Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2, Issue 7, July -2015

Power Quality:Problem,Source and solution

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Abstract- *Electrical power Industries have always been concerned about power quality. They see power quality as anything that affects the voltage, current, and frequency of the power being supplied to the end user, or consumer of electricity. They are intimately familiar with the power quality standards that have to be maintained. They deal with power quality at all levels of the power system, from the generator to the ultimate consumer of electrical power.*

Power quality problems occur when the alternating-voltage power source's 50-Hz sine wave is distorted. Today, highly sensitive computers and computer-controlled equipment require a power source of higher quality and more reliability than standard, less sensitive electricity-consuming equipment of the past.

Given the nature of the electrical operating boundaries and the need for electrical equipment to perform satisfactorily in such an environment, it is increasingly necessary for engineers, technicians, and facility operators to become familiar with power quality issues. In this paper power quality problems, source of this problems and there solution are discussed.

Keywords-power quality, harmonics, voltage sag, UPS, SMPS, RMS value

I INTRODUCTION

Power quality can be defined from two different perspectives, depending on whether you supply or consume electricity. Power quality at the generator usually refers to the generator's ability to generate power at 50 Hz with little variation, while power quality at the transmission and distribution level refers to the voltage staying within plus or minus 5 percent. The type of equipment being used by the end user affects power quality at the end-user level. Two identical devices or pieces of equipment might react differently to the same power quality parameters due to differences in their manufacturing or component tolerance. Electrical devices are becoming smaller and more sensitive to power quality aberrations due to the proliferation of electronics.

The quality of power can have a direct economic impact on many industrial consumers. There has recently been a great emphasis on revitalizing industry with more automation and more modern equipment. This usually means electronically controlled, energy-efficient equipment that is often much more sensitive to deviations in the supply voltage than were its electromechanical predecessors. Thus, like the blinking clock in residences, industrial customers are now more acutely aware of minor disturbances in the power system. The electric utility is concerned about power quality issues as well. Meeting customer expectations and maintaining customer confidence are strong motivators.

There are many misunderstandings regarding the causes of power quality problems. The charts in Fig. 1.1 show the results of one survey conducted by the Georgia Power Company in which both utility personnel and customers were polled about what causes power quality problems. While surveys of other market sectors might indicate different splits between the categories, these charts clearly illustrate one common theme that arises repeatedly in such surveys.

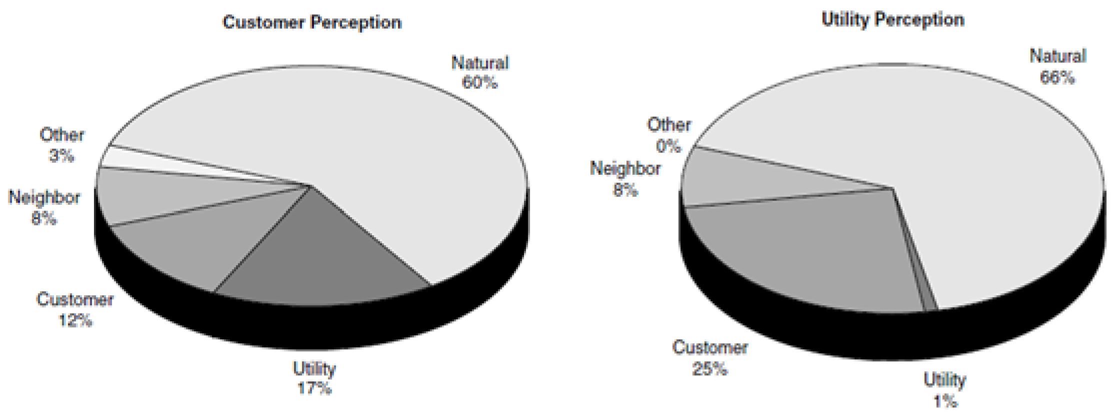

Fig. 1. Results of a survey on the causes of power quality problems. (Courtesy of Georgia Power Co.)

The utility's and customer's perspectives are often much different. While both tend to blame about two-thirds of the events on natural phenomena (e.g., lightning), customers, much more frequently than utility personnel, think that the utility is at fault. When there is a power problem with a piece of equipment, end users may be quick to complain to the utility of an "outage" or "glitch" that has caused the problem. However, the utility records may indicate no abnormal events on the feed to the customer. In addition to real power quality problems, there are also perceived power quality problems that may actually be related to hardware, soft-ware, or control system malfunctions. Electronic components can degrade over time due to repeated transient voltages and eventually fail due to a relatively low magnitude event. Thus, it is sometimes difficult to associate a failure with a specific cause.

II TYPES OF POWER QUALITY PROBLEMS

The ability to define and understand the various types of power quality problems provides the necessary background needed to prevent and solve those problems. The power quality signature, or characteristic, of the disturbance identifies the type of power quality problem. The nature of the variation in the basic components of the sine wave, i.e., voltage, current, and frequency, identifies the type of power quality problem. Voltage sags are the most common type of power quality problem.

A Voltage sags (dips)

Voltage sags are referred to as *voltage dips* in Europe. IEEE defines *voltage sags* as a reduction in voltage for a short time. The duration of a voltage sag is less than 1 minute but more than 8 milliseconds (0.5 cycles). The magnitude of the reduction is between 10 percent and 90 percent of the normal root mean square (rms) voltage at 60 Hz. The rms, or effective, value of a sine wave is the square root of the average of the squares of all the instantaneous values of a cycle and is equal to 0.707 (1/_2_) times the peak value of the sine wave.

Utilities and end users can cause voltage sags on transmission and distribution systems. For example, a transformer failure can be the initiating event that causes a fault on the utility power system that results in a voltage sag. These faults draw energy from the power system. A voltage sag occurs while the fault is on the utility's power system. As soon as a breaker or recloser clears the fault, the voltage returns to normal. Transmission faults cause voltage sags that last about 6 cycles, or 0.10 second. Distribution faults last longer than transmission faults, while large motor loads can cause voltage sag on utility's and end user's power systems. Figure 2 shows voltage sag plot

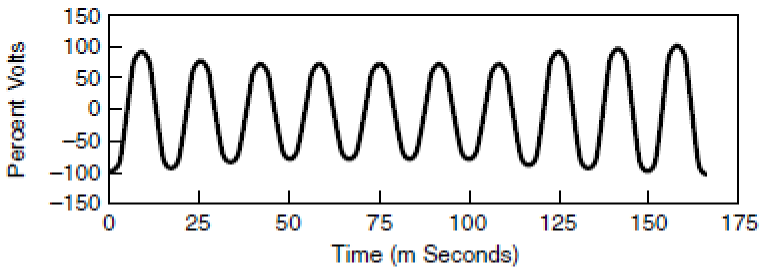

Fig.2.Voltage sag plot

B Voltage swells

Voltage swells, or momentary over voltages, are rms voltage variations that exceed 110 percent of the nominal voltage and last for less than 1 minute. Voltage swells occur less frequently than voltage sags. Single line to ground faults cause voltage swells. Figure 3 shows voltage swells plot.

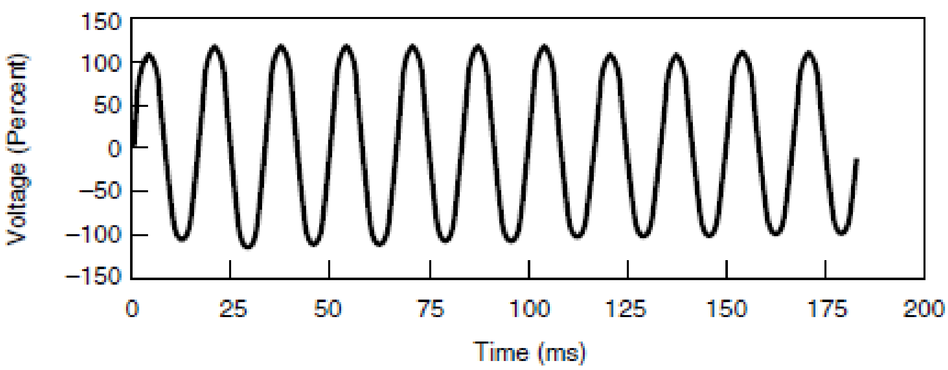

Fig.3.Voltage swells plot

C Long-duration over voltages

Long-duration over voltages are close cousins to voltage swells, except they last longer. Like voltage swells, they are rms voltage variations that exceed 110 percent of the nominal voltage. Unlike swells, they last longer than a minute. Figure 4 shows long duration overvoltage plot.

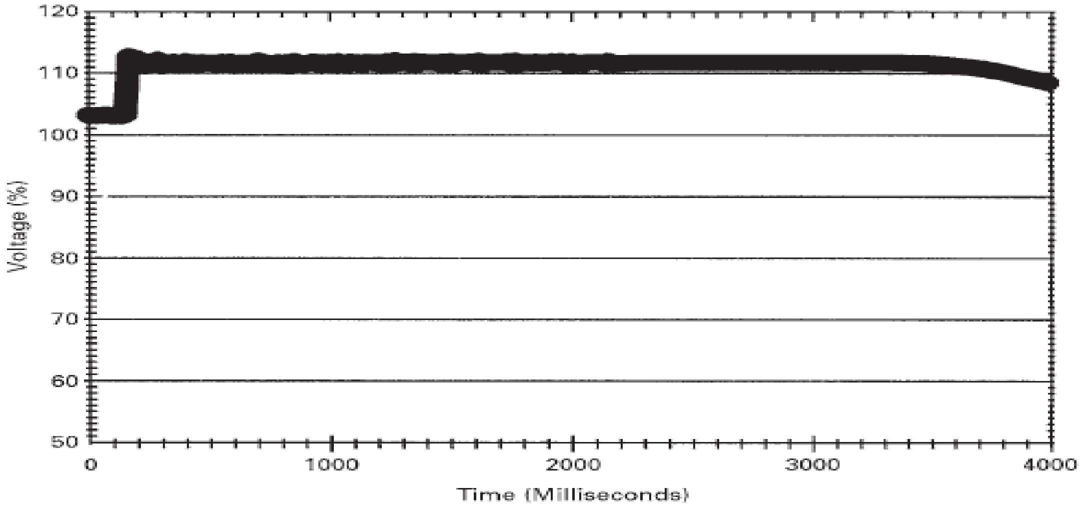

Fig.4.Long duration overvoltage plot

D Under voltages

Under voltages occur when the voltage drops below 90 percent of the nominal voltage for more than 1 minute. They are sometimes referred to as "brownouts," although this is an imprecise nontechnical term that should be avoided. They are recognized by end users when their lights dim and their motors slow down.Figure 5 shows under voltage plot.

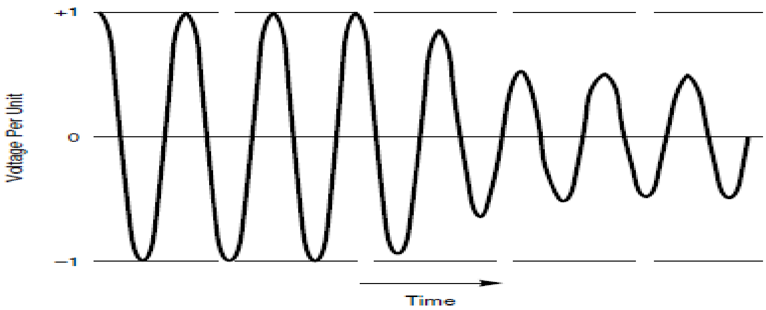

Fig.5.Under voltage plot

E Interruptions

Interruptions are a complete loss of voltage (a drop to less than 10 percent of nominal voltage) in one or more phases. *IEEE Recommended Practice for Monitoring Electric Power Quality* (IEEE Standard 1159- 1995, Copyright © 1995) defines three types of interruptions.

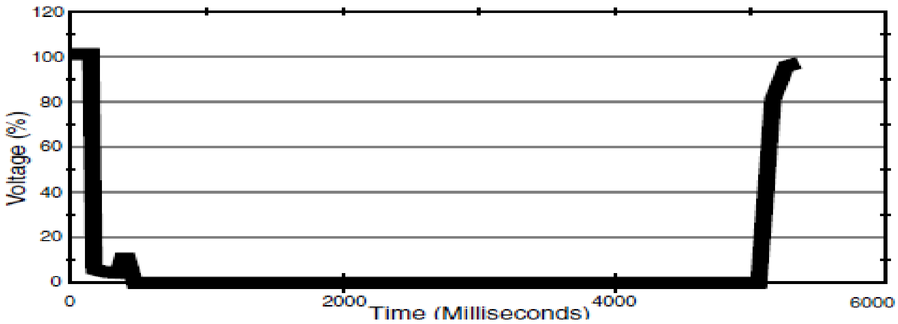

Fig.6. Momentary, temporary, and long-duration interruption plots.

They are categorized by the time period that the interruptions occur: momentary, temporary, and long-duration interruptions. Momentary interruptions are the complete loss of voltage on one or more phase conductors for a time period between 0.5 cycles, or 8 milliseconds, and 3 seconds. A temporary, or short-duration, interruption is a drop of voltage below 10 percent of the nominal voltage for a time period between 3 seconds and 1 minute. Long-duration, or sustained, interruptions last longer than 1 minute. Figure 6 shows a momentary interruption.

F Transients

Transients or surges are sometimes referred to as "spikes" in less technically correct language. A sudden increase or decrease in current or voltage characterizes them. They often dissipate quickly. There are basically two types of transients: impulsive and oscillatory.

The time it takes impulsive transients to rise to peak value and decay to normal value determines their identity. For example, page 13 of IEEE Standard 1159-1995, Copyright © 1995 describes an impulsive transient caused by a lightning stroke. In this example the transient current raises to its peak value of 2000 V in 1.2 microseconds (_s; onemillionth of a second) and decays to half its peak value in 50 _s. Resistive components of the electrical transmission and distribution system dampen (reduce) transient currents. The most frequent cause of impulsive transients is lightning strokes. Figure 7 illustrates an impulsive current transient caused by lightning.

Oscillatory transients do not decay quickly like impulsive transients. They tend to continue to oscillate for 0.5 to 3 cycles and reach 2 times the nominal voltage or current.

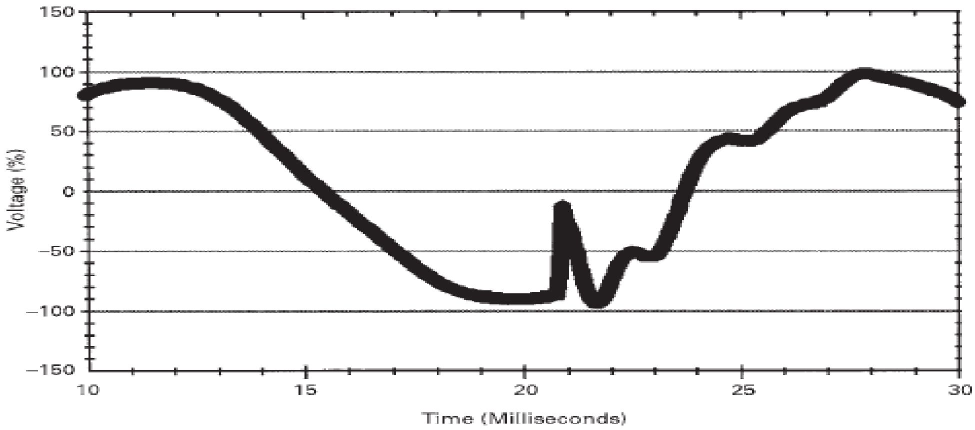

Fig.7. Impulsive transient plot.

G Voltage unbalance

Voltage unbalance or imbalance is the deviation of each phase from the average voltage of all three phases. It can be calculated by the formula:

$$\text{Voltage unbalance} = 100 \times \frac{\text{max. deviation from average voltage}}{\text{average voltage}} \quad \text{---------------------(1)}$$

where average voltage _ (sum of voltage of each phase)/3.

H Voltage fluctuations

Voltage fluctuations are rapid changes in voltage within the allowable limits of voltage magnitude of 0.95 to 1.05 of nominal voltage. Devices like electric arc furnaces and welders that have continuous, rapid changes in load current cause voltage fluctuations. Voltage fluctuations can cause incandescent and fluorescent lights to blink rapidly. This blinking of lights is often referred to as "flicker." This change in light intensity occurs at frequencies of 6 to 8 Hz and is visible to the human eye. It can cause people to have headaches and become stressed and irritable. It can also cause sensitive equipment to malfunction.

I Harmonics

What are harmonics? Harmonics are the major source of sine waveform distortion. The increased use of nonlinear equipment have caused harmonics to become more common. Figure 8 shows the architecture of a standard sine wave. An analysis of the sine wave architecture provides an understanding of the basic anatomy of harmonics.
Harmonics are integral multiples of the fundamental frequency of the sine wave shown in Figure 8 that is, harmonics are

multiples of the 50-Hz fundamental voltage and current. They add to the fundamental 50-Hz waveform and distort it. They can be 2, 3, 4, 5, 6, 7, etc., times the fundamental.

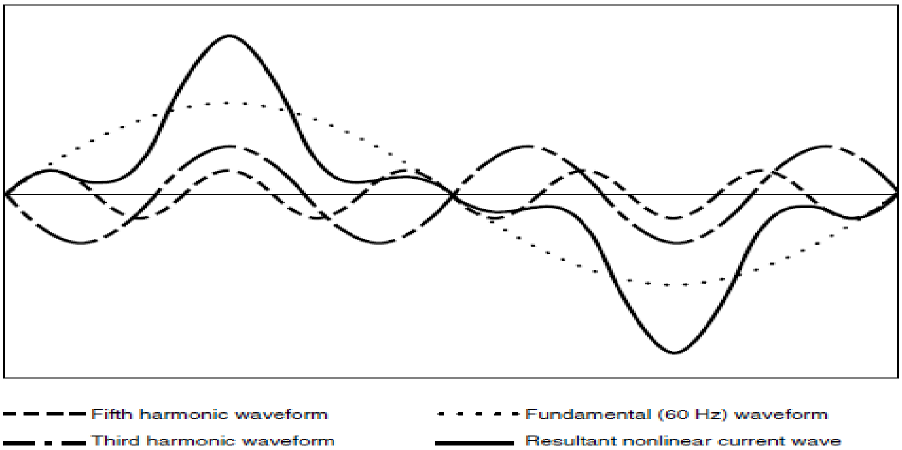

Fig.8. Composite harmonic waveform.

J Electrical Noise

When power quality experts talk about electrical noise, they do not mean these audible noises. They mean the electrical noise that is caused by a low-voltage, high-frequency (but lower than 200- Hz) signal superimposed on the 60-Hz fundamental waveform. This type of electrical noise may be transmitted through the air or wires. High-voltage lines, arcing from operating disconnect switches, startup of large motors, radio and TV stations, switched mode power supplies, loads with solid-state rectifiers, fluorescent lights, and power electronic devices can all cause this type of noise. Electrical noise adds "hash" onto the fundamental sine wave, as shown in Figure 9.

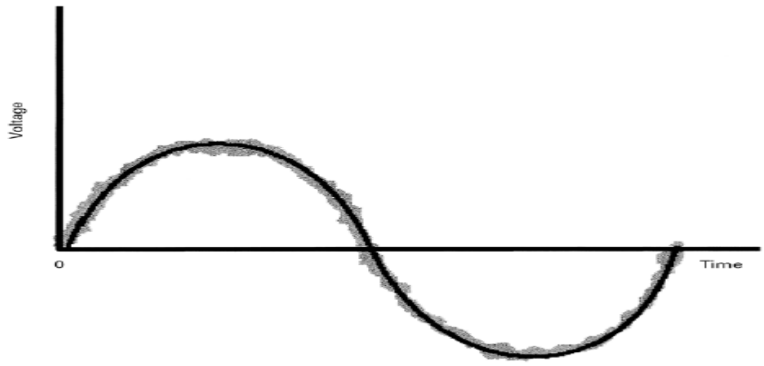

Fig.9. Electrical noise

III SOURSE OF POWER QUALITY PROBLEMS

Power quality experts find it a challenge to analyze any power quality problem and determine the source of the problem. They usually measure the effect of the problem and draw on their experience to identify the type of disturbance from the measurement. Even experienced power quality experts often find it is difficult to determine the source of the power quality problem. They know they need to understand the basic reasons why different devices and phenomena cause power quality problems. One common characteristic of sources of power quality problems is the interruption of the current or voltage sine wave.

The major sources of power quality problems can be divided into two categories, depending on the location of the source in relationship to the power meter. One category is on the utility side of the meter and includes switching operations, power system faults, and lightning. The other category is on the end-user side of the meter and includes non- linear loads, poor grounding, electromagnetic interference, and static electricity. So let's first examine the characteristics of utility-caused power quality problems.

A Utility side of the meter

Sources of power quality problems on the utility side of the meter involve some type of activity on the utility's electrical power system. They can be either man-made or natural events. They all involve some type of interruption of the current or voltage. The most common manmade causes are switching operations.

Utilities switch equipment on and off by the use of breakers, disconnect switches, or re-closers. Usually some type of fault on the power system causes a breaker to trip. Utilities trip breakers to perform routine maintenance. They also trip breakers to insert capacitors to improve the power factor. Lightning striking a power line or substation equipment, a tree touching a power line, a car hitting a power pole, or even an animal touching an energized line may cause the fault. The tripping of the breaker and the initiating fault can cause the voltage to sag or swell, depending on when in the periodic wave the tripping occurs. Utilities set breakers and re-closers to reclose on the fault to determine if the fault has cleared. If the fault has not cleared, the breaker or re-closer trips again and stays open.

Another type of utility activity that can cause oscillatory transients is the switching of power factor improvement capacitors. utilities use power factor improvement capacitors to improve the power factor by adding capacitive reactance to the power system. This causes the current and voltage to be in phase and thus reduces losses in the power system. When utilities insert capacitors in the power system, they momentarily cause an increase in the voltage and cause transients. Capacitors, if tuned to harmonics on the power system, can also amplify the harmonics.

Utility system faults occur on power lines or in power equipment. They are usually categorized by single-phase faults to ground, phase to- phase faults, or three-phase faults to ground. On the utility side of the meter, the type of fault often determines the type of disturbance. On the end-user side of the meter, the type of load or wiring and grounding conditions determine the type of power quality disturbance.

B End-user side of the meter

Sources of power quality problems on the end-user side of the meter usually involve a disruption of the sinusoidal voltage and current delivered to the end user by the utility. These disruptions can damage or cause minister peration of sensitive electronic equipment in not only the end-user's facilities but also in another end-user's facilities that is electrically connected.

a Nonlinear loads

There are today many types of nonlinear loads. They include all types of electronic equipment that use switched-mode power supplies, adjustable-speed drives, rectifiers converting ac to dc, inverters converting dc to ac, arc welders and arc furnaces, electronic and magnetic ballast in fluorescent lighting, and medical equipment like MRI (magnetic radiation imaging) and x-ray machines. Other devices that convert ac to dc and generate harmonics include battery chargers, UPSs, electron beam furnaces, and induction furnaces, to name just a few. All these devices change a smooth sinusoidal wave into irregular distorted wave shapes. The distorted wave shapes produce harmonics.

Most electronic devices use switched-mode power supplies that produce harmonics. Manufacturers of electronic equipment have found that they can eliminate a filter and eliminate the power supply transformer shown in figure 10.

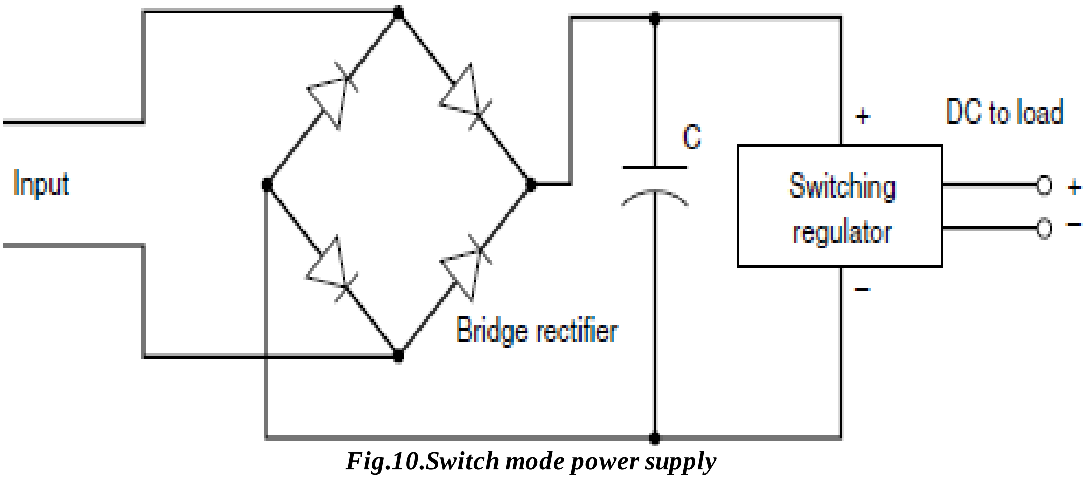

Fig.10.Switch mode power supply

Adjustable-speed drives save energy by adjusting the speed of the motor to fit the load. Residential heat pumps, commercial heating and ventilating systems, and factories that use motors in their processes benefit from the use of adjustable-speed drives. However, adjustable speed drives cause harmonics by varying the fundamental frequency in order to vary the speed of the drive.

Arc furnaces use extreme heat (3000°F) to melt metal. The furnace uses an electrical arc striking from a high-voltage electrode to the grounded metal to create this extreme heat. The arc is extinguished every half-cycle. The short circuit to ground causes the voltage to dip each time the arc strikes. This causes the lights to flicker at a frequency typically less than 60 Hz that is irritating to humans. Arc furnaces also generate harmonic currents.

Most nonlinear loads not only generate harmonics but cause low power factor. They cause low power factor by shifting the phase angle between the voltage and current.

b Power factor

Power factor is a way to measure the amount of reactive power required to supply an electrical system and an end-user's facility. Reactive power represents wasted electrical energy, because it does no useful work. Inductive loads require reactive power and constitute a major portion of the power consumed in industrial plants. Motors, transformers, fluorescent lights, arc welders, and induction heating furnaces all use reactive power.

Nonlinear loads often shift the phase angle between the load current and voltage, require reactive power to serve them, and cause low power factor. Linear motor loads require reactive power to turn the rotating magnetic field in the motor and cause low power factor. Nonlinear and linear loads that cause low power factor include induction motors of all types, power electronic power converters, arc welding machines, electric arc and induction furnaces, and fluorescent and other types of arc lighting. It is generally more energy-efficient and cost-effective to improve the power factor of the electrical system at an industrial plant than to require generators to provide the necessary reactive requirements of the plant's loads. Improving power factor can be accomplished through the addition of shunt capacitors.

Power factor improvement capacitors.

Power factor improvement capacitors improve the power factor by providing the reactive power needed by the load. They also reduce the phase shift difference between voltage and current. They supply the reactive, magnetized power required by electric loads, especially industrial loads that use inductive motors. Motors with their inductive, magnetizing, reactive power cause current to "lag" behind voltage. Capacitors create "leading" current. Capacitors act in opposition to inductive loads, thereby minimizing the reactive power required. When carefully controlled, the capacitor lead can match the motor lag, eliminate the need for reactive power, and increase the power factor toward unity.

c Harmonic resonance

Electrical harmonic resonance occurs when the inductive reactance of a power system equals the capacitive reactance of a power system. This is a good thing at the fundamental frequency of 60 Hz and results in the current and voltage being in phase and unity power factor. However, it is not so good when it occurs at a harmonic frequency. If resonance occurs at a harmonic frequency, the harmonic current reaches a maximum value and causes overheating of transformers, capacitors, and motors; tripping of relays; and incorrect meter readings.

d Poor wiring and grounding-

An EPRI survey found poor wiring and grounding in the end-user's facilities cause 80 percent of all power quality problems. The National Electrical Code (NEC) determines the design of the wiring and grounding. However, the NEC, as described in Section 90-1(b), is intended to protect people from fire and electrocution, not to protect sensitive electronic equipment from damage. As a consequence there is a great need to stablish guidelines for wiring and grounding that not only protects the public but prevents power quality problems.

e Electromagnetic interference (EMI)

Another source of power quality problems is electromagnetic interference (EMI). Some devices, like a large motor during start-up, emit a magnetic field that intersects with an adjacent sensitive device, like a computer or telephone.

f Static electricity

Another cause of power quality problems is static electricity. Static electricity occurs when the rubbing of one object against another causes a voltage buildup. Although static electricity power quality problems are infrequent, they are often overlooked. Static electricity can create voltages of 3000 V or more and damage sensitive electronic equipment.

IV POWER QUALITY SOLUTIONS

A Reduce Effects on Sensitive Equipment

Manufacturers of sensitive equipment can reduce or eliminate the effects of power quality problems by designing their equipment to be less sensitive to voltage variations. For instance, they can simply adjust an under voltage relay or add some device, like a capacitor, to provide temporary energy storage when the voltage sags too low. They can alter their equipment to desensitize it to power quality problems.

B Reduce or Eliminate Cause

Before a power quality engineer can reduce or eliminate the cause of a power quality problem, the engineer must diagnose the power quality problem to determine its source. A systematic approach to preventing a power quality problem is the best approach. A systematic approach requires procedures for designing and installing equipment that is sensitive to electrical disturbances as well as equipment that may cause electrical disturbances.

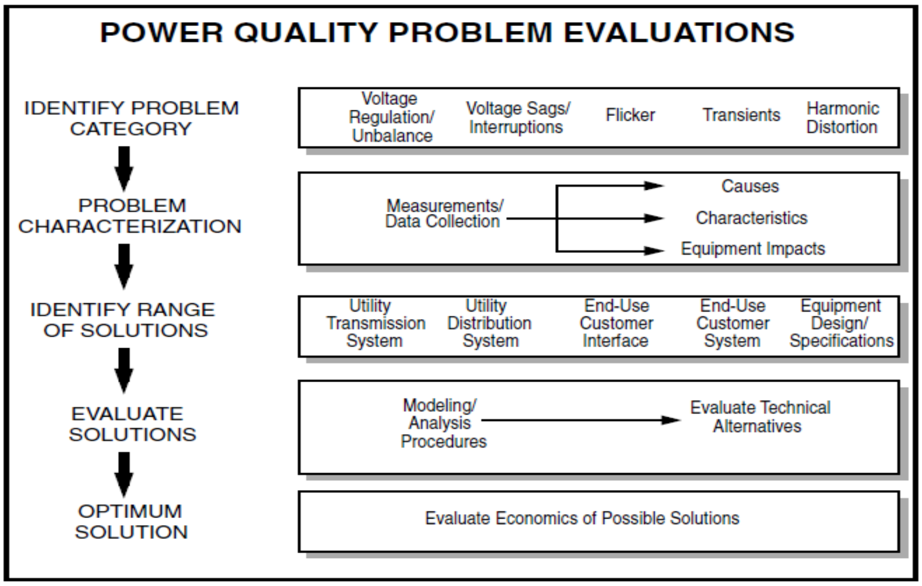

Fig.11 Basic steps in power quality problem evalutions

The location of the disturbance usually determines who is responsible for solving the power quality problem, as illustrated in Figure 12. The type of power quality problem and its cause often determine the solution. Changing the medium transmitting the power quality problem, whether wire or air, may be the best solution to a power quality problem.

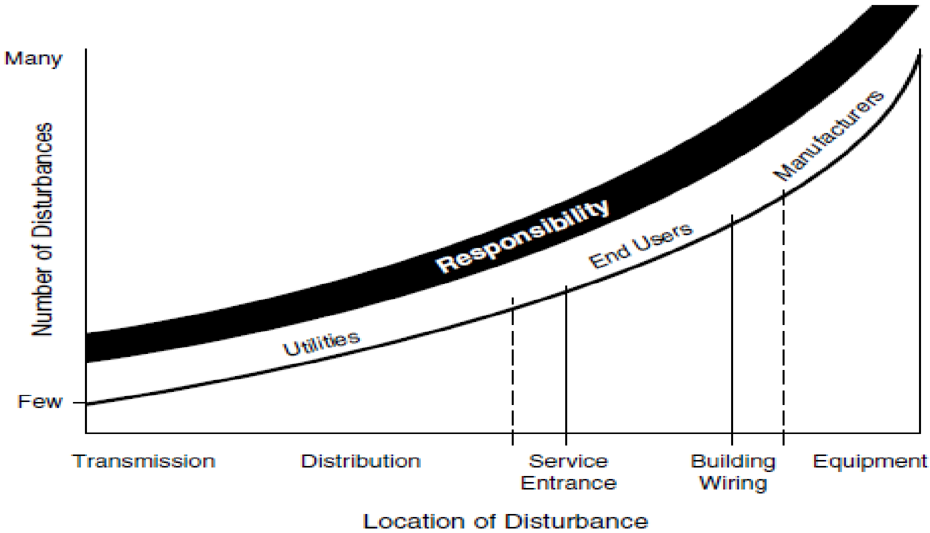

Fig.12 Power quality solution responsibility.

C Reduce or Eliminate Transfer Medium

Often the transmission and distribution system act as a conduit for transmitting harmonics, transients, voltage sag, or flicker from one end user to another. In that case, it is not practical to move the sensitive equipment to a location that is not connected to the system transmitting the power quality problem. For example, a transformer located in Idaho was generating third harmonics that were transmitted by the utility's interconnected transmission and distribution system to digital clocks in Washington and causing them to blink off and on. The best solution was to eliminate the source of the third harmonics by replacing the transformers or installing filters on the transformers.

D- Install Power Conditioning Equipment

Power conditioning equipment provides essential protection against power quality problems. Power conditioning equipment does refer to devices that are supposed to make "dirty" power "clean." Depending on the type of equipment, it conditions (modifies) the power by improving the quality and reliability of the power at any part of the power system. It can be used to condition the source, the transmitter, or the receiver of the power quality problem.

E Other Harmonic Solutions

The first way to prevent harmonic problems is to design equipment so that it is not affected by the harmonics. Equipment can be designed to withstand the heating effects of harmonics. For example, the engineer can design neutral conductors large enough to carry large neutral currents caused by the additive effects of triplen (third, sixth, ninth, twelfth, etc.) harmonics.The second way to prevent harmonic problems is to properly design and specify equipment that is the source of harmonics or the cause of amplifying harmonics.

F Selection of Appropriate Power Conditioning Equipment

End users should implement the following seven steps before selecting the appropriate power conditioning equipment to mitigate their problem:

1. Determine the power quality problem.
2. Correct wiring and grounding and faulty equipment problems before purchasing power conditioning equipment.
3. Evaluate alternative power conditioning solutions.
4. Develop a power conditioning plan.
5. Determine if the utility source is compatible with the load.
6. Select and install power conditioning equipment.
7. Operate and maintain power conditioning equipment properly.

G Grounding and Wiring Solutions

Recent surveys by EPRI and others indicate that improper grounding and wiring cause 80 to 90 percent of the power quality problems. However, many end users overlook improper grounding and wiring in their facilities.

V CONCLUSION

In this paper all the problems relatated to power quality are discussed. It is understood that power quality problems either from utility side or from end user side. Various sources of this problem is discussed. Finally the solution for this problems are discussed. It involves installing power conditioning equipment, such as filters, isolation transformers, UPSs, and TVSSs, to protect sensitive equipment from damage caused by power quality problems. Also by designing equipment so that it does not add to a potential problem.

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