Power Quality in Electric Networks: Monitoring, and Standards

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Abstract :

Power Quality in electric networks is one of today's most discussed topic in Electrical Engineering but also one of the most problematic subject as it is only quite recently that it became one of the main devastating problem in the supply network. It is also considered as one of the most expensive and wasteful parameter in the supply network.

Since the beginning of the use of electricity Power Quality has always been one of the major points of concern for all professionals involved in Electrical Engineering. In this paper common practices in monitoring and standards in power quality in electric networks are reviewed.

Key words: Power Quality, PQ-Standards, PQ-Monitoring, Electric Netwoks

1- Introduction

What exactly is power quality? This is a question with no fully accepted answer, but surely the response involves the waveforms of current and voltage in an ac system, the presence of harmonic signals in bus voltages and load currents, the presence of spikes and momentary low voltages, and other issues of distortion. Perhaps the best definition of power quality is the provision of voltages and system design so that the user of electric power can utilize electric energy from the distribution system successfully, without interference or interruption. A broad definition of power quality borders on system reliability, dielectric selection on equipment and conductors, long-term outages, voltage unbalance in three-phase systems, power electronics and their interface with the electric power supply, and many other areas. A narrower definition focuses on issues of waveform distortion.

One reason for the renewed interest in power quality at the distribution level is that the era of deregulation has brought questions of how electric services might be unbundled and compared from on provider to another. It is possible to provide additional services to some customers on an optional basis, and to charge for those services. Perhaps several competing distribution companies might base their competition on the level of power quality provided. This is an evolving area. Also, modern power engineering is frequently cost-to-benefit ratio driven. Power quality indices often provide ways to measure the level of electrical service and the benefits of upgrading the supply circuits. These areas have brought focus to power quality as evidenced by several new textbooks in the area, one magazine, several conferences, and a number of programs and departments in electric utility companies' infrastructures.

When reviewing a journal concerning electric power and its technical applications in industry, it is quite common to find at least one article discussing problems caused by Power network. Here under is a collection of examples. Some of the problems regarding the power quality are:

Blinking of Incandescent Lights,Power Factor Correction Capacitor Failure, Circuit Breakers Tripping for no visible reason, Computer Malfunction or Lockup or Communication failure, Conductor Failure of Heating, Electronic Equipment Shutting down, Flickering of Fluorescent Lights, Fuses Blowing for No Apparent Reason, Motor Failures and Overheating, Neutral Conductor and Terminal Failures, Overheating of Metal Enclosures, Power Interference on Voice Communication added Noise, Transformer Failures and Over Heating.

Less often, articles discuss the monitoring process of power quality and harmonics as well as possible solutions to these problems based on known standards. There are two main reasons for fewer papers published on these subjects:

1- Standards are quite new and complicated. Only some professionals are familiar with them and usually it is more significant to explain a specific solution than a general concept.

2- Monitoring power quality and harmonics is not as simple as measuring power quality variables. There is a need to understand power network behavior before being able to monitor it, and this is not a simple task.

Moreover, it is more significant to discuss specific problems related to results from measurement and then derive a general concept.

2- Standards

There are three main globally recognized standards dealing with harmonics as their main goal:

- IEEE 1159-1995 : IEEE Recommended Practices for Monitoring Electrical Power Quality.

- IEEE 519-1992 : IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
- IEC 1000 (1991-1995):Electromagnetic compatibility (EMC).

- NFPA 70 (1996 NEC)

These three standards deal separately with two aspects of the problem:

1- Quantity or level of harmonics or other Power Quality deviations tolerated at different points in the network.

2- Ways to measure or monitor Power Quality deviations and harmonics in a network.

First let us consider the differences between the two standards, IEEE 1159-1995 and IEC 1000 (1991-1995) and further NFPA 70, when dealing with Power Quality deviations and harmonic levels in a network (further more when relating to Power Quality deviations and harmonics I am writing only Harmonics for convenience):

Both standards divide the levels of allowed harmonics into different categories:

- The IEEE standard divides the levels according to the level of the short circuit value at the PCC of the network, so that the more robust the network is the more it will be able to handle higher levels of harmonics.

- The IEC standard divides the levels according to the type of equipment connected to the network, so that the network will be sufficiently robust to handle the level of harmonic disturbances that occur then any given equipment is connected to the network at any given point in the network. In fact this approach gives the possibility to analyze any branch in the network or to isolate the requested parameters from any device connected to any point in it.

In fact when evaluating a specific case, no matter how one evaluates the level of harmonics allowed by those standards, one will find them to be similar, so close one to the other, that the differences are negligible. Therefore, it is good practice to use either one of these standards equally, guided by requirements of the case, and perhaps even check results reached when comparing the specific circumstances and calculation based on one standard to those based on the other.

Table 1 gives the general level of tension harmonics in the supply network at the PCC as a percent of the rated voltage according to IEEE.

TABLE I.- Recommended Voltage Distortion Limits for General Systems IEEE 519

Bus Voltage	**Maximum Individual Harmonic Component (%)**	**Maximum THD (%)**
69 kV and below	3.0 %	5.0 %
115 kV to161 kV	1.5 %	2.5 %
Above 161 kV	1.0 %	1.5 %

One of the results caused by the differences between the standards and the variety of interpretations given to them, and also the amount of phenomena in the network that are not cleared in a straight forward matter, is that the requirements for Power Quality deviations and harmonics allowed or tolerated in a network are often unclear.

More to all this is that when an electrician is coming to monitor a network it is difficult for the customer to understand how the monitoring has to be executed to fit the requirement of the standards and one of the standards requirements is to work in common with the customer to be clear and sure about the overall goal of the survey.

After receiving the results of the Power Quality deviations and harmonics surveys, the difficulty is how to interpret those results and how to solve the problems.

3- Monitoring Power Quality and Harmonics

Today, power quality monitoring is an essential service many utilities perform for their industrial and other key commercial customers. Because of the technology and software now available this monitoring is highly effective. Not only can a monitoring system provide information about the quality of the power and the causes of power system disturbances, but it can identify problem condition throughout the system before they cause widespread customer complaints, equipment malfunction, and even equipment failures. Many surveys have shown that the majority of problems are localized within customer facilities. Given this fact, monitoring provides a key opportunity for a utility to protect its reputation and improve its relationship with customers.

One of the most common misconceptions when dealing with harmonics is to ignore the differences between monitoring a network and measuring power quality variables.

The main difficulty in explaining the difference between monitoring power quality variables is that it is crucial to be aware of the fact that a network changes continuously. The network impedance varies continuously and one must monitor the network using models that take this into consideration. Without a relevant representation of the impedance, the results of the monitoring will be worthless.

The specific subject of modeling was discussed in IEEE Computer Applications in Power 04-96.

IEEE 1159-1992 provides us the steps for monitoring a network and the guidelines for understanding properly the results obtained.

As we can see, in order to design a solution for an harmonics problem, we have to execute the following steps:

1- Monitor the network according to the standard.

2- Measure the specific branch that is suspected to be the cause of the problem or the specific branch that is suffering from problems.

3- Analyze the results of both steps 1 & 2 to achieve a unique conclusion with a clear recommendation for a solution.

4- According to the Model chosen to represent the network, make the proper calculation for obtaining a realistic representation of the ohmic resistance values of the network components or branches to avoid unwanted resonance effects (that can be disastrous).

5- Following the implementation of the solution, monitor again the network to compare the expected result to the real one and adjust the elements that require adjustments.

As described above and according to many articles and books related to all the aspects of the Harmonics subject, there are two main obstacles while dealing with Harmonics problems:

- Know and be able to use existing standards and rules.

- Be able to create a relevant model representing the monitored network during the monitoring stage and after adding new elements to the network.

In my opinion, the modeling process still remains the more problematic for two reasons:

- After buying a standard, it is just a question of a proper learning process for a professional to master the understanding of this standard.

- For being able to model properly a network there, great knowledge is needed of the behavior of the elements composing the networks at different frequencies, different levels of use and many different variations of inter connections.

The greatest difficulty when anticipating a network model is that there are neither two identical networks nor a manual describing how to execute and achieve this task.

Why should one be so preoccupied with this kind of problem?

Is there not an exaggeration in the fear from the results of these problems?

I have collected a partial list of possible problems generated by Power Quality and harmonics phenomena:

1- Over heating of transformers and other electromagnetic devices such as motors, relays, and coils (due to the inductive heating effects of eddy currents, skin effect, and hystersis).

2- Over heating of conductors, breakers, fuses, and all other devices that carry current (because of eddy currents, skin effect, and hystersis).

3- Inductive heating of metal parts such as raceways, metal enclosures, and other ferrous (iron or steel) metal parts (because of eddy currents and hystersis).

4- Voltage distortion resulting in unpredictable equipment operation because of harmonics.

5- Excessive neutral current resulting in equipment overheating of failure because of additive harmonic currents, excessive voltage drop, and distortion.

6- Malfunction of generators and UPS systems due to voltage distortion resulting in unpredictable behavior of electric variable.

4 -Conclusions

The main point with which all the professionals involved in power Quality and harmonics in the supply network deal is that the problem is here to stay: the Electric Power Research Institute (EPRI) estimates that in 1992 , 15 to 20% of the total load has been nonlinear, while by the year 2,000 ,50 to 70% of all loads are expected to be nonlinear.

There is at least one concept hat must change fast, i.e. traditional measuring equipment is not useful in monitoring Electric Network Variables in networks the contains nonlinear loads but only equipment that is able to measure true RMS parameters (it is necessary for the user to check up to which level of Harmonics it can measure to be sure that it covers the Power Quality and harmonic deviations present in the local supply network to be monitored).

One of the greatest difficulty of all the organizations involved today in Monitoring and Measuring networks is that there must be a sort of recommendation adequate to describe the professional who are able to perform this kind of very focused monitoring and also be able to analyze the results obtained and lead to a practical and economical solution fitted to the network. Especially they have to be aware of the fact that a wrong solution could be disastrous.

Some organization require today that performing electricians have a certificate that accredit them for being able to monitor and understand network variables, Power Quality and harmonics according to accepted and valid standards.

It is possible to make a general comparison between monitoring an electrical network and measuring the temperature of somebody by just touching the front. After measuring the fever there supposed to be more testing or understanding and according to the combine results of all the tests only prescribe a list of treatments.

After monitoring an Electrical Network a professional has to be able to interpret the results and be accredited to design the proper solution.

5 -References

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