POWER QUALITY MANAGEMENT METHODOLOGY

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ABSTRACT

Power quality problems are among the main causes for business downtime, equipment malfunction and damage. The different types of power quality disturbances, their impact on equipment and electric installation, as well as possible mitigation solutions are well known today. However, there are no standards, recommendations or guidelines on how to implement, manage and continuously improve the power quality in an electrical network.

This paper presents a Power Quality Management Methodology, a framework through which each organization can set and pursue its own goals for improving power quality, reducing unexpected downtime and optimizing equipment lifetime and operating conditions. Inspired by the recommendations provided by ISO 50001 on Energy Management, this methodology can be applied standalone or integrated in Energy Management or Power Management Programs. Also, this paper focuses and provides a detailed explanation on the mandatory and specific for the Power Quality Management steps: measurement, analysis and corrective actions.

INTRODUCTION

Power Quality is an area of growing concern for end users due to the frequency of power quality issues and their financial impact. Today, it is estimated that 30 to 40 percent of all business downtime is related to power quality problems. In some sectors, like Industry, the cost of poor Power Quality can reach 4% of annual turnover [1].

Worldwide customer surveys show that complaints on power quality related disturbances (harmonics, voltage dips, flicker, and etc.) are increasing every year [2]. Customer loads are changing, including more and more electronic equipment and switching devices. Simultaneously, the same equipment is far more sensitive to power quality problems and will fail more often due to power quality events. Due to the increasing awareness of the impacts of variations in the quality of electrical supply customers expect a better quality of electrical service [3].

The electricity market deregulation and the growing use of renewable energies have also resulted in increase of power quality problems. Although much efforts and investments are done by utilities to improve the quality of the supplied power, it is not possible to completely control disturbances. Many of them are due to normal operations such as switching loads and capacitors or faults, which are usually caused by events beyond the operator's control.

A large number of disturbances are generated by customer-owned equipment. In industrial facilities, disturbances may be caused by non linear loads such as arc welders or variable speed drives, switching of capacitors or starting of large motors. In commercial buildings, electronic equipment like computers, printers, servers may generate additional power quality disturbances. For that reason, more and more utilities have put in place incentives and penalties to their customers for rejected to the network power quality disturbances (example – high harmonic level, voltage drop generated by large motors starting and etc.).

There are different types of solutions to manage the power quality problems that exist. However, there is no internationally recognized power quality management methodology. This generates a barrier for facilities who want to improve their power quality, as they do not know how to address critical aspects of their power quality performance – including measurement, monitoring, documentation, reporting, analysis, preventive and corrective actions.

The aim of this paper is to establish a systematic and sustainable approach to manage power quality within a facility.

POWER QUALITY MANAGEMENT METHODOLOGY

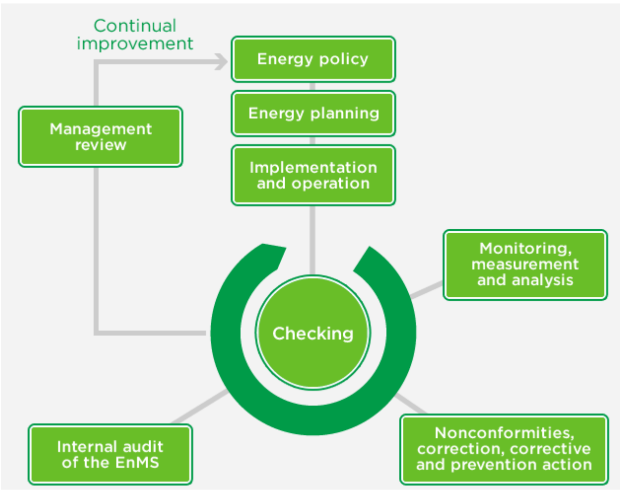
Energy Management and the Power Quality are topics that often go together. Energy management was also suffering from the absence of an internationally recognized methodology, which had repressed a widespread adoption of best energy management practices until 2011, when ISO 50001 was created, providing a framework to manage and improve energy performance.

The guidelines provided by ISO50001 on energy management can potentially be extended to power quality management with few modifications. For that reason the model proposed by ISO 50001 is reviewed in the following section.

ISO 50001 and the Energy Management Model

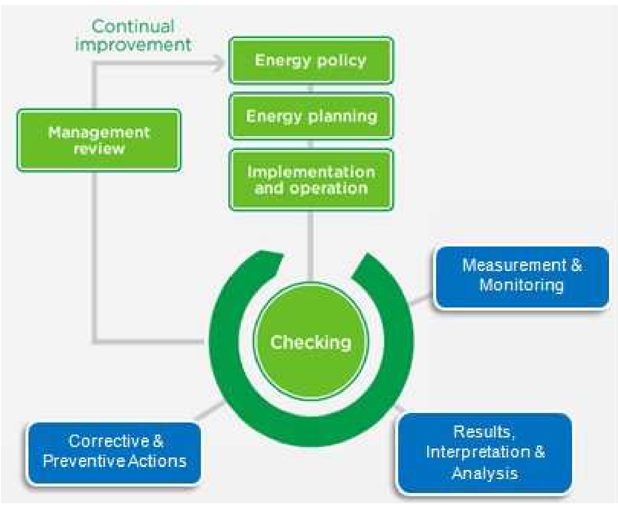
"ISO 50001 Energy Management Systems – Requirements with guidance for use" is a standard

created in 2011 by the International Organization for Standardization (ISO). It establishes a framework for implementing, maintaining and improving an Energy Management System with the aim to achieve continuous improvement of energy performance. It is suitable for any organization – whatever its size, sector or geographical location.
The structure for an Energy Management System is based on the “Plan – Do – Check – Act” Methodology and can be represented by the following model [4]:



Power Quality Management Model

A similar methodology to the ISO 50001 can be applied to Power Quality, where the continuous improvement is key to significantly increase reliability and performance.
Similar to Energy Management, to manage Power Quality it is necessary to establish a power quality policy, baseline, plan and management review.
And it is absolutely mandatory to Measure, Analyse and Improve Power Quality in a continuous process to achieve sustainable results.



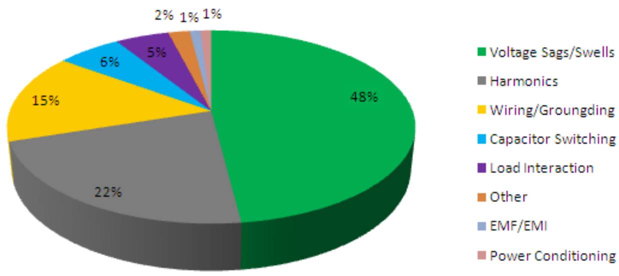
Measurement & Monitoring; Results Interpretation & Analysis; Corrective & Preventive actions are key steps specific to Power Quality Management. For this reason, they are reviewed in detail and the different options for their achievement are presented in the following sections of this paper.

MEASUREMENT & MONITORING

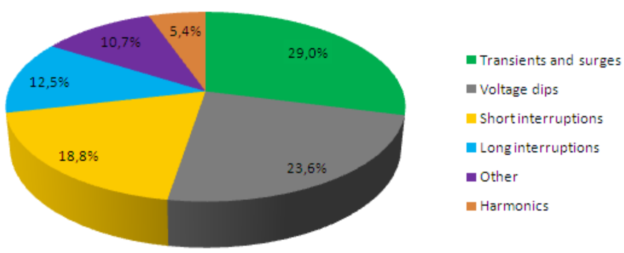
Measurement is key for the identification of Power Quality problems. In the business world, a popular adage states that you can’t manage what you don’t measure. This principle applies to the world of energy management, as it applies for the world of power quality.

Variables to measure

There are a number of different Power Quality Disturbances affecting the magnitude, the waveform, the frequency or the phase balance of the supplied voltage or current. All of them can have a negative impact on the electrical system and equipment. However, the most frequent and the most impactful Power Quality disturbances should be analysed deeper and with higher priority.
Several Power Quality Studies were conducted to evaluate the major Power Quality Disturbances. In the US, study results [3] concluded that voltage dips, voltage swells, transient over-voltages (due to capacitor switching), harmonics and grounding related problems are the most common power quality problems



Another PQ campaign [1], conducted by the Leonardo Power Quality Initiative amongst various customers in the EU-25 countries in 2004 concluded that the power quality disturbances with highest economic impact are voltage sags, interruptions, harmonics and transients:



Both studies confirm that voltage sags and interruptions, transients and harmonics are the main Power Quality issues.
In addition to them, Power Quality Disturbances specific for each facility type and supplied loads should be taken into account.
For example, in Data Centres, IT equipment are sensitive to changes in voltage signals. In Industry, where motors represent often between 60% and 80% of the load, voltage and current unbalance should be systematically taken into consideration. In a Telecommunication system, electrical noise can cause interference signals.

Type of measurement

Temporary versus continuous measurements
Measurement can be done temporarily, for a short period of time or continuously.
A temporary Power Quality Monitoring system allows for detecting steady-state power quality problems – current and voltage harmonics, unbalance and voltage fluctuations. It has the advantage to be flexible and to be connected in strategic places to investigate a specific problem on specific equipment or part of the installation. However, a temporary Power Quality Monitoring System will not detect events such as voltage sags, interruptions and transients, which are among the main Power Quality issues. And it will be a barrier for continuous process and continuous improvement.
A permanently installed Power Quality Monitoring System detects and records all Power Quality Disturbances, continuously. It allows the display of power quality recorded data and analysis of that data in the real time. Even though the installation of this type of system may require more maintenance, it is strongly recommended as it enables continuous measurement which improves system power quality to achieve sustainable results.

Power Quality Monitoring System Requirements

To perform Power Quality Measurements, a system should be equipped with power quality metering devices. They should be able to capture and record short term power quality events, provide current and voltage, continuous disturbance measurements and power quality compliance evaluations.
Power Quality Metering devices usually have a higher cost than ordinary power meters, so it is important to place them in strategic places of the electrical installation: such as the main incomers to monitor the quality of power supply, sensitive loads and critical areas in the installation.
A key for continuous improvement of power quality and power system health is to gather and connect the information of all available sources into one system and provide tools to evaluate, analyze, report and alarm on power quality issues.
For Electrical Distribution Networks, guidelines for implementing large scale power quality monitoring systems for transmission network are provided by [5], where number, location and cost of power quality measurement devices are discussed and system-wide examples of cost calculations are provided.

RESULTS INTERPRETATION & ANALYSIS

Analysis includes interpretation of recorded data and the evaluation of Power Quality impact on the Electrical Installation & Equipment. The analysis can be performed regularly (example: once per month) or ad hoc (when there is a problem potentially caused by Power Quality Disturbance)
Analysis should be performed by a professional, skilled and experienced person, with competencies on Power Quality, Electric Installation and Equipment, capable to correlate power quality disturbances with equipment damage, malfunction or electric installation downtime.
Measurement analysis and interpretation can also be partially provided by a power quality monitoring system. Automated processing of power quality data based on a known baseline of voltage and current parameters, trend limits and custom models can be used for alarming and system behavior prediction. Automated model-based analysis of long-term PQ parameter trends can provide results useful to PQ experts.
The power quality monitoring system can cover the cost aspects of power quality too, estimating losses due to poor power quality [6]. "Putting a price tag" on power quality issues makes it easier to do the cost-benefit analysis of power quality solutions and the return of investment evaluations on power quality monitoring systems.

CORRECTIVE AND PREVENTIVE ACTIONS

Based on interpretation results and conclusions, different solutions can be considered. They may include equipment for the mitigation of Power Quality Disturbances, Settings Modification, Design and Architecture modification or even selection of Equipment less-sensitive to Power Quality Disturbances.
The example of harmonic mitigation is taken to illustrate corrective and preventive actions and their field of application

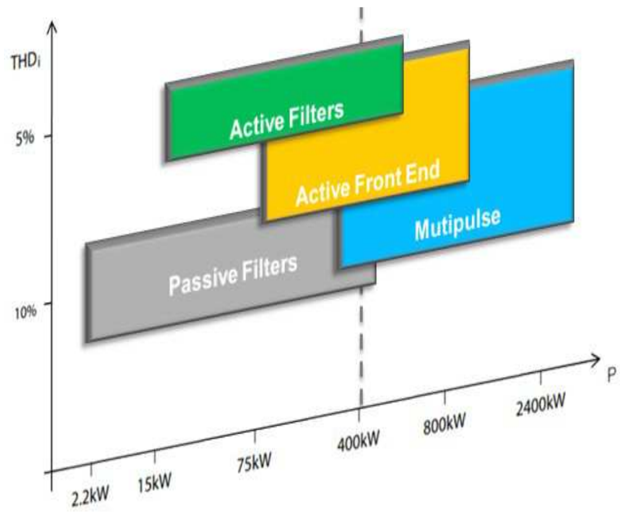
Example for Power Quality Improvement from End-User perspective: Harmonics mitigation

Harmonics mitigation is a growing concern. Non-linear loads and especially embedded power electronics circuits are increasing in all type of installations (industrial, commercial or residential). Moreover, the percentage of such loads in overall electrical consumption is also growing steadily. There are several possible solutions that can be grouped into the following categories: equipment, network and architecture.

Harmonic mitigation at Equipment Level

The selection of appropriate harmonic mitigation equipment requires measurement and analysis but to reach acceptable performance, there is generally more than one solution for a given segment or application.

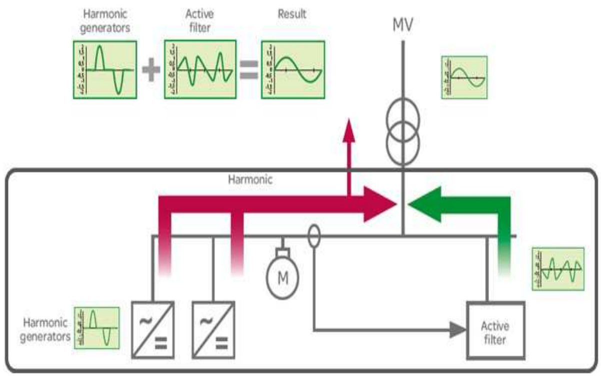
To decrease the total harmonic distortion for equipment like a variable speed drive, we can select multipulse (12, 18, 24-pulses) or active front end technologies, but we can also decide to add a passive filter with chokes or, an active filter. The choice of the selected solutions depends on the installed power and the requested THDi as shown on the figure here after.



Harmonics mitigation at network and architecture Level

Main harmonic solutions in residential, commercial or light industry sectors are applicable at the equipment level. However, in some sectors like industry or infrastructure, regulations are enforced by Utilities and applied to global installations. Moreover, the overall power quality management methodology is leveraged if we reconsider the system architecture.

For example, a global approach might be to differentiate the type of loads and group, as much as possible, the non-linear loads. Then, it is possible to mitigate the harmonics generated in this specific subpart of the installation in a single and cost effective solution. Some type of equipment like Active filters has the ability to mitigate harmonics disturbances generated by multiple non-linear loads at the same time.



Architecture improvement is also a simple and efficient way to protect sensitive equipment from main power quality disturbances without adding any specific equipment.

Most of the time, harmonics create unnoticed issues until they lead to damaged equipment, corrupted data or cause production losses. An efficient Power quality management system will allow the users to act in a cost-effective and preventive way, improving both capital and operational expenses.

Next generation Power Quality improvement devices

With the Power Quality management methodology presented in this paper, it makes sense to develop the whole cycle of Power Quality continuous improvement as well as each of the different steps individually.

In the past, Power Quality improvement devices have often been considered as the "set and forget" type. After their installation, there was no specific follow-up to verify and quantify the efficiency and the result of the solution. Next generation Power Quality improvement devices will have self learning alarming systems that adapt to and alert in real time if performance decreases suddenly or deviates slowly over the time. In addition to the alarming system, the embedded intelligence will also be useful to calculate and prove the real efficiency gain after the solution installation. Return on investment calculations will be more positive and this will help to increase the rate of advance device adoption. Flexibility in the design and adaptability over the time will be the two most important features in an evolving electrical distribution network where capital expenditure will become tighter.

CONCLUSION

The Power Quality Management Methodology presented in this paper is designed to continuously improve power quality, increase electric installation uptime, and optimise equipment performance, efficiency and lifetime. The three fundamental and specific steps for power quality management (Measurement & Monitoring, Results Interpretation & Analysis, Corrective and Preventive actions) are presented and recommendations for each of them are provided. Finally application examples of the presented methodology are explained and discussed.

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