

# Electric Power Quality-Issues, Effects And Mitigation

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**Abstract**—Electric power quality relates to non-standard voltage, current or frequency deviation that results in failure or misoperation of end-user equipment. The power quality can effect the performance of the electrical equipments. The electrical equipments may have to be derated for the poor power quality. Further, sensitive loads like ASD's may trip leading to financial and time losses to the industry. This paper gives the power quality issues, their effects on the electrical equipments and the methods to reduce them.

**Index Terms**-- Electric Power Quality, Power Quality Effects, Active Filters

## I. INTRODUCTION

Power quality is a young challenging subject, which was introduced in the early 1980s. The term power quality has been used to describe the variation of the voltage, current and frequency on the power system. The power quality is a measure, analysis, and improvement of the load bus voltage which results in that voltage being sinusoidal at rated voltage and frequency. Utilities may define power quality as reliability. The manufactures of load equipment define power quality as those characteristics of power supply that enable the equipment to work properly. The power quality is ultimately a customer driven issue and the customer's point of reference takes precedence.

In last twenty years there has been increasing awareness of the power quality problem. Power quality problem has resulted in lost time, lost production, production of scrap, lost sales, delivery delays, and damaged production equipment. Power disturbances that affect sensitive electronic loads have a variety of sources. Lightning, utility switching, and utility outages are often-cited sources of power disturbances. However, power disturbances are often caused by uses themselves, through switching of loads, ground faults or normal operation of equipment. The sensitive load can also generate some disturbances themselves. Their nonlinear load characteristics can cause interrelation with power systems.

In this paper, electric power quality issues are given. The effects of poor power quality are discussed. And, the methods to mitigate the effect on power quality are given.

## II. POWER QUALITY ISSUES

Power quality is a simple term, yet it describes a multitude of issues that are found in any electrical power system and is a subjective term. The concept of good and bad power depends on the end user. If a piece of equipment functions satisfactorily, the user feels that the power is good. If the equipment does not function as intended or fails prematurely, there is a feeling that the power is bad. In between these limits, several grades or layers of power quality may exist, depending on the perspective of the power user. The understanding of power quality issues is a good starting point for solving any power quality problem [1-13].

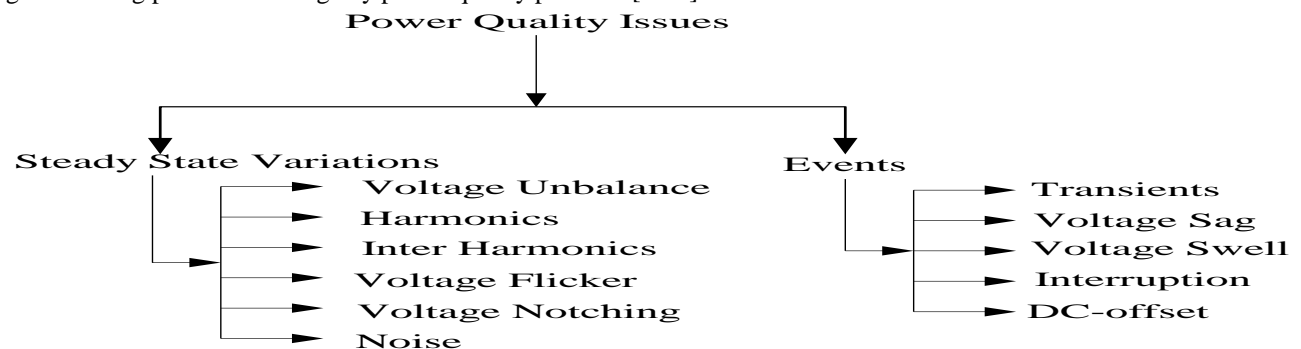


Fig. 1. Power quality issues

Power quality issues contain events which are significant and sudden, and small deviations termed as variations which. These abnormal conditions are explained in detail as under:

### A. Transients

This is an undesirable momentary deviation of the supply voltage or load currents. Transients are generally classified into two categories, (1) Impulsive (2) Oscillatory. These terms reflect the wave-shape of a current or voltage transient.

#### 1) Impulsive Transient

An impulsive transient is a sudden, non-power frequency change in the steady-state condition of voltage, current, or both, that is unidirectional in polarity (primarily either positive or negative) as shown in fig. 2. These are commonly known as switching surges or voltage spikes. They can be caused by circuit breakers out of adjustment, capacitors switching, lightning, or system faults.

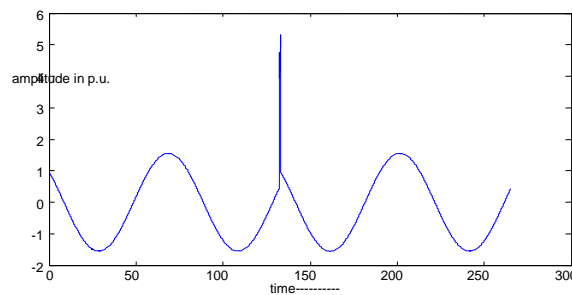


Fig.2. Impulsive transients

#### 2) Oscillatory Transient

An oscillatory transient consists of a voltage or current whose instantaneous value changes polarity rapidly and is bidirectional as shown in fig. 3. This is a sudden bi-directional non-power frequency change: a rising. For high frequency ringing over 500 kHz of 1-  $\mu$ s duration and for 5- 500 kHz ringing with tens of  $\mu$ s duration, it is likely the results of either the system response or the load response to an impulsive transient, with a frequency of less than 5 kHz and 0.3 – 50 ms duration. Back-to-back capacitor energization results in oscillatory transient currents in the tens of kilohertz. Oscillatory transients with principal frequencies less than 300 Hz can also be found on the distribution system. These are generally associated with Ferro-resonance and transformer energization. The oscillatory transient can lead to transient over voltage, causes tripping, component failure, hardware reboot is required, software glitches, poor product quality and may damage the power line insulators.

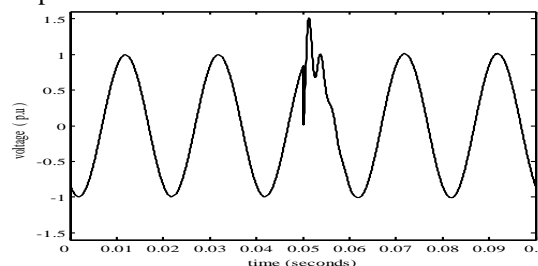


Fig.3. Oscillatory transients

### B. Voltage Sag

This is a short-term, few-cycles duration, drop in voltage (as shown in fig.4.) in the range of 0.1 to 0.9 p.u., for duration greater than half a mains cycle and less than 1 minute. Voltage sags are usually associated with system faults but can also be caused by switching of heavy loads or starting of large motors. Voltage sag can cause loss of production in automated process since a voltage sag trip a motor/system or cause its controller to malfunction, it may be vary costly to end user as machine/system downtime, scrap cost, cleanup cost, product quality and repair costs makes these types of problems costly. Impact of long duration variation is greater than those of short duration variation [4].

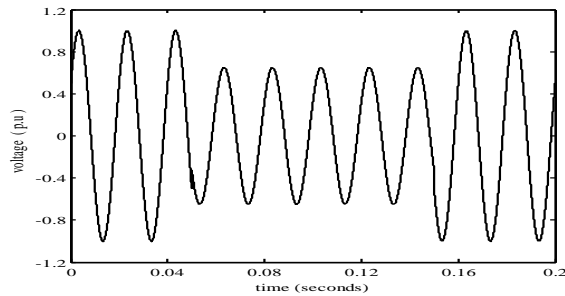


Fig.4. Voltage sag

### C. Voltage Swell

This is a short term increase in voltage of a few cycles duration, voltage swell is an increase in RMS voltage (as shown in fig.5.) in range of 1.1 to 1.8 p.u for duration greater than half a mains cycle and less than 1 minute. Swells are usually associated with system fault conditions, but they are much less common than voltage sags. A swell can occur due to a single line-to-ground fault on the system resulting in a temporary voltage rise on the unfaulted phases. Swells can also be caused by switching off a large load or switching on a large capacitor bank. Voltage swells can put stress on computer and many home appliances, there by shortening their lives. Voltage swell may also cause tripping of protective circuit of an adjustable speed drive.

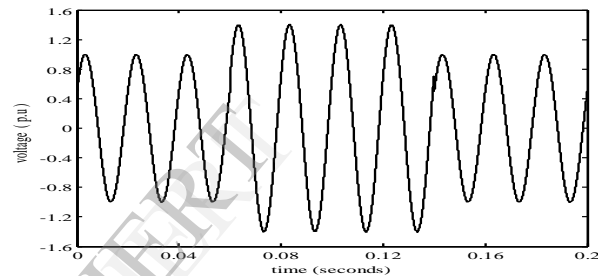


Fig.5. Voltage swell

### D. Interruption

An interruption occurs when the supply voltage or load current (as shown in fig.6.) decreases to less than 0.1 p.u for a period of time not exceeding 1 minute. Interruptions can be the result of power system faults, equipment failures, and control malfunctions. The interruptions are measured by their duration since the voltage magnitude is always less than 10% of nominal. The duration of an interruption due to a fault on the utility system is determined by utility protective devices and the particular event that is causing the fault. The duration of an interruption due to equipment malfunctions or loose connections can be irregular. Ninety percent of fault on overhead distribution lines are of temporary nature. Typically, these faults result from lightning, tree limbs or animals causing ground or shorts. Distribution lines are protected by, a form of a circuit breaker called a reclosure. Reclosures interrupt faults, than automatically restore the circuit, or reclose, and if the fault has cleared, the reclosure stage closed. If the fault still persists, the reclosure trips and again automatically close back in. A temporary interruption lasting a few seconds can cause a loss of production, erasing of computer data etc. The cost of such an interruption during peak hours can be very heavy.

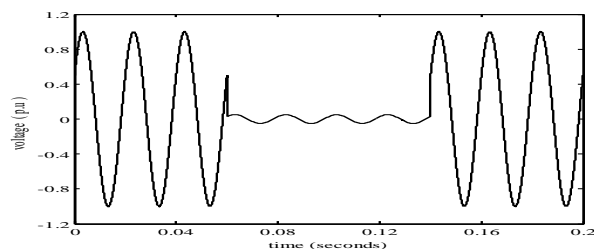


Fig.6. Interruption

### E. DC-offset

The presence of a dc voltage or current in an ac power system is termed dc offset. This phenomenon can occur as the result of a geomagnetic disturbance or due to the effect of half-wave rectification. Direct current in alternating current networks can be detrimental due to an increase in transformer saturation, additional stressing of insulation, and other adverse effects. DC offset causes wave form distortion, and can cause saturation in the power transformer magnetic circuits.

### F. Voltage Unbalance

Voltage imbalance (fig.7) is, deviation in the magnitude and phase of one or more of the phases, of a three phase supply, with respect to the magnitude of the other phase and the normal phase angle ( $120^\circ$ ). Voltage imbalance (or unbalance) is defined as the ratio of the negative or zero sequence components to the positive sequence component. The negative or zero sequence voltages in a power system generally result from unbalanced loads causing negative or zero sequence currents to flow. Voltage imbalance can cause temperature rise in motors and can even cause a large motor to trip.

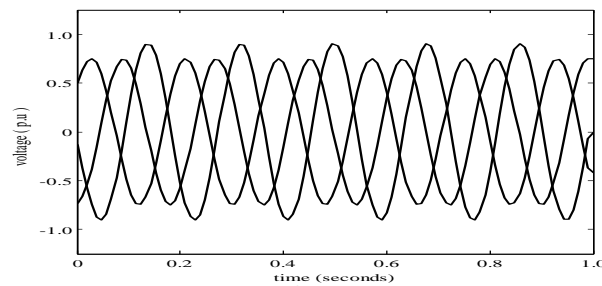


Fig.7. Voltage unbalance

### G. Harmonics

It is a sinusoidal component of a periodic wave or quality having a frequency that is an integral multiple of the fundamental frequency as shown in fig.8. Harmonics can be considered as voltages and/or current present on an electrical system at some multiple of the fundamental frequency. Non-linear elements in power systems such as power electronic switches/static power converters, saturated magnetic components and arc discharge devices, and, to a lesser degree rotating machines, create current distortion. Static Power converters of electrical power are largest nonlinear loads and are used in industry for a variety of purposes, such as electrochemical power supplies, adjustable speed drives, and uninterruptible power supplies. These devices are useful because convert ac to dc, dc to dc, dc to ac, and ac to ac. Harmonics cause wave form distortion power system problems such as communication interference, heating, and solid-state device malfunction can be direct result of harmonics [6].

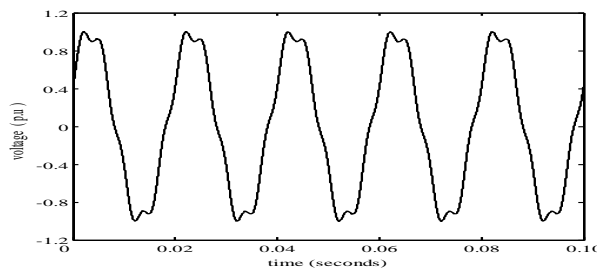


Fig.8. Voltage harmonics

### H. Inter-harmonics

Distorted voltage or current wave forms containing periodic distortions of sinusoidal nature that are not integer multiples of the fundamentals supply frequency are termed inter- harmonics. They can result from ASDs with insufficient DC-link filtering. With inadequate Dc- link filtering, inverter harmonics that are multiples of a non-50/60 Hz fundamental pass into the power system, where they appear as non multiples of the 50/60 Hz fundamental. This phenomenon can also occur with cycloconverter-type ASDs that have no DC link and with arc furnaces that develop an infinite spectrum of parasitic frequencies Power-line carrier signals can also be considered as interharmonics. Inter-harmonics voltage can upset the operation of fluorescent lamps and televisions, receivers;

produce acoustic noise in power equipment.

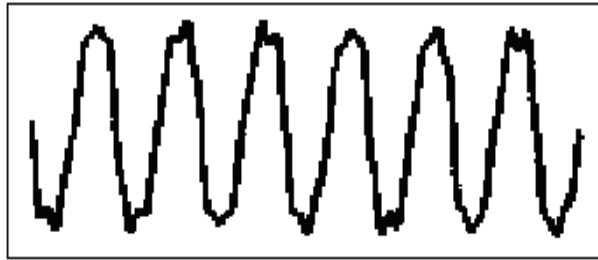


Fig.9. Voltage distortion

### I. Voltage Flicker

Flicker is defined as the “Impression of fluctuating brightness or color, occurring when the frequency of observed variation lies between a few Hertz and the fusion frequency of images”. Flicker comes from the aggravating, rapid on-off sensation of incandescent and fluorescent lamps as perceived by the human eye. It results from the rapid variation in voltage due to fast load changes. Flicker can result from electric arc furnaces, welders, rapidly cycling loads or it can result from a large ASD with inadequate DC-link filtering on a weak distribution system. With inadequate Dc-link filtering, the inverter harmonics, which are a function of a non 50/60 Hz fundamental, flow into the power system, causing a pulsating of the 50/60 Hz fundamental. Voltage flickers are caused by arc discharge lamps, arc furnaces, starting of large motor, arc welding machines etc. Flicker caused light intensity from indecent lamps to vary, makes visual irritation to human observers. It have adverse effects on human health as the high frequency flickering of light bulbs, fluorescent tubes or television screen can cause strain on the eyes resulting in headaches or migraines. The flicker also reduces the life span of electronic equipment, lamps etc.

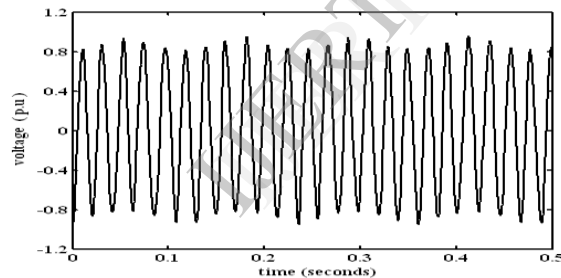


Fig.10. Voltage flicker

### J. Notching

Notching (shown in fig.11.) is a periodic voltage disturbance caused by the normal operation of power electronics devices when current is commutated from one phase to another. It is a switching disturbance of the normal power voltage wave form, lasting less than 0.5 cycle, which is initially of opposite polarity than the wave form and is thus subtracted from the normal wave form in term of the peak value of the disturbance voltage. The main cause of notching are power electronic devices like converter in which, when the current is commutated from one phase to another during the momentary short circuit between the two involved phase. It can be a significant problem on weak electric systems, where it can produce noise currents causing control system misoperation. Voltage notching causes wave from distortion. It can damage capacitate components connected in shunt due to high rate of voltage rise at the notches.

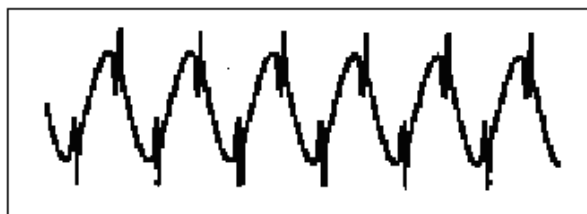


Fig.11. Voltage notching

### K. Noise

Noise (shown in fig.12.) is unwanted electrical signals with broadband spectral content lower than 200 kHz superimposed upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines. Noise in power systems can be caused by power electronic devices, control circuits, arcing equipment, loads with solid-state rectifiers, and switching power supplies. The frequency range and magnitude level of noise depend on the source, which produces the noise and the system characteristics. A typical magnitude of noise is less than 1% of the voltage magnitude. Noise disturbs electronic devices such as microcomputer and programmable controllers. The problem can be mitigated by using filters, isolation transformers, and some line conditioners.

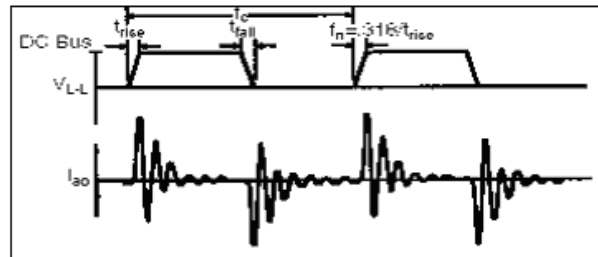


Fig.12. Noise

### III. EFFECTS OF POWER QUALITY ON ELECTRICAL EQUIPMENTS

The power quality affects the performance of various electrical equipments. This section gives the effects of poor power quality on various equipments [14-16].

#### Effect on Transformers

Harmonics can affect transformers primarily in two ways. Voltage harmonics produce additional losses in the transformer core as the higher frequency harmonic voltages set up hysteresis loops, which superimpose on the fundamental loop. Each loop represents higher magnetization power requirements and higher core losses. A second and a more serious effect of harmonics is due to harmonic frequency currents in the transformer windings. The harmonic currents increase the net RMS current flowing in the transformer windings which results in additional  $I^2R$  losses.

An important effect in the power transformers is the circulation of triplen zero sequence currents in the delta windings. The extra circulating currents can overrate the windings unless these are taken into account in the design.

Transformers that are required to supply large nonlinear loads must be derated to handle the harmonics. This derating factor is based on the percentage of the harmonic currents in the load and the rated winding eddy current losses. One method by which transformers may be rated for suitability to handle harmonic loads is by  $k$  factor ratings. The  $k$  factor is equal to the sum of the square of the harmonic frequency currents (expressed as a ratio of the total RMS current) multiplied by the square of the harmonic frequency numbers:

$$k = I_1^2(1)^2 + I_2^2(2)^2 + I_3^2(3)^2 + \dots + I_n^2(n)^2$$

where  $I_n$  is the ratio between  $n^{\text{th}}$  harmonic current and the total rms current.

$$\text{or } k = \sum I_n^2 h^2 \quad (h = 1, 2, 3, \dots, n)$$

Also, transformers that supply large third harmonic generating loads should have the neutrals oversized. This is because, as we saw earlier, the third harmonic currents of the three phases are in phase and therefore tend to add in the neutral circuit. In theory, the neutral current can be as high as 173% of the phase currents.

#### Effect on Capacitors

Capacitor banks are commonly found in commercial and industrial power systems to correct for low power factor conditions. The capacitor bank acts as a sink, absorbing stray harmonic currents and causing overloads and subsequent failure of the bank. A more serious condition with potential for substantial damage occurs due to a phenomenon called harmonic resonance. In a harmonic-rich environment, both series and parallel resonance may be present. If a high level of harmonic voltage or current corresponding to the resonance frequency exists in a power system, considerable damage to the capacitor bank as well as other power system devices can result. Therefore before installing a capacitor bank, it is important to perform a harmonic analysis to ensure that resonance

frequencies do not coincide with any of the characteristic harmonic frequencies of the power system.

### ***Effect on Power Cables***

Cables involved in system resonance, subject to voltage stress and corona, which can lead to dielectric (insulation) failure. Cables that are subject to ordinary levels of harmonic current are prone to heating.

Current flowing in a cable produces  $I^2R$  losses. When the load current contains harmonic content, additional losses are introduced. To compound the problem, the effective resistance of the cable increases with frequency because of the phenomenon known as skin effect.

The current rating factor ( $q$ ) is the equivalent fundamental frequency current at which the cable should be rated for carrying nonlinear loads containing harmonic frequency components:

$$q = I_1^2 E_1 + I_2^2 E_2 + I_3^2 E_3 + \dots + I_n^2 E_n$$

where  $I_1, I_2, I_3$  are the ratios of the harmonic frequency currents to the fundamental current, and  $E_1, E_2, E_3$  are the skin effect ratios.

### ***Effect on Conventional Electric Drives***

Application of distorted voltage to a motor results in additional losses in the magnetic core of the motor. Hysteresis losses increase with frequency and eddy current losses increase as the square of the frequency. Also, harmonic currents produce additional  $I^2R$  losses in the motor windings which must be accounted for. Another effect, and perhaps a more serious one, is torsional oscillations due to harmonics. Excessive vibration and noise in a motor operating in a harmonic environment should be investigated to prevent failures.

The sum effect of the harmonics is a reduction in efficiency and life of the machinery [6].

Induction motor operating under unbalanced voltage conditions would experience a reduction in efficiency. The increased heating effect of unbalanced voltage operation of induction could lead to premature motor failure.

The electric motor is suitably rerated when fed from non rated supply.

### ***Effect on Modern dc/ac Drives (ASD's)***

In modern DC/AC drives, the input ac supply is converted to dc, forming a dc link. The dc link thus available is used as a constant voltage source for further dc/ac conversions. Since the internal DC link capacitor is essentially connected alternately across each of the three phases, drives of this type can be extremely sensitive to overvoltages (voltage transients, swell) and under-voltage (voltage sag) on the AC power side. One event of particular concern is capacitor switching on the utility system. As an arc is drawn switching the capacitor bank, it excites an LC ring wave at the natural frequency of the inductance of the system and the bank capacitance. These utility generated voltage switching transients result in a surge of current into the DC link capacitor and cause an overvoltage to occur. If this overvoltage exceeds the voltage tolerance thresholds associated with the overvoltage protection, the tripping of ASD occurs. Like wise a ground fault in the feeder ahead, results in undervoltage and the ASD trips. This is called nuisance tripping because the situation can occur day after day, often at the same time of the day.

### ***Telephone Interference***

The presence of harmonic currents or voltages in circuitry associated with power conversion apparatus can produce magnetic and electric fields that will impair the satisfactory performance of communication systems that, by virtue of their proximity and susceptibility, can be disturbed. The TIF weighting is a combination of the C message weighting characteristic, which accounts for the relative interfering effect of various frequencies in the voice band (including the response of the telephone set and the ear), and a capacitor which provides weighting that is directly proportional to frequency to account for the assumed coupling function. The disturbance to the communication system can be reduced by multiphasing of the conversion equipment, residual or ground return currents, commutation effects, filtering etc.

### ***Effect on Protective Devices***

Harmonic currents can increase heating and losses in switchgear, thereby reducing steady-state current carrying capability and shortening the life of some insulating components. Fuses suffer a derating because of the heat generated by harmonics during normal operation. Relay response under distorted condition may vary among relays having the same nominal fundamental frequency characteristics, not among different relay manufacturers, but also among different vintages of relays from the same manufacturer [6].

Harmonic currents influence the operation of protective devices. Fuses and motor thermal overload devices are

prone to nuisance operation when subjected to nonlinear currents. This factor should be given due consideration when sizing protective devices for use in a harmonic environment. Electromechanical relays are also affected by harmonics. Depending on the design, an electromechanical relay may operate faster or slower than the expected times for operation at the fundamental frequency alone. Such factors should be carefully considered prior to placing the relays in service.

#### ***Effect on Electronic Equipment/Consumers Equipments***

Harmonics can cause changes in TV picture size and brightness, excessive heating of Fluorescent and mercury arc lighting and may cause failure, problems in computer and data processing supply system, problem in synchronizing of coverter equipment etc.

### **IV. MITIGATION TECHNIQUES**

#### ***Equipment Design***

The importance of equipment design in minimizing harmonic current production has taken on greater importance, as reflected by technological improvements in fluorescent lamp ballasts, adjustable speed drives, battery chargers, and uninterruptible power source (UPS) units.

#### ***Multipulse technique***

Adjustable speed drive (ASD) technology is evolving steadily, with greater emphasis being placed on a reduction in harmonic currents. Older generation ASDs using current source inverter (CSI) and voltage source inverter (VSI) technologies produced considerable harmonic frequency currents. The significant harmonic frequency currents generated in power conversion equipment can be stated as:

$$n = kq \pm 1$$

where  $n$  is the significant harmonic frequency,  $k$  is any positive integer (1, 2, 3, etc.), and  $q$  is the pulse number of the power conversion equipment which is the number of power pulses that are in one complete sequence of power conversion.

With six-pulse-power conversion equipment, harmonics below the 5th harmonic are insignificant. Also, as the harmonic number increases, the individual harmonic distortions become lower due to increasing impedance presented to higher frequency components by the power system inductive reactance. So, typically, for six-pulse power conversion equipment, the 5th harmonic current would be the highest, the 7th would be lower than the 5th, the 11th would be lower than the 7th, and so on, as shown below:

$$I_{13} < I_{11} < I_7 < I_5$$

We can deduce that, when using 12-pulse-power conversion equipment, harmonics below the 11th harmonic can be made insignificant. The total harmonic distortion is also considerably reduced. Twelve-pulse-power conversion equipment costs more than six-pulse-power equipment. Where harmonic currents are the primary concern, 24-pulse-power conversion equipment may be considered.

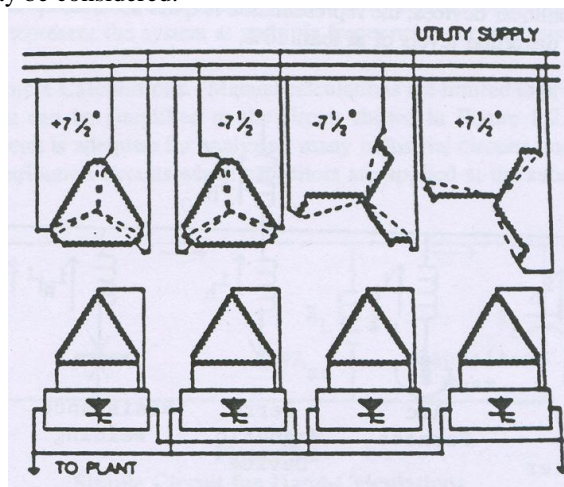


Fig.13. Multipulse technique for harmonic reduction



### Power factor correction at Design stage

The input current drawn by the front end converter may be made sinusoidal and near unity power factor by using a Buck- Boost chopper at the D. C. link. The advantage is that with this additional power factor correction capacitor bank and filters are not required.

### Harmonic Filters

Nonlinear loads produce harmonic currents that can travel to other locations in the power system and eventually back to the source. One means of ensuring that harmonic currents produced by a nonlinear current source will not unduly interfere with the rest of the power system is to filter out the harmonics. Application of harmonic filters helps to accomplish this.

Harmonic filters are broadly classified into passive and active filters. Passive filters, as the name implies, use passive components such as resistors, inductors, and capacitors. A combination of passive components is tuned to the harmonic frequency that is to be filtered. Fig. shows a typical series-tuned filter. Here the values of the inductor and the capacitor are chosen to present a low impedance to the harmonic frequency that is to be filtered out. Due to the lower impedance of the filter in comparison to the impedance of the source, the harmonic frequency current will circulate between the load and the filter. This keeps the harmonic current of the desired frequency away from the source and other loads in the power system. If other harmonic frequencies are to be filtered out, additional tuned filters are applied in parallel. Applications such as arc furnaces require multiple harmonic filters, as they generate large quantities of harmonic currents at several frequencies.

### Passive filters

Passive filters or power line filters are simple filters consisting of discrete capacitors and/or inductors. Passive filters are normally designed to alternate high frequencies, fitted to equipment to remove higher order harmonic frequencies from the supply.

However Shunt Passive filters have many problems like: As source impedance varies with the system configuration which is not accurately known, strongly influences filtering characteristics of shunt passive filter. The shunt passive filter acts as a current sink to harmonic voltage included in source voltage. In worst case, the shunt passive filter falls in series resonance with the source impedance.

At a specific frequency an anti resonance or parallel resonance occurs between source impedance and the shunt passive filter, which is to called harmonic amplifying phenomenon [18].

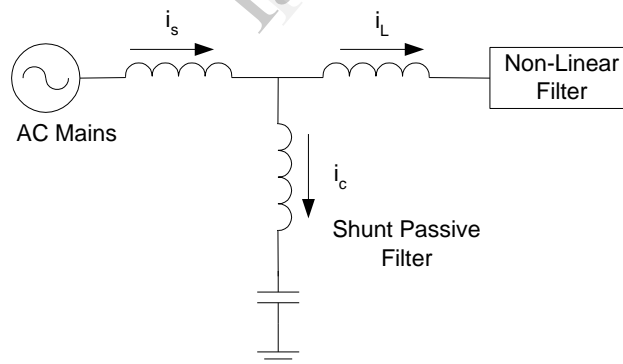


Fig.14. Passive filter

### Active Filters, Hybrid and Unified Power quality Conditioner (UPQC)

The control of reactive power and therefore harmonics can be achieved by controlling reactive current element. The reactive current compensation can be done, by switching capacitors and inductors in shunt with power system, using thyristors. Static VAR compensators (SVCs) are used to absorb or inject reactive currents to eliminate the harmonic distorting currents drawn by non – linear loads. However, full rating inductors and capacitors are required leading to bulky system.

With the advent of instantaneous reactive power theory [17] the compensation can be achieved without passive elements. Fig. 15 shows the working of an active filter. Active filter injects the required compensator current for harmonic mitigation and displacement power- factor correction. The shunt active filter is used for power factor correction, load balancing, harmonic reduction and to some extent voltage regulation. However full rating of the

converter is limitation. Fig. 16 shows the hybrid filter which is a combination of shunt passive and active filters reduces the overall cost of the compensator with active filter compensating for higher order harmonics.

Fig. 17 shows the working of a series active filter which injects voltage for voltage conditioning (voltage unbalance, distortion, regulation) at point of common coupling (PCC) series active filters are better option. Voltage balance is achieved by injecting a correcting voltage in only one phase. The required kVA rating of the line conditioner is low. The required magnitude of the injected voltage is also low. The additional voltage source for injected voltage can be easily obtained from a battery backup system. The booster transformer is rated for power frequencies and no special design is required. If the load is sensitive to voltage magnitudes, a modification with two control voltages injected into the lines enables the voltage to be regulated.

Fig. 18 shows a unified power quality conditioner (UPQC) which is a combination of series and shunt active filters for both current and voltage compensation [19]. An energy storage device may also be used at the DC link of the filters for real power demand of the loads for a limited time [20].

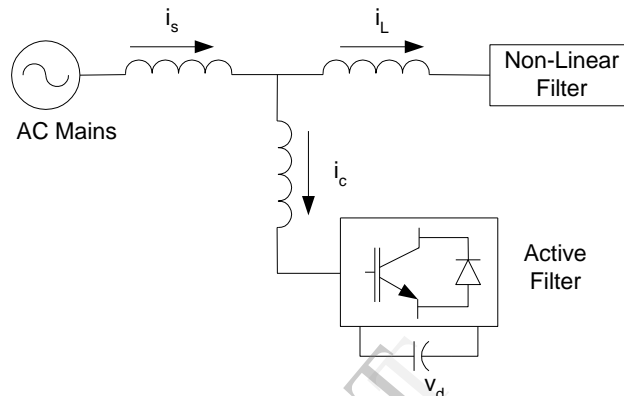


Fig.15. Shunt active filter

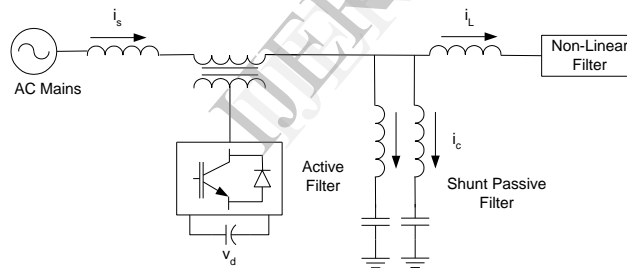


Fig.16. Hybrid filter

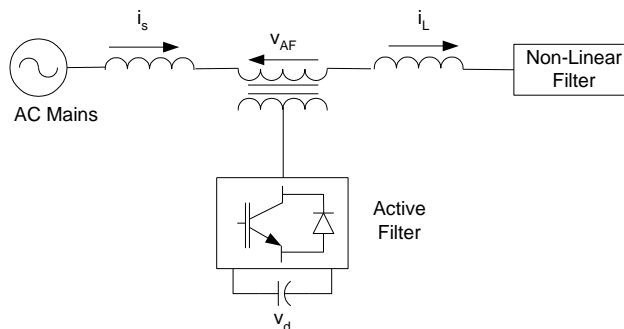


Fig.17. Series active filter

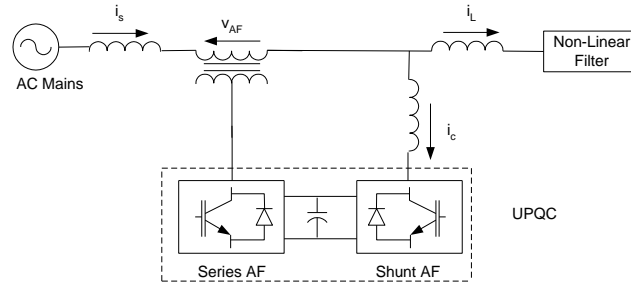


Fig.18. Unified power quality conditioner

### Harmonic current cancellation

Transformer connections employing phase shift are sometimes used to effect cancellation of harmonic currents in a power system. Triplen harmonic (3rd, 9th, 15th, etc.) currents are a set of currents that can be effectively trapped using a special transformer configuration called the zigzag connection. In power systems, triplen harmonics add in the neutral circuit, as these currents are in phase. Using a zigzag connection, the triplens can be effectively kept away from the source.

### Solid State transfer switches (SSTS)

Transfer switches are used to transfer a load connection from one supply to another, allowing the choice of two supplies for the load. If one supply suffer power distribution the other supply will be automatically switched in reducing the possibility of supply distributions to the load.

A solid-state transfer switch can protect a sensitive load from voltage sag or interruption by quickly transferring the load to a healthy or alternate feeder [3].

### Solid State Breaker (SSB)

The solid state breaker will allow the isolation of faulted circuits in the shortest possible time frame, other nearby loader will therefore have improved power quality [3].

## V. CONCLUSION

The power quality is a measure, analysis, and improvement of the load bus voltage which results in that voltage being sinusoidal at rated voltage and frequency. The power quality issues have been considered important because of sensitive power electronic loads. These loads itself are a source of emission and should be immune to the power quality problems. Thus power quality relates to the concept of emission and immunity of the sensitive equipments. The mitigation of power quality problems is necessary where it is harmful to the operation of the equipments. The economic aspects are to be taken into consideration before making a choice of the suitable mitigating device.

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