POWER QUALITY ISSUES, PROBLEMS, STANDARDS & THEIR EFFECTS IN INDUSTRY WITH CORRECTIVE MEANS

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ABSTRACT

Latest innovative ideas to make the life easier using the technology depends upon the application of power electronics in turn about power quality. With increasing quantities of non-linear loads being added to electrical systems, it has become necessary to establish criteria for limiting problems from system voltage degradation.
This paper presents the power quality problems, issues, related international standard, effect of power quality problem in different apparatuses and methods for its correction, which is actually a technology management. This is important for design engineers and researchers in power quality to know the international standards used for power quality.

Keywords

IEEE 519, Power quality, Voltage Sag, THD.

I. INTRODUCTION

The paper and the technology on which it is grounded are largely motivated by the power quality issues. The term power quality is rather general concept. Broadly, it may be defined as provision of voltages and system design so that user of electric power can utilized electric energy from the distribution system successfully, without interference on interruption.
Power quality is defined in the 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 [8].
From the Power Quality market or industry perspective, it is any product or service that is supplied to users or utilities to measure, treat, remedy, educate engineers or prevent Power Quality issues, problems and related items [6,8,12,13,15,23,28].
This paper critically discusses about the power quality problems, issues and related standards, assessment of power quality issues and methods for its correction with giving a thorough knowledge of harmonics, power quality indices, parameters effecting electric power etc.

II. POWER QUALITY PROBLEMS & ISSUES

A recent survey of Power Quality experts indicates that 50% of all Power Quality problems are related to grounding, ground bonds, and neutral to ground voltages, ground loops, ground current or other ground associated issues. Electrically operated or connected equipment is affected by Power Quality [9, 10,11, 12, 15, and 16].
Determining the exact problems requires sophisticated electronic test equipment. The following symptoms are indicators of Power Quality problems:

- Piece of equipment misoperates at the same time of day.
- Circuit breakers trip without being overloaded.
- Equipment fails during a thunderstorm.

- Automated systems stop for no apparent reason.
- Electronic systems fail or fail to operate on a frequent basis.
- Electronic systems work in one location but not in another location.

The commonly used terms those describe the parameters of electrical power that describe or measure power quality are Voltage sags, Voltage variations, Interruptions Swells, Brownouts, Blackouts, Voltage imbalance, Distortion, Harmonics, Harmonic resonance, Interharmonics, Notching, Noise, Impulse, Spikes (Voltage), Ground noise, Common mode noise, Critical load, Crest factor, Electromagnetic compatibility, Dropout, Fault, Flicker, Ground, Raw power, Clean ground, Ground loops, Voltage fluctuations, Transient, Dirty power, Momentary interruption, Over voltage, Under voltage, Non-linear load, THD, Triplens, Voltage dip, Voltage regulation, Blink, Oscillatory transient etc [4,6,14,18,19]. The issue of electric power quality is gaining importance because of several reasons:

- The society is becoming increasingly dependent on the electrical supply. A small power outage has a great economical impact on the industrial consumers. A longer interruption harms practically all operations of a modern society.
- New equipments are more sensitive to power quality variations.
- The advent of new power electronic equipment, such as variable speed drives and switched mode power supplies, has brought new disturbances into the supply system.

III. POWER QUALITY STANDARDS

Power quality is a worldwide issue, and keeping related standards current is a never-ending task. It typically takes years to push changes through the process.
Most of the ongoing work by the IEEE in harmonic standards development has shifted to modifying Standard 519-1992.

A. 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 [1,18].
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.

a. IEEE 519 Standard for Curent Harmonics

- *General Distribution Systems [120V- 69 kV]*

Below current distortion limits are for odd harmonics. Even harmonics are limited to 25% of the odd harmonic limits [1,3,5]. 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". I_L 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 kV-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.

TABLE 1
Current Distortion Limits For Harmonics

I_{SC}/I_L	h<11	11≤h <17	17≤h<23	23≤h<25	h≥35	TDD (%)
<50	2.0	1.0	0.75	0.3	0.15	2.5
≥50	3.0	1.5	1.15	0.45	0.22	3.75

TABLE 2: Current Distortion Limits For Harmonics.

I_{SC}/I_L	h<11	11≤h<17	17≤h<23	23≤h<25	TDD (%)
<20	4.0	2.0	1.5	0.6	5
20-50	7.0	3.5	2.5	1.0	8
50-100	10	4.5	4.0	1.5	12
100-1000	12	5.5	5.0	2.0	15
>1000	15	7.0	6.0	2.5	20

b. 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 percent harmonic distortion for an individual frequency component and 5 percent for total harmonic distortion.

TABLE 3 : Voltage Distortion Limits For Harmonics.

Bus voltage	Individual V_b(%)	THDV(%)
V <69 kV	3.0	5.0
69≤V<161 kV	1.5	2.5
V≥161 kV	1.0	1.5

B. IEC 61000-3-2 and IEC 61000-3-4 (formerly 1000-3-2 and 1000-3-4)

a. 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 [2,10,15].

b. IEC/TS 61000-3-4 (1998-10

It specifies to electrical and electronic equipment with a rated input current exceeding 16 A per phase and intended to be connected to public low-voltage ac distribution systems of the following types:

- nominal voltage up to 240 V, single-phase, two or three wires;
- nominal voltage up to 600 V, three-phase, three or four wires;
- nominal frequency 50 Hz or 60 Hz

These recommendations specify the information required to enable a supply authority to assess equipment regarding harmonic disturbance and to decide whether or not the equipment is acceptable for connection with regard to the harmonic distortion aspect. The European standards, IEC 61000-3-2 & 61000-3-4, placing current harmonic limits on equipment, are designed to protect the small consumer's equipment. The former is restricted to 16 A; the latter extends the range above 16 A.

C. 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.

D. 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 [3, 6].

E. 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 [6].

F. 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 [4,6,7,8,11].

G. 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 [6,8]

H. 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 [5,8,12,13,14].

I. IEEE Standard 1250-1995, Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

Computers, computer-like products, and equipment using solidstate 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 [6,19,36].

J. 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

H. 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 [2].

I. 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 [2].

J. 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 [4,5, 6,7].

K. Standards related to Distributed Generation

The new IEEE Standard P1547 provides guidelines for interconnecting distributed generation with the power system [5, 6,11].

IV. EFFECT OF POWER QUALITY PROBLEMS IN EQUIPMENTS & METHODS FOR ITS CORRECTION

The first sign of a power-quality problem is a distortion in the voltage waveform of the power source from a sine wave, or in the amplitude from an established reference level, or a complete interruption. The disturbance can be caused by harmonics in the current or by events in the main voltage supply system. The disturbance can go for a fraction of a cycle (milliseconds) to great durations (seconds to hours) in the voltage supplied by the source.

The aim for method for correction is to make the power source meet an international standard. Power-quality problems can basically start at four levels of the system that delivers electric power, first one, includes Power plants and the entire area transmission system. The second one are Transmission lines, major substations where as third one includes distribution substations, primary, and secondary power lines, and distribution transformers and last and fourth one includes service equipment and building wiring.

In addition, the problems can be caused by the equipment supplied with electric power—for example, power-electronic converters. Redundancy at all levels of the electric-power system reduces the incidence and duration of line-voltage disturbances [9, 11, 12, 14, 16, 17, 22, 23].

A. Effect of power quality problems in different equipments

Some of the equipment affected by power-quality problems are discussed under the following heads:

a. Aircraft electrical System
b. Personal computers
c. Controllers
d. Adjustable speed drives
e. Contactors and Relays

a. Aircraft Electrical System

Aircraft requires reliable, redundant, and uninterruptible electrical power systems to supply flight critical fly-by-wire loads and mission critical loads. But switched loads and other transient conditions effect the electrical bus power quality.

One problem is the presence of rectifiers supplying such loads as electrically powered flight control actuators, other speed controlled motor loads, or avionics loads, see Figure 1.

The other problem is a load which changes load level most often. An electrical flight control actuator supplied with dc would cause transient loading on the dc bus, and affect power quality. A fuel transfer pump, electrically driven compressor, or other non-continuous ac load would cause applied-load transients on the ac bus.

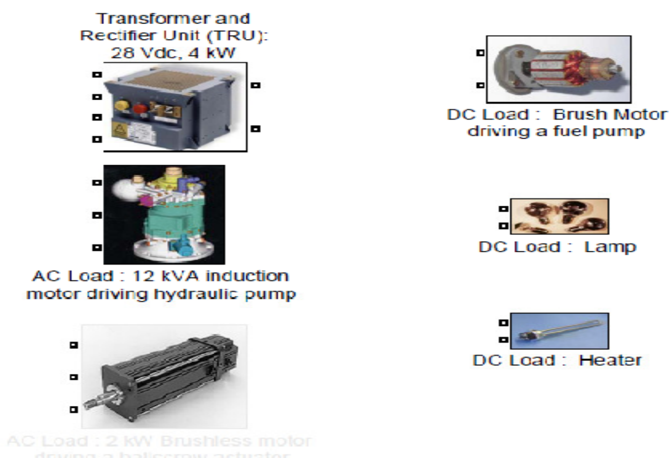

Figure 1 Different type of loads used in Aircraft [37]

Another problem may occur when a source fails and the loads are switched from one bus to another. This type of transient occurs infrequently and would produce an actual power interruption. Many connected devices such as induction motors, could through such a power interruption, even if two buses were not synchronized [31].

b. Personal Computers

A personal computer is a device designed to be operated by one person at a time for computing and many general purposes. The malfunction of PCs incorporated in a real-time system because of voltage disturbances effects more badly than the malfunction of the PC used offline. The modes of personal computer malfunction under line voltage sag occur as the DC filter capacitor voltage of the power supply doesn't go with time. The software problems creates the problems which include; Lockup, interruption,(blue screen), Blocking of the operating system, No response to any command from the keyboard (freeze screen), Hardware misoperation can be identified by automatic restarting of the system, or a permanent black screen, making a manual restart necessary [24,27,32,33,58].

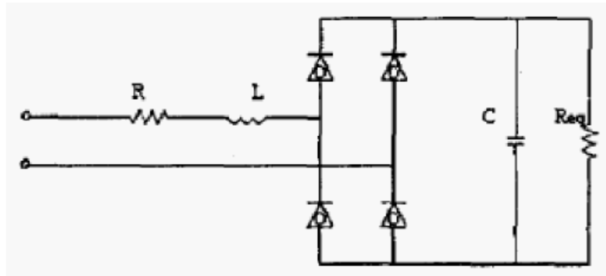

Figure 2 Harmonic Model of a Typical PC load

c. Controllers

A controller is defined as a device which controls, the electric power delivered to the connected apparatus. Controllers can operate in three means electrical, hydraulic, and mechanical e.g. speed regulator of a motor-drive system, voltage regulator, the temperature controller of an industrial furnace.
When line-voltage sag happened, a controller will be unable to recover if the sensitivity of the relays is less than the percent sag or the logic circuits supplied from the internal switch-mode power supply [12, 15, 16, 26, 34].

d. ASDs

Induction motors (and in ASDs) represent a huge part of the three-phase electrical load in commercial and industrial facilities. They are affected by line voltage sags and interruptions [20, 25, 28, 29, 30, 35, 36, 44].

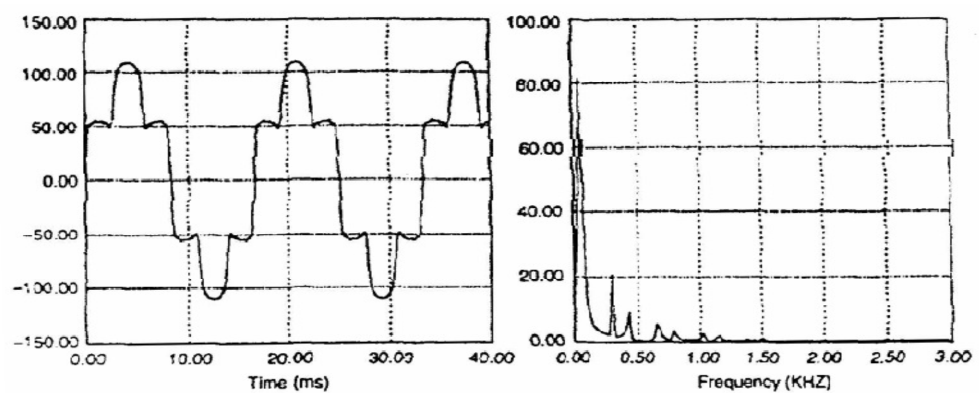

Figure 3 Input current and harmonic spectrum of a Typical ASD

e. AC Contactors and relays

Contactors and relays are made for all operation in a different range of coil voltage and contact ratings. Now a days, most of the places, the contactor function has been displaced by power-electronics devices such as GTOs, IGBTs. Whereas the control relay functions have been displaced by PLCs using digital logic. Whether electromagnetic or solid state, the devices are impacted by line-voltage sags and interruptions.
The device, the relay, or the contactor can be subjected to voltage sag, to a voltage interruption, or both [34, 35, 36,65].

B. Methods for Power Quality Problems Correction

Correction methods include the following:

- Proper designing of the Load equipment.
- Application of passive, active and hybrid harmonic filters.

- Proper designing of the power supply system
- Application of voltage compensators.
- Use of uninterruptible power supplies (UPSs)
- Reliability on standby power

We know that Engine-generator (E/G) sets Deviations in source voltage and current for critical load equipment and must be corrected to insure reliable operation of the equipment [12,14,15,16,17,18,27,28,29,34].

Different international standards, define corrected values. Methods of correction has been discussed above, if consider can be helpful in today's innovative technology management

V. RESULTS & DISCUSSIONS

We have discussed about the Power quality problems, issues, related power quality standards and the Effect of power quality problems in equipments. For which correction methods have been discussed. As a result, we can correct the problem and thereafter judge it by ensuring the results within internationals standards limits.

The following recommended standards for equipment is developed to help preserve voltage integrity by limiting harmonic current injection of single-phase loads which are likely to appear in increasing numbers in power distribution systems. By addressing harmonic current distortion at the individual sources, system problems may be avoided. The harmonic current limits established in the standards are proposed with the intent of minimizing the impact on existing equipment design

VI. CONCLUSION

This paper presented an innovative technology management by critical analyzing about power quality problems, issues, related international standards, and their effect in life and the corrective measures using different means.. The corrective measures are also discussed which can be remedy for power quality problems generated in different equipments. Coordination with existing industry practices and international harmonic standards is also considered in this paper. This paper will help research workers, users and suppliers of electrical power to gain a guideline about the power quality.

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