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Research Paper

POWER QUALITY

Vignesh R[1]*, Vivek S[1], Saravanan S[1] and Sabarish S[1]

*Corresponding Author: Vignesh R, ✉ vignesh.ee14@bitsathy.ac.in

The power quality plays a major role in the life of our equipment. For the proper functioning of our equipment the supplied power should be of good quality. Power quality declines due to many factors. Some of which includes lightning, switching transients, brown outs, sharing of neutrals in large infrastructural areas. It also causes harmonic distortions. Poor power quality leads to large economical loses. the loses are in the range of several billion dollars. Poor Power quality affects the power supply system and cause damage to the power supply systems and cause more economical loss to the consumers. Low power quality mainly affects the domestically appliances like personal computer, inductive motors and commercial appliances like aircraft controlling systems, rectifiers, etc. Power quality monitoring is the mechanism widely used to monitor the power over power supply systems and made the record of fluctuations in the waveform, voltage supply, harmonic distortion, etc. Harmonic distortions widely play role in power quality and increase frequencies of harmonics will generate great destruction to the power supply systems. To overcome all such difficulties rectification of power supply is made. Good rectification is made through of proper grounding of power equipment and well designed loads in the power supply systems. In order to have good quality of power we have to maintain power factor near unity. In order to maintain the power factor in places where large inductive loads are used, a capacitor is connected in parallel to the inductive load. Uninterrupted power supplies are also used to safeguard the sensitive equipment from the interruptions. It has island switching mechanism which will cause the sensitive loads to run on batteries.

Keywords: Power quality, Harmonics, Loads, Brownouts, Power factor, Economical losses, Blackouts, Rectification, Grounding, Transients, Power quality standards

INTRODUCTION

Power quality may be defined as the fitness of the power to the consumer devices. The supply power is said to be of good quality if the systems connected to it performs without loss of performance of life. Quality inn any other parameter has no objective and varies according to the person. But in case of power quality it has an objective and has a clear metric. The supplied power should be free from

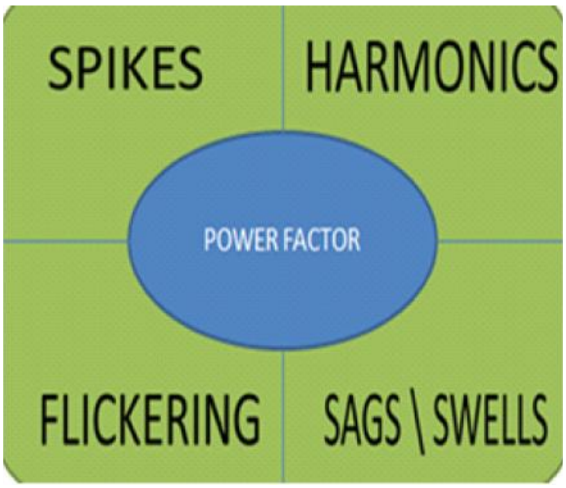
[1] Department of EEE, Bannari Amman Institute of Technology, Sathyamangalam, India.

interferences. The quality of power is ruined by many factors like lighting and usage of some nonlinear devices like rectifiers, computers, printers, battery chargers and variable speed drives. In order to maintain the proper functioning of our equipment we should make sure that the power used is of good quality. We could maintain power quality by hybrid harmonic filters, uninterrupted power supplies, etc. This paper discuses about the various problems related to the power quality and their rectification methods.

DEFINITION FOR POWER QUALITY

Power Quality is defined in the Institute of Electrical and Electronics Engineers (IEEE) 100 Authoritative Dictionary of IEEE Standard Terms as "the concept of powering and grounding 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." Utilities may want to define power quality as reliability (WWW.APQI.ORG).

Figure 1



The electrical power is perfect for end users if voltage and current are correctly balanced and describe a pure sinusoidal wave form. This can be distorted by disturbances such as interruptions, dips or surges, harmonic pollution, and interference. Power quality can be degraded by any of these phenomena (Leonardo Energy Power Quality).

CAUSES FOR POOR POWER QUALITY

some of the causes of power quality problems are

1. Lightning
2. Shared neutrals on branch circuits
3. Miss wired receptacles
4. Switching of utility capacitor
5. Utility automatic breaker reclosure (Engineering Exchange).

The lightning, utility grid switching and usage of heavy industrial equipment leads to voltage spikes and surges. Sometimes electrical noises are produced due to the usage of arc welders, switch mode power supplies and fault cleaning devices. The switch mode power supplies and the nonlinear loads cause harmonics. Harmonics are the integral multiples of the actual frequency in the given wave. On the other hand voltage fluctuations are caused by brown outs, unstable generators. Sudden switching of heavy loads also causes voltage fluctuations. Usage of backup generator start up leads to power outage and interruption. They are also caused by blackouts and sometimes due to overloads (Vikash Anands (Journal)).

Some problems are a result of the shared infrastructure. For example, a fault on the network may cause a dip that will affect some customers; the higher the level of the fault, the greater the number affected. A problem on one customer's site may cause a transient that affects all other customers on the same subsystem. Problems, such as harmonics, arise within the customer's own installation and may propagate onto the network and affect other customers. Harmonic problems can be dealt with by a combination of good design practice and well proven reduction equipment (Wikipedia, The Free Encyclopedia)

BROWNOUTS

The term blackout is renamed as brownout in 1940's. Brownout is defined as an intentional or unintentional drop in voltage. Intentional brownouts are used for load reduction in an emergency. These reduction lasts for minutes or seconds. Brownouts are nothing but the dimming experienced by lighting when the voltage sags (dip). In some media reports the term brownouts refers to an intentional or unintentional power outage or blackout of some areas , rather than to a drop in the voltage (Steven Warren Blume, 2007).

Effects

- Brownouts causes unexpected behavior in systems with digital control circuits.
- Reduced voltages bring control signals below the threshold at which the logic circuits can reliably detect which state is being represented.
- Brownouts cause a motor to begin running backwards.
- Commutaded electric motors, such as universal motors will run at reduced speed or with reduced torque.
- Induction motors will draw more current to compensate for the decreased voltage which may lead to overheating and burnout.
- A SMPS which has a regulated output, will be affected.
- An unregulated direct current supply will produce a lower output voltage for electronic circuits (Wikipedia, The Free Encyclopedia).

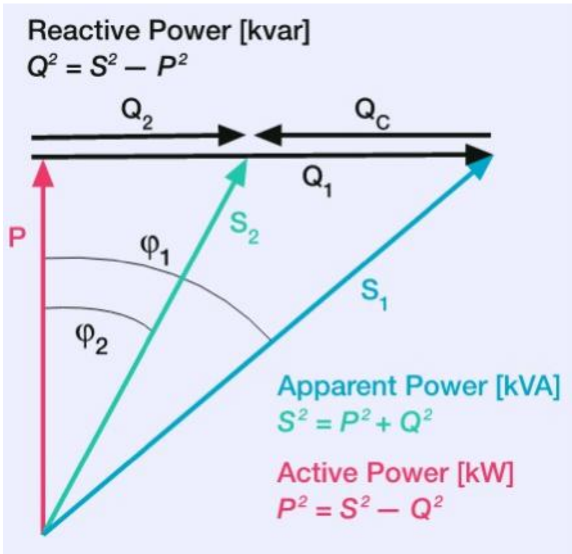
EFFECTS OF POWER QUALITY IN DIFFERENT POWER SYSTEM

Most of the power equipment systems are affected by the power quality. Some the devices affected by the power quality are:

Electrical Systems of Aircrafts

Aircraft power systems require uninterrupted, reliable power supply for the fly-by-wire loads and to the critical loads. When the critical loads switched between one to another it will affect the power quality. The transient conditions will

Figure 2

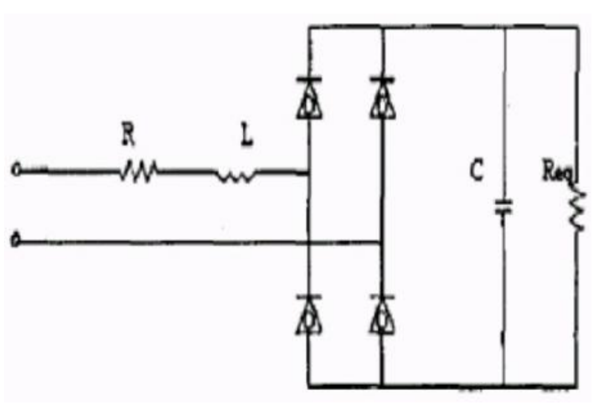


also affect the power quality. The major problem for the arise of power quality problems is mainly due to presence of rectifies which supply the power signals for the flight control devices (avionic devices). Another major cause for the problem is loads. When the load level changes within f short interval time it will greatly produce the voltage fluctuations in the supply.

Personal Computers

A computer is a device which is a very high computing machine works based on the numerous integrated power circuits and the critical power supplies. The voltage disturbances in the power supply greatly affects the personal computer and produce malfunction to the system. When the DC filter capacitor voltage of the power supply is not synchronized with respective time it mainly creates the major problems like locking of the screen, blocking of operating system and no response to the output devices (freeze screen), etc.

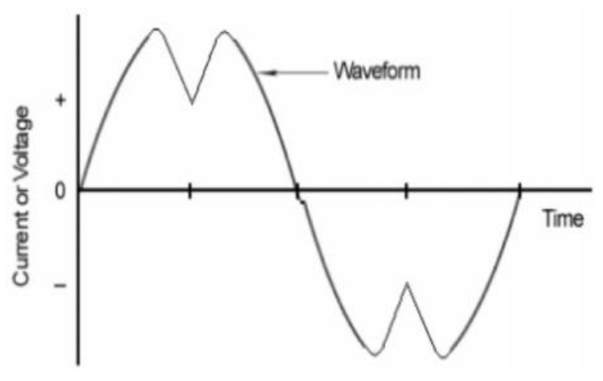
Figure 3



Controllers of the Power Supply

Controller is a device used to control the power supply to the ac components by means of electrical, mechanical, and hydraulic

Figure 4



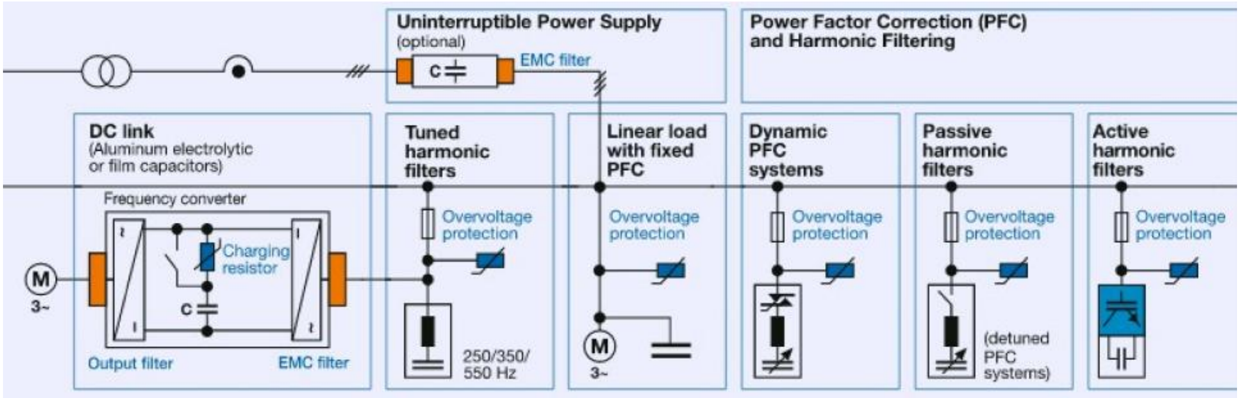
controlling systems. When the voltage sag occurs in the controlling devices it is difficult for the controllers to overcome the sensitivity of relays with the power supplies supplied from the switched mode supplies (Khalid and Bharti Dwivedi).

HARMONIC DISTORTION EFFECTS

The loads are basically two types which are linear and non-linear. The linear loads mostly consume the current in the sinusoidal form which does not produce more distortion in the waveform of the power supply. Most of the household devices are linear loads. A perfect waveform does not contain any distortions in it and it is basically a ideal sinewave. Total harmonic distortion of the waveform is given by the summation of all current and voltage waveforms of the all harmonic components in the voltage component systems.

Harmonics will continue to emerge in the supply of power system from the very first power generators. Harmonics distortion will greatly increase when the power supply systems consists of more consumer loads in it. High frequency harmonics will produce the core loss in the inductive motors and also lead

Figure 5



to the damage of inductive core in the motors. When the harmonics distortion are unidentified for the long time the increase in temperature due to the harmonic distortion and interference of the harmonics will greatly lead to complete destruction of the equipment and the lifetime of the power systems could be greatly reduced (hyperphysics.phy-astr.gsu.edu/hbase/waves/funhar.html and ecmweb.com › content).

ECONOMICAL LOSSES DUE TO POOR POWER QUALITY

Berkeley Lab Study Estimates $80 Billion Annual Cost of Power Interruptions … Research News, Berkeley Lab, February 2, 2005

$50 billon per year in the USA is lost as a results of power quality breakdowns …. Bank of America Report

A manufacturing company lost more than $3 million one day last summer in Silicon Valley when the "lights went out." … New York Times January 2000.

"A voltage sag in a paper mill can waste a whole day of production - $250,000 loss" … Business Week, June 17, 1996.

Half of all computer problems and one-third of all data loss can be traced back to the power line … Contingency Planning Research, LAN Times (John Levine).

Figure 6

Category	Cost of Momentary Interuption ($/kW Demand) Minimum	Maximum
Industrial		
Semiconductor Manufacturing	$20.0	$60.0
Electronics	$8.0	$12.0
Automobile Manufacturing	$5.0	$7.5
Pharmaceutical	$5.0	$50.0
Glass	$4.0	$6.0
Rubber and Plastics	$3.0	$4.5
Petrochemical	$3.0	$5.0
Food Processing	$3.0	$5.0
Textile	$2.0	$4.0
Metal Fabrication	$2.0	$4.0
Mining	$2.0	$4.0
Paper	$1.5	$2.5
Printing(Newspapers)	$1.0	$2.0
Commercial		
Hospitals, banks, civil service	$2.0	$3.0
Communications, information processing	$1.0	$10.0
Resturants, bars, hotels	$0.5	$1.0
Commercial shops	$0.1	$0.5

Source: EPRI "The Economics of Custom Power", IEEE T&D 2003

Table 1

	Industry Category	Momentary US $	Planned US $/hr	Unplanned US $/hr
1.	Food, beverage and tobacco products	301.61	301.61	363.24
	Food and other	211.68	166.18	279.28
	Liquor	2.60	7.41	7.41
	Beverage	139.48	160.67	160.67
	Tobacco products	4362.88	15.55	4318.43
2.	Textile, wearing apparel and leather products	121.55	107.94	186.36
	Apparel	120.99	81.77	161.28
	Textile	109.87	133.55	198.70
	Leather	247.98	247.98	354.08
3.	Chemical, petroleum, rubber and plastic products	155.57	83.12	217.90
	Chemicals, paints and fertilizers	220.98	315.81	315.81
	Rubber	66.63	56.97	110.07
	Plastic and PVC	187.17	110.17	288.27
	Pharmaceutical detergent and other	179.52	4.55	199.49
	Petroleum products	0.00	65.00	65.00
4.	Nonmetallic mineral products	169.32	108.08	266.51
	Diamond processing	50.48	50.99	50.99
	Ceramic products	100.02	98.34	171.81
	Cement	782.39	581.59	1636.31
	Building material and other	134.79	54.00	151.10
5.	Fabricated metal products, machinery and transport equipment	125.25	415.90	429.31
6.	Tea industry	4.23	21.75	21.75
7.	Coconut industry	0.82	75.17	131.20
8.	Hotel industry	0.00	25.57	25.57

The momentary interruptions are the interruptions which are independent from the time period in which the interruptions take place. But the planned and the unplanned outages are directly dependent on the time period and over course of time they become functions of time. European Power Quality Survey (Leonardo Energy, 2008).

The following average costs by type of poor Power Quality event were calculated from the survey results:

Surge or transient: €120,000-180,000

Long interruption: €90,000

Short interruption, service sectors: €18,000-36,000

Short interruption, industry: €7,000-14,000

Voltage dip: €2,000-4,000

Industry: Typical financial loss per event Semiconductor production €3,800,000

Financial trading €6,000,000 per hour

Computer centre €750,000

Telecommunications €30,000 per minute

Steel works €350,000

Glass industry €250,000

The above survey was performed in the European countries (Leonardo Energy, 2008)

POWER QUALITY MONITORING

Power quality monitoring is a mechanism which is used to measure continuously the power quality in the power supply systems. This mechanism examines the list of conditions in the power supply systems.

1. Harmonic fluctuations between the loads and required power system equipments.
2. During the startup high absorption of current by the equipment is detected.
3. Transient response.
4. Interruptions of waveforms.
5. Voltage sag and swells
6. Waveform distortion.
7. Voltage fluctuation.
8. Frequency variations.

ADVANTAGES OF POWER QUALITY MONITORING

1. Be easy to use.
2. Best suited for continuous monitoring in indoors and outdoors.
3. Storage of waveforms can be easily done.

RECTIFICATION OF POWER QUALITY PROBLEMS

1. Proper construction of the load equipment.

Figure 7

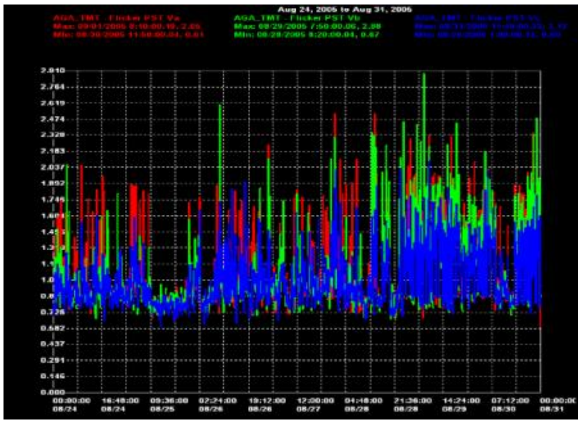
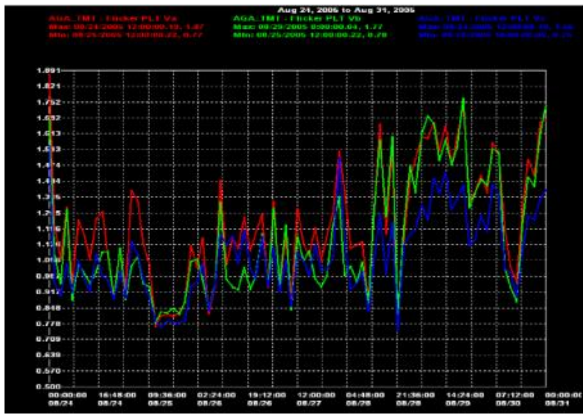


Figure 8



2. Usage of active, passive and hybrid harmonic filters.
3. Well design of the power supply system.
4. Using the standby power.
5. Use of uninterrupted power supplies.
6. Application of voltage compensators.

Figure 9

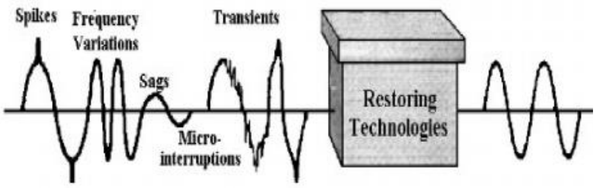
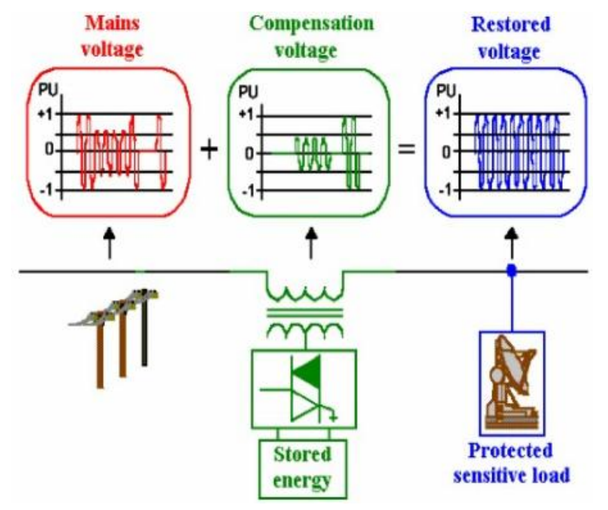


Figure 10



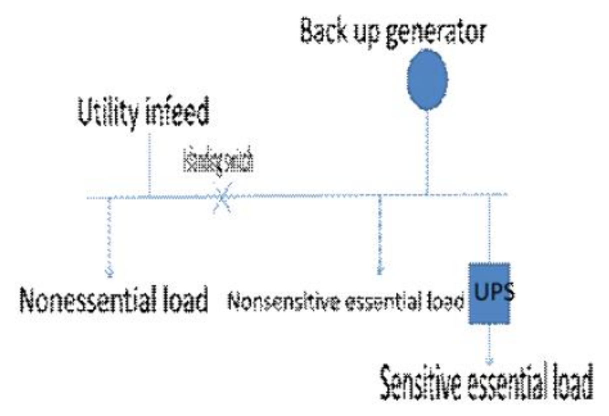
IMROVEMENT OF EQUIPMENT

There are some long-term solutions for the power quality problems. The voltage sags can be avoided by installing an additional capacitor. But this causes additional causes for installing the capacitor. Meanwhile installing an additional capacitance will cause the inrush on the voltage recovery to become severe. This method also has its limits. It is not viable for dc drives. It cannot maintain balanced voltage sag across the various drives (*Math H. J. Bollen.*).

UPS AND BACKUP GENERATORS

The Uninterrupted Power Supply (UPS) is also used to reduce the voltage sags and eliminate the interruptions in the power supply. It mainly protects the sensitive loads which are easily damaged by high voltages. Large loads cannot be driven for a long time by the batteries. The charge will be drained within a few seconds. To avoid this there is an islanding switch. When there is a interruption in the power supply the islanding switch opens. This will disconnect the sensitive loads from the main power supply. Now the sensitive loads will be running on the batteries. All the other loads are powered by the backup generator. The energy storage requirement will become minimized if the island switching operation takes place quickly.

Figure 11



POWER FACTOR IMPROVEMENT

To have good power quality the power factor has to be maintained properly. The power factor is expressed as:

The power factor has to be maintained unity in order to have sufficiency. When the inductive reactance is higher in the given load the power factor will get reduced. In order to bring unity the inductive reactance must be equal to the capacitive reactance. Hence $X_L = X_C$, now the reactance due to the capacitor and the inductor gets cancelled. Now the power factor will become unity.

We come to know that when the power factor is reduced due to inductive load. This can be reduced by adding a capacitive load in parallel to the inductive load. Hence the power factor nearly becomes unity.

Power factor can also be reduced by using synchronous condenser and phase advancer (*Math H. J. Bollen.*).

POWER QUALITY STANDARDS

The standards for the power quality parameters mentioned by the IEEE association are as follows:

1. IEEE 519 IEEE 519-1992, Recommended Practices and Requirements for Harmonic Control in Electric Power Systems, established limits on harmonic currents and voltages at the Point of Common Coupling (PCC), or point of metering. The limits of IEEE 519 are intended to: 1) Assure that the electric utility can deliver relatively clean power to all of its customers, 2) Assure that the electric utility can protect its electrical equipment from overheating, loss of life from excessive harmonic currents, and excessive voltage stress due to excessive harmonic voltage. Each point from IEEE 519 lists the limits for harmonic distortion at the Point of Common Coupling (PCC) or metering point with the utility. The voltage distortion limits are 3% for individual harmonics and 5% THD. All of the harmonic limits in IEEE 519 are based on a customer load mix and location on the power system. The limits are not applied to particular equipment, although, with a high amount of nonlinear loads, it is likely that some harmonic suppression may be necessary.

IEEE 519 Standard for Curent Harmonics

General Distribution Systems [120 V-69 kV] Below current distortion limits are for odd harmonics. Even harmonics are limited to 25% of the odd harmonic limits. For all power generation equipment, distortion limits are those with I SC/I L<20.I SC is the maximum short circuit current at the point of coupling "PCC". IL is the maximum fundamental frequency 15-or 30-minutes load current at PCC. TDD is the Total Demand Distortion (= THD normalized by I L).

General Sub-transmission Systems [69 k V-161 kV]

The current harmonic distortion limits apply to limits of harmonics that loads should draw from the utility at the PCC. Note that the harmonic limits differ based on the I SC/I L rating, where I SC is the maximum short-circuit current at the PCC, and I is the maximum demand load current at the PCC.

IEEE Standard for Voltage Harmonics

IEEE-519-Voltage Distortion Limits the voltage harmonic distortion limits apply to the quality of the power. For instance, for systems of less than 69 kV, IEEE 519 requires limits of 3% harmonic distortion for an individual frequency component and 5% for total harmonic distortion.

IEC 61000-3-2 and IEC 61000-3-4 (Formerly 1000-3-2 and 1000-3-4)

IEC 61000-3-2 (1995-03) It specifies limits for harmonic current emissions applicable to electrical and electronic equipment having an input current up to and including 16 A per phase, and intended to be connected to public low-voltage

distribution systems. The tests according to this standard are type tests.

2. IEEE Standard 141-1993, Recommended Practice for Electric Power Distribution for Industrial Plants A thorough analysis of basic electrical-system considerations is presented. Guidance is provided in design, construction, and continuity of an overall system to achieve safety of life and preservation of property; reliability; simplicity of operation; voltage regulation in the utilization of equipment within the tolerance limits under all load conditions; care and maintenance; and flexibility to permit development and expansion.

3. IEEE Standard 142-1991, Recommended Practice for Grounding of Industrial and Commercial Power Systems. This standard presents a thorough investigation of the problems of grounding and the methods for solving these problems. There is a separate chapter for grounding sensitive equipment.

4. IEEE Standard 446-1987, Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications. This standard is recommended engineering practices for the selection and application of emergency and standby power systems. It provides facility designers, operators and owners with guidelines for assuring uninterrupted power, virtually free of frequency excursions and voltage dips, surges, and transients.

5. IEEE Standard 493-1997, Recommended Practice for Design of Reliable Industrial and Commercial Power Systems. The fundamentals of reliability analysis as it applies to the planning and design of industrial and commercial electric power distribution systems are presented. Included are basic concepts of reliability analysis by probability methods, fundamentals of power system reliability evaluation, economic evaluation of reliability, cost of power outage data, equipment reliability data, and examples of reliability analysis. Emergency and standby power, electrical preventive maintenance, and evaluating and improving reliability of the existing plant are also addressed.

6. IEEE Standard 1100-1999, Recommended Practice for Powering and Grounding Sensitive Electronic Equipment Recommended design, installation, and maintenance practices for electrical power and grounding (including both power-related and signal-related noise control) of sensitive electronic processing equipment used in commercial and industrial applications.

7. IEEE Standard 1159-1995, Recommended Practice for Monitoring Electric Power Quality. As its title suggests, this standard covers recommended methods of measuring power-quality events. Many different types of power-quality measurement devices exist and it is important for workers in different areas of power distribution, transmission, and processing to use the same language and measurement techniques Monitoring of electric power quality of AC power

systems, definitions of power quality terminology, impact of poor power quality on utility and customer equipment, and the measurement of electromagnetic phenomena are covered.

8. IEEE Standard 1250-1995, Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances Computers, computer-like products, and equipment using solid-state power conversion have created entirely new areas of power quality considerations. There is an increasing awareness that much of this new user equipment is not designed to withstand the surges, faults, and reclosing duty present on typical distributions systems. Momentary voltage disturbances occurring in ac power distribution and utilization systems, their potential effects on this new, sensitive, user equipment, and guidance toward mitigation of these effects are described. Harmonic distortion limits are also discussed.

9. IEEE Standard 1346-1998 Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment A standard methodology for the technical and financial analysis of voltage sag compatibility between process equipment and electric power systems is recommended. The methodology presented is intended to be used as a planning tool to quantify the voltage sag environment and process sensitivity

10. Standards related to Voltage Sag and Reliability The distribution voltage quality standard, i.e., IEEE Standard P1564 gives the recommended indices and procedures for characterizing voltage sag performance and comparing performance across different systems. A new IEC Standard 61000-2-8 titled "Environment—Voltage Dips and Short Interruptions" has come recently. This standards warrants considerable discussion within the IEEE to avoid conflicting methods of characterizing system performance in different parts of the world.

11. Standards related to Flicker Developments in voltage flicker standards demonstrate how the industry can successfully coordinate IEEE and IEC activities. IEC Standard 61000-4-15 defines the measurement procedure and monitor requirements for characterizing flicker. The IEEE flicker task force working on Standard P1453 is set to adopt the IEC standard as its own.

12. Standards related to Custom Power IEEE Standard P1409 is currently developing an application guide for custom power technologies to provide enhanced power quality on the distribution system. This is an important area for many utilities that may want to offer enhanced power quality services.

13. Standards related to Distributed Generation The new IEEE Standard P1547 provides guidelines for interconnecting distributed generation with the power system.

If we follow this standards we could maintain power quality.

CONCLUSION

Power quality is the major crisis in the power supply systems. Low Power quality causes major economical losses for the industries. Very poor power quality will cause the shortage of electricity for domestic appliances and for the machineries in the industries. Many issues were arised on the topics of power quality and many steps were taken for the maintenance of power quality in the industries. More concentration should be taken on the proper grounding of the power systems and in the designing of the loads, etc. Poor power quality causes huge economical loses in range of several billions. The electrical parameters should be maintained in a standard values in order to keep up power quality. The standards for the electrical parameters are given above. If these standards are maintained properly power quality can be easily maintained. Hence a large number of scholars are working in order to maintain good power quality in order to avoid considerable loses in industries which have very sensitive loads.

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