVT)- It is a completely static regulator which maintains nearly constant output voltage during large variations in input voltage.

E. Uninterrupted Power Supply (UPS)

UPS systems provide continuous supply in the case of a complete power interruption. It should be applied where “down time” resulting from any loss of power is unacceptable. UPS are designed to provide continuous power supply to the load in the event of momentary interruptions. They also provide varying degrees of protection from surges, sags, noise or brownout [14]. There are three major UPS topologies each providing different levels of protection:

a) Off-Line UPS (also called Standby) – It is an economic solution for small, less critical and stand alone application such as PLC, personal computers and their peripherals. It is highly efficiency, low cost and high reliability.
b) Line-Interactive UPS- Line-Interactive UPS provides highly effective power conditioning plus battery backup.
c) True On-Line UPS-True - On-Line UPS provides the highest level of power protection, conditioning and power availability. It includes elimination of any transfer time and superior protection from voltage fluctuations.

F. Dynamic Voltage Restorer (DVR)

A dynamic voltage restorer (DVR) acts as a voltage source connected in series with the load. The output voltage of the DVR is maintain nearly constant at the load terminals by using a step-up transformer and/or stored energy to inject active and reactive power in the output supply through a voltage converter [16].

G. Static VAR compensator (SVC)

Static VAR compensators (SVC) use a combination of capacitors and reactors to regulate the voltage level quickly. Solid state switches control the insertion of the capacitors and reactors at the right magnitude to prevent the voltage from fluctuating. It is normally applied to transmission networks to counter voltage dips/surges during the faults and enhance power transmission capacity[14].

H. Thyristor based Static switch

The static switch is versatile device when voltage support is needed for switching a new element into the circuit. To correct rapidly for voltage spikes, sags or interruptions, the static switch can be used to switch in capacitor, filter, alternate power line, energy storage system etc. It protects against 85% of the supply interruptions and voltage sags [18].

I. Unified Power Quality Conditioner (UPQC)

The UPQC employs two voltage source inverters (VSI) that connected to a dc capacitor. A UPQC combines the operations of a Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Regulator (DVR). This allow 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 [13].

VII. CONCLUSION

The availability of high quality of electric power is crucial for the modern running society. If some sectors are satisfied with the power quality provided by utilities, some others will demand more. Even when the most robust equipment is affected, then other measures must be taken, such as installation of restoring technologies, distributed generation or an interface device to prevent power quality issues.. Optimized use of power quality improving devices is required as the cost, complexity, flexibility of various techniques is different and this optimization issue is under research to find perfect approach towards the power quality problems. So this paper has very good approach for power quality problem and good future scope and it will help research workers and electrical power supplier to gain a guideline about the power quality.

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