Power Quality Issues, Problems and Related Standards

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Summary:

The growth in power electronics has impacted many loads that traditionally were considered linear in nature. As a result, the number of nonlinear loads has increased and is expected to increase dramatically in the years ahead. 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 and related international standards. The presentation is done with giving a thorough knowledge of harmonics, power quality indices, parameters effecting electric power etc. Latest research work in giving different international standards for different type of power quality problems is also been given. This is important for design engineers and researchers in power quality to know the international standards used for power quality.

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. Utilities may want to define power quality as reliability. Equipment manufacturers, in turn may define it as a power that enables the equipment to work properly. In other words power quality can be defined as, "Any power problem manifested in voltage, current or frequency deviations that results in failure of or disoperation of customer equipment."

From the utility perspective, Power Quality has been defined as the parameters of the voltage that affect the customer's supersensitive equipment.

From the power user perspective, Power Quality may be defined as any electrical parameter or connection that affects the operation of the equipment. This included all electrical parameters, connections and grounds, whether the source from the utility, local equipment or other users.

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]

This paper critically discusses about the power quality problems, issues and related standards with giving a thorough knowledge of harmonics, power quality indices, parameters effecting electric power etc.

The above said areas are discussed under the following heads:

1. Power quality problems & issues
2. Harmonics and harmonics sequences
3. Power quality indices
4. Power quality standards

1. Power Quality Problems & Issues:

Voltage sags are considered the most common Power Quality problem. These can be caused by the utility or by customer loads. When sourced from the utility, they are most commonly caused by faults on the distribution system. These sags will be from 3 to 30 cycles and can be single or three phase. Depending on the design of the distribution system, a ground fault on 1 phase can cause a simultaneous swell on another phase.

A recent survey of Power Quality experts in Arizona 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 [10, 12, 15, 16].

Determining the exact problems requires sophisticated electronic test equipment. The following symptoms are indicators of Power Quality problems:

1. Piece of equipment misoperates at the same time of day.
2. Circuit breakers trip without being overloaded.
3. Equipment fails during a thunderstorm.
4. Automated systems stop for no apparent reason.
5. Electronic systems fail or fail to operate on a frequent basis.
6. 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, 12, 15].

Power Quality has been an issue since electrical power was invented. It has only become a well published issue in recent years because of the loads it affects. If your favorite TV program is interrupted by the local sewage pump operating on a Variable Speed drive interfering with it, you are aware of a Power Quality problem. When the lights blink and your PC reboots, you are aware of a Power Quality problem. The electrical loads get more sensitive [6].

There are hundreds of manufacturers making thousands of different Power Quality solutions today [7].

The categories of these solutions are:

- Utility based solutions for the substation level.
- User based solution for whole facility protection.
- User load level solutions for specific loads
- Designed in solutions, built in by the equipment manufacturer to reduce the sensitivity to Power Quality problems.

The issue of electric power quality is gaining importance because of several reasons:

1. 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.

2. New equipments are more sensitive to power quality variations.

3. 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.

4. Deregulation is resulting in structural changes in the utility industry (Traditionally, the generation, transmission, distribution and retail services have been bundled into one regulated company the task of which, among the others, was to be responsible for the quality of power. In a deregulated environment, it is worthwhile to ask, who will be responsible for the power quality?

5. The deregulated environment may reduce the maintenance of and investments into the power system and, hence, reduce the margins in the system.
6. Emerging of distributed generation (known also as embedded and dispersed generation) as a side effect of the deregulation. Distributed generation changes the way how the utility grid is operated and introduces new power quality challenges. The end users' awareness in power quality issues has increased.

The nature of electricity as a product is special. Similar to the conventional products its characteristics affect its usefulness to the customer. Different from the conventional products the application of it is one of the main factors that have an influence on its characteristics. The current that the customer's appliance draws from the supply network flows through the impedances of the supply system and causes a voltage drop, which affects the voltage that is delivered to the customer. Hence, both the voltage quality and the current quality are important. It is rather natural to split up the responsibilities so that the power distribution supplier is responsible for the voltage quality and the customer is accountable for the quality of current that he or she is taking from the utility.

2. Harmonics and Harmonics Sequences:

In power systems harmonics appear as a waveform distortion of the voltage or the current. The harmonics are generated by nonlinear loads. The sinusoidal voltage applied to the nonlinear load does not result in a sinusoidal current. Further, this nonsinusoidal current will produce a nonsinusoidal voltage drop while flowing through the finite source impedance, and, hence, cause harmonic voltages. Alongside with the harmonics, interharmonics and dc-component may distort the waveform. The spectral component with frequency of f is

Harmonic;

If $f = nf_{fund}$, where n is an integer > 0

DC-component;

If $f = 0$ ($f = nf_{fund}$, where $n = 0$)

Interharmonic;

If $f = nf_{fund}$, where n is an integer > 0

Subharmonic;

If $f > 0$ and $f < f_{fund}$, where f_{fund} is the fundamental power system frequency. The interharmonics and subharmonics are also referenced in IEC Std 60050-551-20 (2001). In power systems the harmonics have an interesting property called the sequence. Natural sequences are shown in Table 2. The sequence indicates the phase sequence of the phase quantities.

The fundamental component is of positive sequence, meaning that phase a is leading phase b, which is leading phase c. The phase order is then a-b-c. The phase order of a negative sequence component is a-c-b. With zero-sequence components all phase quantities are similar and the phase order can not be defined. If a space-vector is constructed from a harmonic sequence it is noticed that positive sequence components rotate into the positive direction and negative sequence components into the negative direction. The zero-sequence component does not contribute to the space-vector at all [4,6,9].

Table 1: Natural sequences of characteristic current harmonics of converters

Order	Sequence	Order	Sequence
1	Positive	6	Zero
2	Negative	7	Positive
3	Zero	8	Negative
4	Positive	9	Zero
5	Negative	10	Positive

Transients may be impulsive or oscillatory in nature. Impulsive transients are typically caused by lightnings and high oscillatory transients as a response of a local system to the impulsive transient. A low frequency oscillatory transient may be a result of a capacitor switching. Short duration variations are typically caused by faults or energization of large loads which require high starting currents. Long duration under- or overvoltages usually result in switching of large load or generation unit or a capacitor bank. An incorrect transformer tap setting may also be a cause of such a situation. Voltage unbalance may be caused by excess of poorly balanced single phase loads or blown fuses in one phase of a capacitor bank. Waveform distortions are caused by nonlinear loads in the power systems. A half-wave rectification may cause dc-offset. Harmonics are originating from many sources, in which typically power electronics are involved, but may also be produced by nonlinearly magnetizing inductances. Interharmonics are mainly caused by cycloconverters and arcing devices. Notching is a periodic voltage disturbance typically caused by commutations of power electronic device. Notching could be regarded as harmonics with high orders, but is typically considered as a special case. Voltage fluctuation may be caused by rapidly varying loads or generation. Certain voltage fluctuations are often called flicker, because of the visible effect to incandescent lamps. Power frequency variations may be caused by power system faults or disconnection or connection of large load or generation unit.

3. Power Quality Indices:

3.1 General harmonic indices

A complete description of a given distortion is the spectrum, but it is not very practical for rough comparisons and assessments. Hence, several harmonic indices have been developed to measure and characterize harmonic distortions with a single figure [4, 6]. The most common harmonic index is the total harmonic distortion (THD).

$$THD = \frac{\sqrt{\sum_{h=2}^{h\max} X_h^2}}{X_1}$$

(1)

X1 is the fundamental wave RMS value and Xh is the RMS value of the harmonic component h. Typical rule-of-thumb values for acceptable waveforms are a 5% THD for the current and a 2% THD for the voltage in the customer’s point of connection. There exists also an alternative definition of the THD, which is sometimes called distortion index (DIN)

$$\text{DIN} = \frac{\sqrt{\sum_{h=2}^{h_{\max}} X_h^2}}{\sqrt{\sum_{h=1}^{h_{\max}} X_h^2}} = \frac{\sqrt{\sum_{h=2}^{h_{\max}} X_h^2}}{X_{rms}}$$

(2)

DIN is frequently used in the European literature but rarely in the United States The advantage of this formulation is that it is always between zero and one. The THD goes infinitely large as the distortion increases. For small distortions, however, both definitions give approximately the same result [4, 6, 8, 9].

The THD’ denotes the ratio of the energy content of the harmonics to that of the fundamental component [4].

THD’= (Total Signal Enery- Fundamental Wave Signal Energy) / Fundamental Wave Signal Energy

Where the fundamental frequency (and hence also the fundamental wave period) is defined by the power frequency. THD is calculated as:

$$THD' = \frac{\sqrt{X_{rms}^2 - X_1^2}}{X_1}$$

In a periodic case, evidently, THD = THD. In IEC Std 61800-4 (2002) THD is called total distortion ratio, and it is noted that it may be approximated with THD if interharmonics are disregarded due to their low amplitude. Further, it is noted that assessment of THD and THD lead typically to the same result in case of a voltage, but there may be significant differences in case of a current.

This misleading property may be avoided by relating the harmonics to the nominal or the maximum current instead of the fundamental wave of the present current waveform. This is known as the total demand distortion (TDD).

$$TDD = \frac{\sqrt{\sum_{h=2}^{h_{\max}} I_h^2}}{I_n} \quad (4)$$

4. 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. One of the most important developments in the power quality arena is the increased emphasis on coordinating IEEE standards with international standards developed by the International Electrotechnical Committee [1, 3, 5, 8, 14, 15].

Most of the ongoing work by the IEEE in harmonic standards development has shifted to modifying Standard 519-1992.So let's take a closer look at some of the recent developments within these two organizations [8].

The Power Quality Standards Coordinating Committee, SCC-22, sponsored a task force to pull together a list of power quality terms and definitions. However, as the task force began compiling the definitions from various IEEE and IEC standards, they found many confusing or conflicting terms. Despite this hurdle, they tried to identify official definitions and provide examples of properly used terms. Accurate comparisons of power quality levels from one facility and system to another require consistent methodology. Existing IEEE Standard 1159 provides only general guidelines and definitions, so its group is actively developing more specific procedures for systems monitoring. Standard 1159.3 is actually based on the development of a Power Quality Data Interchange Format (PQDIF). The format is a means for exchanging power quality monitoring information between different applications. It will allow software developers to design applications that analyze power quality problems independently from the manufacturers of the monitoring equipment [1]. As for the IEC, there are some specific standards related to the monitoring requirements for each type of power quality phenomena. For example, IEC Standard 61000-4-7 deals with the requirements for monitoring and measuring harmonics, while IEC Standard 61000-4-15 describes the instrumentation and procedures for monitoring flicker. IEC Standard 61000-4-30 have some future plans on providing overall recommendations for monitoring all types of power quality phenomena while still referring to other specific standards where appropriate. IEEE is currently adopting this standardized approach as well [3].

CONCLUSION

This paper presented a brief and critical discussion about power quality problems, issue and related international standards. 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. Coordination with existing industry practices and international harmonic standards is also considered in this paper. This paper should help research workers, users and suppliers of electrical power to gain a guideline about the power quality.

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