POWER QUALITY: AN IMPORTANT ASPECT

Article *in* International Journal of Engineering Science and Technology · November 2010

Source: DOAJ

2 authors:

Saifullah Khalid
Civil Aviation Research Organisation, Airports Authority of India

Bharti Dwivedi
Institute of Engineering & Technology - Lucknow

POWER QUALITY: AN IMPORTANT ASPECT

[1] S.Khalid, [2] Bharti Dwivedi ,

Department of Electrical Engineering, I.E.T., Lucknow, India

ABSTRACT

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. Which in turn polluting the power quality and creating problems.
This paper discusses about harmonics, power quality problems, their analysis and terms defining their limits. The presentation is done with giving a detailed mathematical analysis of harmonics, power quality indices, parameters effecting electric power etc.

Keywords: IEEE 519, Power quality, THD, TDD

INTRODUCTION

The increase in electricity generation capacity has not been keeping up with the growing steady state and escalating peak demand in many parts of the world. The threatened limitations of traditional electrical power sources have focused a great deal of attention on power, its application, monitoring and correction. With the high cost of power generation, transmission, and distribution, it is of paramount concern to effectively monitor and control power quality.

Power quality can be defined from utility point of view as reliability i.e. as the parameters of the voltage that affect the customer's supersensitive equipment. From manufacturer's perspective, it can be define 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 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.

This paper presents the aspect of power quality problems, with giving a thorough knowledge of harmonics, power quality indices, parameters effecting electric power etc.

1. POWER QUALITY

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.

The usually terms used for describing the power quality are Distortion Voltage sags, Ground, Voltage variations, Clean ground, Ground loops, Voltage fluctuations, Transient, Dirty power, Interruptions Swells, Brownouts, Blackouts, Voltage imbalance, , Harmonics, Harmonic resonance, Interharmonics, Notching, Noise, Impulse, Non-linear load, THD, Triplens, Voltage dip, Voltage regulation, Blink, Oscillatory transient Spikes (Voltage), Ground noise, Common mode noise, Critical load, Crest factor, Electromagnetic compatibility, Dropout, Fault, Flicker, , Raw power, Momentary interruption, Over voltage, Under voltage, 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 [6,8,13,20].

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 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 & 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

A. 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).

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

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)

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

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).

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

4. POWER QUALITY STANDARDS

Power quality is a an international issue, and defining standards current is a never-ending task. It typically takes years to push changes through the process.

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].

Mainly followed standard is IEEE 519-1992, Recommended Practices and Requirements for Harmonic Control in Electric Power Systems, which defines limits on harmonic currents and voltages at the point of common coupling (PCC),

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.

It's difficult to keep up with the wide variety of power quality standards and guides under development. The best way to stay on top of things is to participate in the process. As power quality professionals, we have the opportunity to increase our participation in these working groups and better coordinate the efforts of the IEC and IEEE [1,2,3, 5, 11].

5. CONCLUSION

This paper discussed about power quality problems, harmonics, their analysis, terms defining their limits and international standards. By limiting the harmonic current and voltage within the limits defined by standards, system problems may be avoided. This paper will help, users, suppliers of electrical power to get a brief guideline about the power quality and its related terms.

REFERENCES:

[1] "IEEE Recommended Practices and requirements for Harmonic Control in Electrical Power Systems," IEEE Std. 519-1992.
[2] "Electromagnetic Compatibility, Part 3: Limits- Sect.2: Limits for Harmonic Current Emission," IEC 1000-3-2, 1st ed., 1995.
[3] IEEE 100, The Authoritative Dictionary of IEEE Standard Terms, seventh edition, 2000, p. 234.
[4] Mohan, Underland and Robbins, Power Electronics, John Wiley and Sons, 1995.
[5] D.D. Sabin and A. Sundaram, "Quality Enhances Realiablity," IEEE Spectrum, Vol. 32, No. 2, pp. 34-41, 1996.
[6] M. Jovanovic and D.E. Crow, "Merits and Limitations of Full-Bridge Rectifier with LC Filter in Meeting IEC 1000-3-2 Harmonic-Limit Specifications," in Conf. Proc. of IEEE-APEC pp. 354-360, 1996.
[7] T. Key and J.S.Lai, "Analysis of Harmonic Mitigation Methods for Building Wiring Systems," IEEE Trans. on Power Systems, PE-086-PWRS-2-06-1997, pp. 1-9, July 1997.
[8] P. W. Hammod, "A New Approach to Enhance Power Quality for Medium Voltage AC Drives," IEEE Trans. on Ind. Appli, Vol. 33, No. 1, pp. 202-208, 1997.
[9] S. Buso, L. Malesani, P.Mattabeli and R. Veronese, "Design and Full Digital Control of Parallel Active Filters for Thyristor Rectifiers to Comply with IEC-1000-3-2 Standards," IEEE Trans. on Ind. Appli, Vol. 34, No. 3, pp. 508-517, 1998.
[10] D.O. Koval, W. Xu, and J.salmon, "Power Quality Charcteristics of Rural Electric Secondary Power Systems," IEEE Trans. on Ind. Appli, Vol. 35, No. 2, pp. 332-338, 1999.
[11] J.S.Lai and F.Martzloff, "Coordinating Cascaded Surge Protection Devices: High-Low Versus Low-High," IEEE Trans. on Ind. Appli, Vol. 29, No. 4, 1993, pp. 680-687.
[12] T. Key and J.S.Lai, "Comparison of Standards Limiting Harmonic Distortion in Power Systems," IEEE Trans. on Ind. Appli, Vol. 29, No. 4, pp. 688-695, 1993.
[13] M. B. Hughes, J. S. Chan, and D. O. Koval, "Distribution Customer Power Quality Experience," IEEE Trans. on Ind. Appli, Vol. 29, No. 6, pp. 1204-1211, 1993.
[14] Van Zyl, J. H .R. Enslin, and R. Spee, "Converter-Based Solution To Power Quality Problems on Radial Distribution Lines," IEEE Trans. on Ind. Appli, Vol. 32, No. 6, pp. 1332-1330, 1996.
[15] "Power Quality Standards", An Internet Search on www. google.com
[16] Bhim Singh, Kamal Al-Haddad, Ambrish Chandra, A review of active filters for power quality improvement, IEEE Trans. on Industrial Electronics, Vol.46, No. 5, pp. 960-971, October 1999.
[17] R. C. Dugan, M. F. McGranaghan, S. Santosa, and H. W. Beaty, Electrical Power Systems Quality, 2nd edition, McGraw-Hill, 2002.
[18] Blajszczak, G. Antos, P, "Power Quality Park - Idea and feasibility study," Proc. Of Electric Power Quality and Supply Reliability Conference (PQ), 16-18 June, pp 17 – 22, 2010.
[19] S.Khalid, B.Dwivedi, "A Review of State of Art Techniques in Active Power Filters and Reactive Power Compensation," National Journal of Technology, No 1, Vol. 3, pp.10-18, Mar. 2007.
[20] Alexander Kusko, Marc T. Thompson, "Power Quality in Electrical Systems, McGraw-Hill, New York, 2007.
[21] S.Khalid, B.Dwivedi, "Comparative Critical Analysis of Advanced Controllers used for Active Power Filter," National Conference on Power Electronics and Renewable Energy Systems**,** PEARES, Kalavakkam, 2009.
[22] Molder, H.,Vinnal, T., Beldjajev, V., "Harmonic losses in induction motors caused by voltage waveform distortions," Electric Power Quality and Supply Reliability Conference (PQ), 16-18 June, pp 143 - 150 ,2010.L. Manz, "Applying Adjustable-Speed Drives to Three-Phase Induction NEMA Frame Motors," IEEE Trans. on Ind. Appl., vol. 33, no. 2, March/April 1997.
[23] Jouanne, P. N. Enjeti, and B. Banerjee, "Assessment of Ride-Through Alternatives for Adjustable Speed Drives," IEEE Trans. on Ind.

Appl., vol. 35, no. 4, pp. 908–916, July/August 1999.
[24] M. E. Barab, Craven, “Effects of Power Disturbances on Computer Systems,” IEEE Trans. on Power Del., vol. 14, no. 4, pp. 1309–1315, October 1998.
[25] D. O. Koval and C. Carter, “Power Quality Characteristics of Computer Loads,” IEEE Trans on Ind. Appl., vol. 33, no. 3, pp. 613–621, May/June 1997.
[26] S. Z. Djokic, J. V. Milanovic, and D. S. Kischen, “Sensitivity of AC Coil Contactors to Voltage Sags, Short Interruptions, and Undervoltage Transients,” IEEE Trans. on Power Delivery, vol. 19, no. 3, pp. 1299–1307, July 2004.
[27] J. C. Gomez, M. M. Morcos, C. A. Reineri, and G. N. Campetelli, “Behavior of Induction Motor Due to Voltage Sags and Short Interruptions,” IEEE Trans. on Power Delivery, vol. 17, no. 2, pp. 434–440, April 2002.