INTERNATIONAL JOURNAL OF SCIENTIFIC PROGRESS AND RESEARCH (IJSPR) ISSN: 2349-4689
Issue 179, Volume 79, Number 01, January 2021

A Review On Harmonic Analysis To Utilize A Smart Grid Monitoring System

Ruchi Bisen, Arvind Jain

Abstract:* Monitoring of power efficiency has evolved from a way of investigating consumer grievances to an important part of measurements of power system performance. In addition to special purpose power quality sensors, data on power quality is obtained from several other system control instruments. The effect is an immense amount of calculation data that is continually accumulated and must be analyzed to determine if the data will draw meaningful conclusions. Because of the wide variety of features involved, it is a major obstacle, varying from very sluggish fluctuations in the steady state voltage to microsecond transients and high frequency distortion. In fact, data for harmonics, including voltage or current harmonics, can now be obtained from a broad variety of locations and from a wide variety of Power Quality (PQ) instruments. The conventional power output measurement and reporting explores harmonic orders to the 50th. This means that the harmonic data available for study is far greater than, for example, changes in steady state voltage, where only a few parameters are studied. This study explores a variety of innovative research and reporting approaches that can be used to minimize large quantities of harmonic data for individual harmonic orders down to a limited number of indices or graphical representations that can be used to explain harmonic behaviour both at an individual site and at several sites through an electricity network.

***Keywords:* Grid Monitoring, Harmonic data, Power efficiency, Electricity network. Power quality**

I. INTRODUCTION

Problems with the efficiency of electric power cover a wide variety of various phenomena, with time scales varying from tens of nanoseconds to steady state. Any of these phenomena can have a number of different causes and, thus, require multiple remedies that can be used to increase the efficiency of power and the output of equipment. Many concerns with power quality (PQ) emerge from the incompatibility between the utility delivery grid and the devices it serves in the electrical world. There are also PQ concerns that result from negative interactions between the machinery and the delivery chain. Nonlinear loads, for example, are known to create harmonic currents that can excite the supply system into resonance [1]. As the time scales of PQ disruptions differ greatly, power management systems should preferably have the capacity to record events ranging from DC to a few megahertz frequencies. Since the majority of PQ events have frequency material below 5 kHz, many commercial power quality monitoring instruments have sampling rates of 256 samples per cycle. The effect on consumer equipment of low power efficiency (PQ) has been well reported [1-2]. Electrical energy providers typically have a statutory obligation to ensure that the consistency of the service to particular consumers stays within the scope of technical requirements and national standards. One of the main measures to ensure consistency with national standards is for utilities to track a wide variety of positions within their respective network limits, evaluating criteria such as steady state voltage, voltage imbalance, voltage sags, and distortion of waveforms.

1.1 Concept of Microgrid

Microgrids can be described as a controllable close assembly of small generators, storage devices and loads to maximize the use of renewable and/or alternative generation [3,5] as one of the latest concepts used in some modern-day EPS. This definition is demonstrated by Fig 1.1 as it demonstrates clean energy generators such as wind and photovoltaic turbines, combined heat and power (CHP) for sustainable energy supply, energy storage loads and batteries.

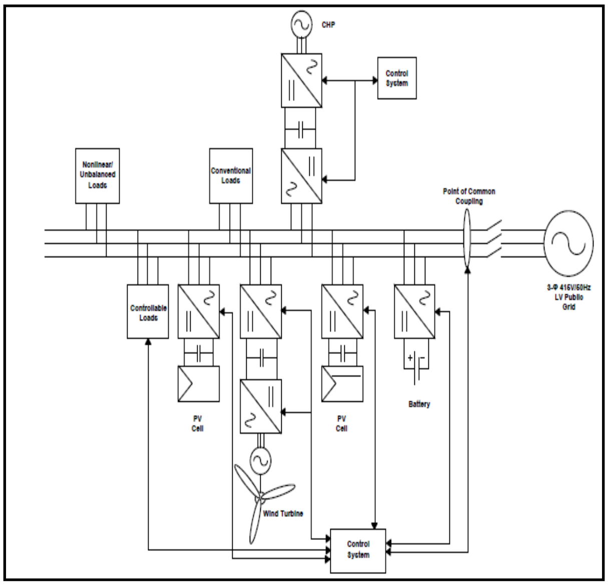

Fig. 1.1 Concept of a Microgrid

A benefit of the microgrid is that it might supply its own small distributed generation plants to its site, which can be a local city or an industrial area, and may also be used to meet the load demand of the grid. During malfunctions and other network discrepancies, they are often required to detach from the grid [3]. Appropriate operational mechanisms, monitoring methods and security systems maintain a balance between supply and demand and ensure continuity of supply to their local communities even after they have been removed from the national grid in order to operate in a stand-alone manner, also known as islanding mode[4].

A vast number of experiments and studies have been carried out on different microgrid principles, studies have focused on the microgrid dynamics, the controllability of the microgrid and its generating units, and problems with power efficiency. Most concentrated on the impact of converters, non-linear loads and unbalanced loads on a microgrid in terms of power quality problems, and hoped to improve the power quality of the microgrid by introducing different control schemes for converters and microgrid, and different switching strategies for microgrid converters [5]. The traditional grid has enjoyed years of development focused on proven techniques and researchers must now consolidate on established research used in the management and operation of real world microgrids to refine them in order for the microgrid to progress exponentially in the future.

II. CHALLENGES IN ANALYSIS OF ELECTRIC POWER QUALITY

Problems with the efficiency of electric power cover a wide variety of various phenomena, with time scales varying from tens of nanoseconds to steady state. Any of these phenomena can have a number of different causes and, thus, require multiple remedies that can be used to increase the efficiency of power and the output of equipment. Many concerns with power quality (PQ) emerge from the incompatibility between the utility delivery grid and the devices it serves in the electrical world. There are also PQ concerns that result from negative encounters between the machinery and the system of supply. For example, it is known that nonlinear loads create harmonic currents that can excite the supply system into resonance [11].

2.1 Power Quality Problems Characterization

The bulk of concerns with power efficiency can be defined by voltage and current measurements. Because PQ disruptions are relatively infrequent and the periods in which they arise are unplanned, it is sometimes important to track or control continuously over a prolonged period. PQ tracking has been commonly used to measure system-wide efficiency in addition to characterizing PQ concerns (benchmarking). A utility may detect irregular characteristics (may be an indicator of equipment or device problems) through knowing the usual power quality output of a system, which can provide consumers with knowledge to help them balance their sensitive equipment characteristics with practical power quality characteristics.

As the time scales of PQ disruptions differ greatly, power management systems should preferably have the capacity to record events ranging from DC to a few megahertz frequencies. Most commercial power quality control tools have a sampling rate of 256 samples per loop, as most PQ events have a frequency material below 5 kHz [11]. Due to technological and economic barriers, the supply of high-end instruments to catch rare, very high-frequency events is minimal. When more and more PQ monitors are mounted in the utility and consumer services, voluminous data is also inundated by end users of PQ monitors. It is not unusual for end-users to experience "drinking from the fire hose," especially at the time when the data analysis results are most needed [12-14].

2.2 **Online and Offline Power Quality Monitoring**

As utilities and industrial clients have extended their monitoring programs for power quality, the roles of data management, analysis, and interpretation have been the most critical tasks in the overall monitoring effort for power quality. The move from a conventional data collection system to a fully integrated intelligent analysis system in the use of power quality management systems would significantly improve the importance of power quality monitoring, as suggested in [14]. There are two streams of data analysis of power efficiency, that is, offline and online studies.

2.2.1 Offline Power Quality Monitoring

The data analysis of offline power efficiency, as the term implies, is carried out offline at the central processing locations. On the other hand, online data collection is carried out inside the tool itself or directly after the information is processed at a central processing site. The findings of online research are very useful in promoting steps that need to be taken (e.g., determination of fault location from voltage and current waveforms).

The following are examples of signal processing software:

i. RMS variance analysis, which involves voltage sag and swell tabulations, scatter magnitude duration plots based on CBEMA, ITIC, or user-specified magnitude duration curves, and a broad variety of RMS indices such as SARFI computations. To measure voltage sag and swell efficiency, signal processing strategies may be used. In addition, signal processing methods can be used in combination with load equipment models to forecast the effect of voltage sags on sensitive equipment [15-16].

ii. Steady state study of RMS voltage patterns, RMS currents, negative and zero-sequence imbalances, actual and reactive power, harmonic distortion levels, individual harmonic components, etc. Moreover, several information programs offer statistical analysis at different amounts of minimum, estimates, median, standard deviation, count, total likelihood. Statistics can be aggregated and automatically sorted temporally. The time pattern of step A RMS voltage along with its histogram representation is represented in following figures. Using such steady-state results, statistical signal processing can be used to predict voltage regulator output or health status on distribution circuits [17].

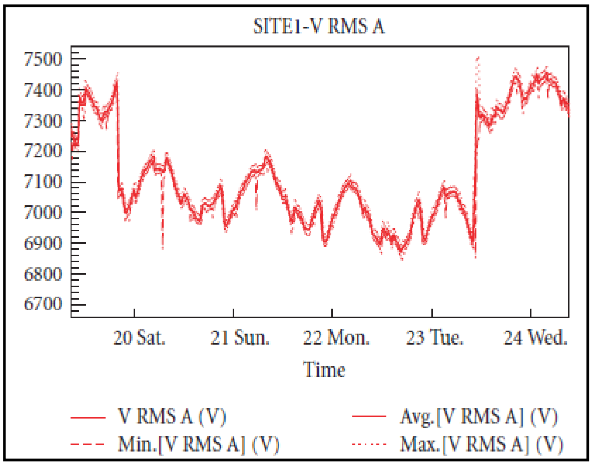

Fig. 1.2 Time trend of an RMS voltage in PQ analysis

(iii) Harmonic analysis, where voltage and current harmonic spectra can be measured by users, comparative analysis of different harmonic indexes, and pattern over time. In order to detect excessive harmonic distortion in power systems as a result of device dynamics (resonance conditions) and load characteristics, such studies can be very useful.

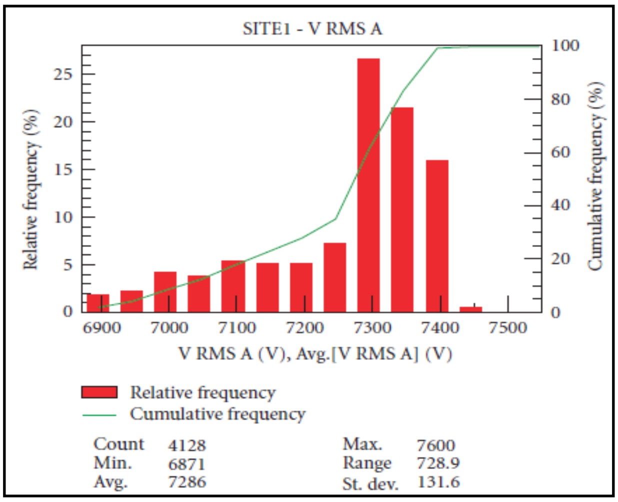

Fig. 1.3 Histogram representation of RMS voltage indicates the statistical distribution of the RMS voltage magnitude

2.2.2 Online Power Quality Monitoring

Data measurement of online power output requires data interpretation as it is collected. The findings of the study are available for quick dissemination immediately. The complexity of the online test program architecture criteria is typically greater than that of offline. In an online environment, the bulk of features available in offline research applications will also be made available. One of the key benefits of online data analysis is that it can offer quick transmission of messages and inform consumers of particular events of interest. On getting the updates, consumers may then take prompt action. The origin of a fault on a delivery circuit is an exceptional example of an online analysis. In order to extract and analyze voltage and current waveforms, signal processing methods will be used. The measurement would show the location of the fault and this data would be disseminated to the line crew quickly [8].

III. POTENTIAL FUTURE APPLICATIONS

In designing diverse applications of power quality data analysis, signal processing techniques can be very beneficial. This section lists some of the most significant implementations. This list also contains the examples listed in the previous segment.

3.1 Industrial Power Quality Monitoring Applications

i. Energy and demand profiling for the recognition of energy are saving and demand reducing opportunities.

ii. Harmonics tests to define transformer loading problems, harmonics origins, equipment mal-operation issues (such as converters) and resonance issues associated with the adjustment of the power factor.

iii. Unbalance profiling of voltage to classify impacts and loss of life on three phase motor heating.

iv. Assessment of voltage sag impacts to determine sensitive equipment and potential prospects for development of process driving.

v. Assessment of power factor correction to identify proper operation of capacitor banks, switching problems, resonance issues, and efficiency enhancement to reduce electric bills.

vi. Beginning engine assessment to detect switching issues, existing inrush issues, and function of the safety system.

vii. Profiling of variations in voltage (flicker) to detect issues with load switching and load efficiency.

3.2 Power System Performance Assessment And Benchmarking

i. Trending and analysis of parameters of steady-state power quality (voltage control, imbalance, flicker, harmonics) for patterns in efficiency, connection with device conditions (capacitor banks, generation, loading, etc.) and detection of conditions that need to be addressed.

ii. Evaluation of the steady efficiency of state force with respect to national and international norms. In terms of mathematical power quality features, most of these specifications include identification of power quality output criteria.

iii. Characterization and measurement of voltage sags to determine the origin of voltage sags (transmission or distribution) and to characterize occurrences for classification and review (including aggregation of multiple events and identification of sub events for analysis with respect to protective device operations).

iv. Characterizing capacitor flipping to classify the transient source (upline or downline), find the capacitor bank, and characterize database maintenance and review incidents.

v. Measurement and monitoring of performance indexes for system benchmarking purposes and for prioritizing expenditures for system repair and development.

3.4.3 Applications for System Maintenance & Reliability

i. Fault localization that is one of the most significant advantages of tracking systems. It will significantly increase reaction time for circuit repair and even detect trouble conditions in the same area connected to multiple faults over time.

ii. Efficiency evaluation of the capacitor bank. Smart applications may understand fuse blowing, glitches, problems with switching (re-strikes, re-ignitions), and questions about resonance.

iii. Output review of the voltage regulator to detect irregular procedures, arcing issues, control problems, and so on. With trending and related study of unbalance, voltage curves, and voltage differences, this can be done.

IV. SAMPLING TECHNIQUES FOR HARMONIC DISTORTION

Many electric utilities employ power quality control tools that report periodic measurements in order to determine harmonic distortion. For each of the three phases and the neutral, power quality engineers configure these instruments to capture a sample of voltage and current. At daily time intervals, the monitors report (for example, every thirty minutes). The measurements usually consist of a continuous cycle. Thousands of calculations that need to be effectively summarized can be reported by power efficiency monitors. The waveforms reported include data on many characteristics of the steady state, including harmonic distortion, phase unbalance, power factor, form factor, and crest factor. The study of these waveforms for harmonic content will be the subject of this article. By using Fourier analysis, harmonic distortion can be studied due to its periodic existence. A Swift Fourier Transform is the computational process of measuring the magnitude and phase angle for each harmonic of a waveform (FFT). A mapping of time domain information to the frequency domain is the FFT. It shows the graphical output of an FFT in which the simple voltage variable, VI, has normalized the harmonic components. It is important to use indexes to summarize the multiple single-cycle calculations. A simple distortion analysis determines one unique useful index while the basic frequency variable normalizes the total voltage harmonic information. This value is called the voltage's complete harmonic distortion (THD). The definition of THD is given by equation 1.

$$V_{THD} = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \quad \text{……………………..(1)}$$

For circumstances in which there is no fundamental component [3], the limits of the utility of THD have been established. Although this should be remembered, most of the indexes discussed here are at the primary level of delivery or customer care, where this issue is generally baseless.

Daily, weekly, and seasonal variations follow the variance of harmonic distortion. An overview of everyday patterns of harmonic distortion occurs in Figure. It illustrates how a regular cyclical trend always parallels THD. The measurements were reported at a 13.2 kV distribution substation delivering a residential load from phase A. THD is relatively high when nonlinear loads are high compared to the sum of linear load in a device. This situation often happens at night and during the early morning hours with a residential feeder.

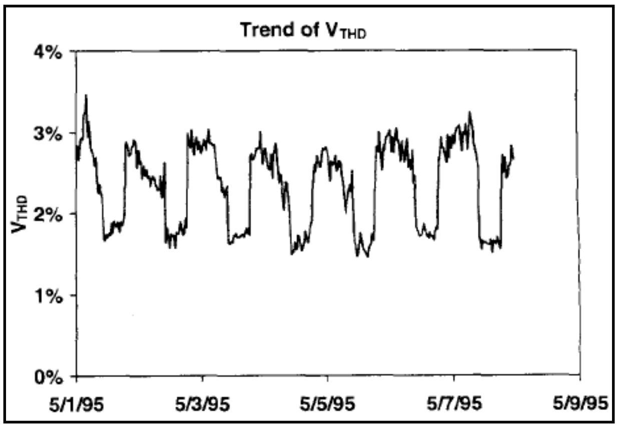

Fig. 1.4 Trend of Voltage Total Harmonic Distortion Demonstrating Daily Cycle for One Week

As seen in Figure, a convenient way to summarize a time series of numbers is by making a histogram. This graph displays data obtained for one month from the same location of the substation indicated in previous figure. In the distribution, two different peaks are evident, illustrating an example of the often bimodal aspect of harmonic distortion. Cumulative frequency is an important calculation that we can produce from a distribution. As a curve in figure, the cumulative frequency values are overlaid.

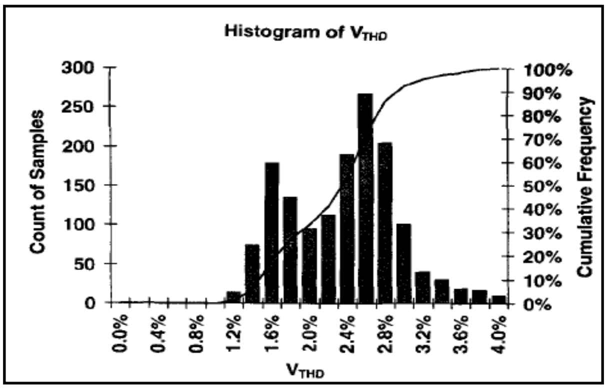

Fig. 1.5 Histogram of Voltage Total Harmonic Distortion for One Month Demonstrating Bimodal Distribution

From figure, the cumulative frequency curve was isolated for clarification from the columns of the histogram. We have also demonstrated how the 95th percentile value of the example distribution can be graphically computed. This is the value, also known as CP95, which is greater than 95 percent of all other samples in the distribution. The CP95 is often more valuable than a distribution's maximum value because it is less sensitive to measurements that are spurious. In order to be distributed in Fig. 4, the voltage THD value of CP95 was 3.17 percent. By drawing intersecting lines on the graph, we can estimate the value or, using a statistical analysis program, we can calculate it.

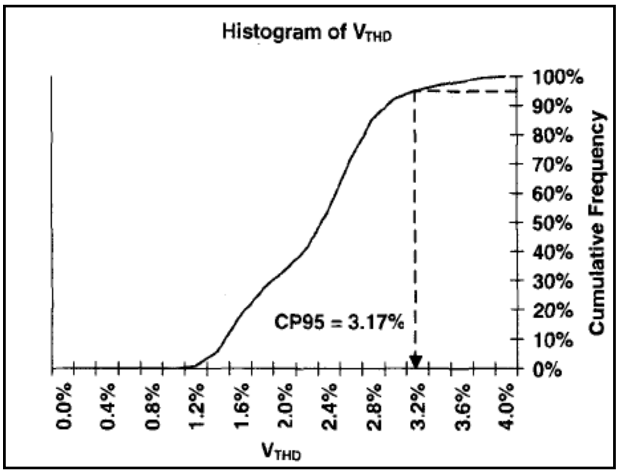

Fig. 1.6 Demonstration of Graphical Method of Calculating the CP9S of a Distribution

Usually, at more than one location, an electric utility will collect measurements. It is then possible to generate a histogram that is similar to Fig. 4 for each site of the monitoring. For every monitoring location, a different CP95 value can be computed. If many locations are tracked, then it is helpful to create a histogram of these CP95 values themselves. In figure, for different observations in time, showed the variance of the distortion at a single site. The new histogram can present the variable from different measurement sites. Figure provides an example of such a histogram, which serves to summarize both temporally and spatially the measurements. We can also graphically identify a CP95 value.

Since utility budgets reduce the number of sampling sites, the number of samples in the temporal spatial distribution will typically be less than the number of samples in the temporal distribution. This CP95 value can be viewed as a "statistic of a statistic." The number of samples in the temporal distribution is limited only by the number of weeks or months of installation of the instrument.

4.1 Problem Statement for Harmonic Distortion

For several years, harmonic distortion has occurred in electric power systems. However, electric utilities have increasingly established more tools for tracking and assessing the nature and impact of system and consumer interface distortions. This increased sensitivity is the product of concerns that in many electric power systems, harmonic distortion levels can increase [21-22]. There are two aspects that significantly add to this issue. In order to maximize the efficiency of current delivery grid infrastructures, the first is the expanded usage of utility and commercial capacitors. The second problem is the growing scale and application of nonlinear instruments, which, for distribution systems, produce the bulk of harmonic distortions. Due to the additional energy efficiencies and versatility they provide, the proportion of electric power that passes through electronic power devices is rising. With respect to harmonics, electronic power devices present a two-fold challenge. Not only do they produce harmonics, but they are often usually more sensitive than more common power system instruments to the resulting distortion. Therefore, with the volume of distorting technologies being used, consumer perceptions of the quality of service offered improve.

V. CONCLUSION

Power quality control is increasingly becoming an important part of the monitoring of a general delivery grid, as well as a wide variety of situations and disruptions are protected by power quality. Thus, as mentioned above, the specifications for the monitoring system can be very significant. Knowledge from testing systems for power quality will help increase the system's operational performance and the reliability of customer operations. There are advantages which should not be disregarded. The capabilities and software for monitoring of power efficiency are consistently included. Again, this is an area of potential work which will potentially prove to be more informative than the approaches discussed in this work. Finally, in a compact manner, a graphical system of network reporting of harmonics was introduced that demonstrates detailed detail of the harmonic output over several pages.

REFRENCES

[1] IEC 1000-4-7, “Testing and Measurement Techniques - Section 7: General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected thereto”, 1st Edition , 1991.

[2] IEEE Standard 519-1992, “Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems” - 1992.

[3] W. Reid, “Power Quality Issues - Standars and Guidelines”, IEEE Transactions on Industry Applications, Vol 32, Nº3, May/June 1996.

[4] IEC 61000-3-2, “Electromagnetic compatibility EMC part 3-2: Limits - Limits for harmonic current emissions (equipment input current less than16 A per phase)”, Edition 2.1, 2001.

[5] IEC 61000-3-4, “Electromagnetic compatibility EMC part 3-4: Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A”, 1st Edition, 1998.

[6] Sabin, D.D.; Brooks, D.L.; Sundaram, A., “Indices for assessing harmonic distortion from power quality measurements: definitions and benchmark data”, IEEE Transactions on Power Delivery, Vol. 14, No 2, April 1999, pp 489 - 496.

[7] Jaramillo S., Heydt G., O'Neil-Carrillo E, “Power Quality Indices for Aperiodic Voltages and Currents”, IEEE Transactions on Power Delivery}, Vol 15, No 2, April 2000, pp 784- 790.

[8] R. C. Dugan,M. F.McGranaghan, S. Santoso, and H.W. Beaty, Electrical Power System Quality, 2nd ed. New York: McGraw-Hill, 2003.

[9] S. Chen, “Open design of networked power quality monitoring systems,” IEEE Trans. Instrum. Meas., vol. 53, no. 2, pp. 597–601, Apr. 2004.

[10] I. Y. Chung, D. J. Won, J. M. Kim, S. J. Ahn, and S. I. Moon, “Development of a network-based power quality diagnosis system,” Elect. Power Syst. Res., vol. 77, no. 8, pp. 1086–1094, 2007.

[11] C. Barbulescu, M. Cornoiu, S. Kilyeni, C. Stoian, and P. Stoian, “Electric power quality issues: Harmonic analysis for real network,” in IEEE EUROCON, Jul. 2013.

[12] G. Rafajlovski, K. Najdenkoski, L. Nikoloski, and H. Haidvogl, “Power quality monitoring and sample size analysis beyond EN 50160 and IEC61000-4-30,” in 22nd International Conference and Exhibition on Electricity Distribution (CIRED 2013), Jun. 2013.

[13] Electromagnetic compatibility (EMC)—Part 4–7: Testing and measurement techniques—General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto, IEC 61000-4-7:2002, 2002.

[14] A. Maitra, S. M. Halpin, and C. A. Litton, “Applications of harmonic limits at wholesale points of delivery,” IEEE Trans. Power Del., vol. 22, no. 1, pp. 263–269, Jan. 2007.

[15] S. Vlahini´c, D. Brnobi´c, and N. Stojkovi´c, “Indices for harmonic distortion monitoring of power distribution systems,” in Proc. Int. Instrum. Meas. Technol. Conf., Victoria, BC, Canada, May 12–15, 2008, pp. 421–425.

[16] A. Boscolo, I. Vlahini´c, and S. Vlahini´c, “Harmonic distortion source identification in power systems with capacitor banks,” in Proc. 12th IMEKO Int. Symp. Elect. Meas. Instrum. (TC4), Zagreb, Croatia, 2002, pp. 311–316.

[17] A. E. Emanuel, “On the assessment of harmonic pollution,” IEEE Trans. Power. Del., vol. 10, no. 3, pp. 351–359, Jan. 1995.

[18] L. Cristaldi, A. Ferrero, and S. Salicone, “A distributed system for electric power quality measurement,” in Proc. IEEE Instrum. Meas. Conf., Budapest, Hungary, May 2001, pp. 2130–2135.

[19] A. Ferrero, “Measuring electric power quality: Problems and perspectives,” Meas., vol. 41, no. 2, pp. 121–129, Feb. 2008.