Proactive Energy Management

Incorporating Real-time Online Power Quality Monitoring System

Introduction

Real-time online power quality (PQ) monitoring exploits the Internet as a tool, enabling remote PQ monitoring of even distant sites in an energy management system. Apart from managing energy usage, monitoring and trending energy consumption, it helps to proactively identify PQ conditions that may result in electrical failures if uncorrected. As shown in the insurance claims data of the NFPA 70B maintenance standard, almost half the cost associated with electrical failures could be averted by regular maintenance. This is further supported by a study published in IEEE 493-1997, reporting that a poorly maintained system can attribute 49% of its failures to lack of maintenance. Therefore, it is important for the PQ of all electrical systems to be monitored proactively.

iQpm

Quality Power Management Pte Ltd’s latest innovation, iQpm, is an example of an effective online real time PQ monitoring system. iQpm utilises a small set of measurements from the electrical meters to predict power distribution and critical load failures. Current measurements are used to trend changes in the load. Information on voltage stability, voltage unbalance and harmonic distortions are gathered to provide indications of a load and distribution system’s state of health. These measurements can all be acquired without disrupting operations. Such data from the electrical meters are digitised and transferred to a software for real-time analysis. Basically, the effect of the entire electrical system (up to the load) can be monitored in this way. The iQpm can also be customised to include monitoring of the busbar temperature, current leakage, energy per floor area consumption, carbon footprint, etc. By incorporating these features with cloud computing and internet technology, iQpm is a powerful tool for predictive maintenance application.

Developing a functional PQ monitoring system

Several key features and critical points have to be taken into consideration to avoid major pitfalls during software development. This paper aims to share our technical expertise in developing the iQpm.

Comparison Between Conventional System And iQpm System

In a conventional PQ monitoring software, multiple high-end meters (each capable of performing PQ parameter calculations) are used to analyze PQ and diagnose PQ problems. The meter measures the power quality parameters, processes them and communicates the information to the PC. The PC then displays the results using the graphic user interface. However, such a system cannot work in a network of simple meters. Costly meters capable of performing calculations must be in place before the system can be linked up for PQ monitoring, making it less cost effective.

On the other hand, an advanced PQ monitoring system employs sophisticated software to perform the necessary calculations, tapping into the meters only to retrieve raw PQ data. iQpm is an example of a system where any type of digital electrical meter can be linked up for PQ monitoring.

The advantages and disadvantages of the two systems are listed in Table I. It is evident that a system like iQpm would be much more cost-effective and easy to implement than the conventional system. When capabilities are embedded in the hardware (ie the meter), it becomes very difficult to scale up or change things whereas in an advanced system such as the iQpm, scalability and flexibility of the software is limited only by the engineer's imagination.

The only apparent disadvantage of the advanced system is the heavy communication load that is handled by the software. However, when designed correctly, as in the case of iQpm, this load is manageable, especially when we tap into the Ethernet as a communication channel.

	Conventional System	**iQpm System**
Cost of meter	High	Low
Price of entire system	High	Low
Ease of integration into existing meter network	May need to change all meters to the high-end type.	Easy
Real-time display	With lag time	Instantaneous
Modularity	Fixed and difficult to expand	Modular
Scalability	Fixed and not scalable	Readily scalable
Data transfer load	Light	Heavy but manageable
Upgrade	Difficult	Easy
Maintenance	Difficult	Easy

Table 1 - The advantages and disadvantages between Conventional System & iQpm System

System Architecture And Algorithm

The iQpm system is made up of two parts (Figure 1). The first part is installed at an onsite mini server and is responsible for data acquisition (iQpm-DA). The second part is the PQ analyzer (iQpm-PQA) which is installed at the central server.

iQpm first taps into the meters via a MODBus protocol to draw out the raw data. Next, the meters (also known as MODBus serial meters) are bridged to the TCP/IP Ethernet at the onsite mini server housing the iQpm-DA. The iQpm-DA collates PQ parameters on a per-second basis, sending to the central server the PQ parameters (maximum, minimum and average values only) in blocks of 10 minutes or as desired.

Upon receipt at the central server, analyses are carried out by the iQpm-PQA to characterise these PQ parameters and to identify PQ events. Calculations are performed using various signal processing algorithms. Trends are analyzed statistically and indices calculated. The information is then processed as graphical presentations and PQ summary reports. Clients can log in to the central server remotely at any time to access the processed data and view PQ history over any period.

For greater flexibility, iQpm's system architecture is also supported by various libraries of meter register addresses. This essentially makes iQpm a "plug-and-play" system, suitable for all digital electrical meters.

In the next phase of iQpm's development, the architecture will be further enhanced with the incorporation of a wireless device that can be attached to any existing meter. This enables the wireless transmission of each meter's data to the iQpm system for processing, bypassing the Ethernet. In essence, it removes the need for extensive wiring, making it simpler and cheaper to incorporate a PQ monitoring system into any network of meters.

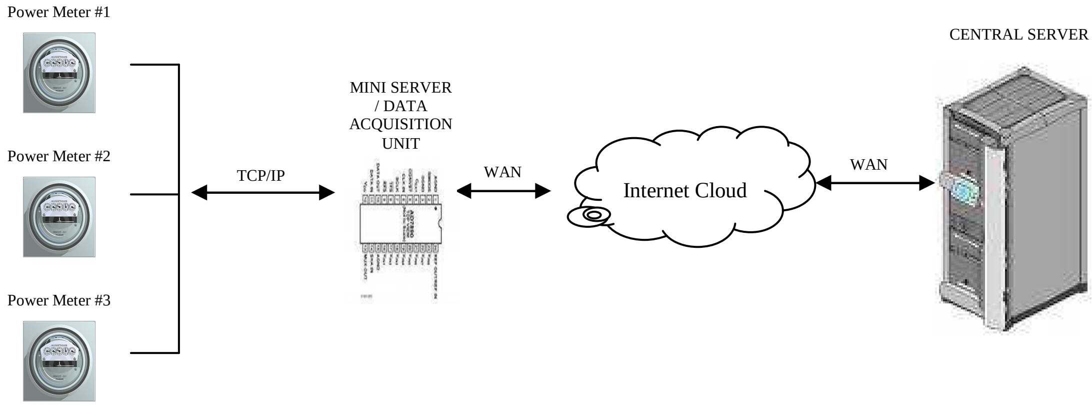

Figure 1 - iQpm system: Data acquisition (iQpm-DA) Unit & the PQ analyzer (iQpm-PQA) Unit

Features Of A Good PQ Monitoring System

A functional PQ monitoring programme should cover the following key areas:-

1. High-speed communication with the internet network, including statistical analyses and calculations through uninterrupted PQ measurements. The ability to perform power quality diagnosis would be a bonus.

2. Display of real-time PQ information and results of analyses via the web-browser. Any authorised personnel should be able to access data remotely from any location through a web browser or via any mobile telecommunication device (eg mobile phone) (Figure 2).

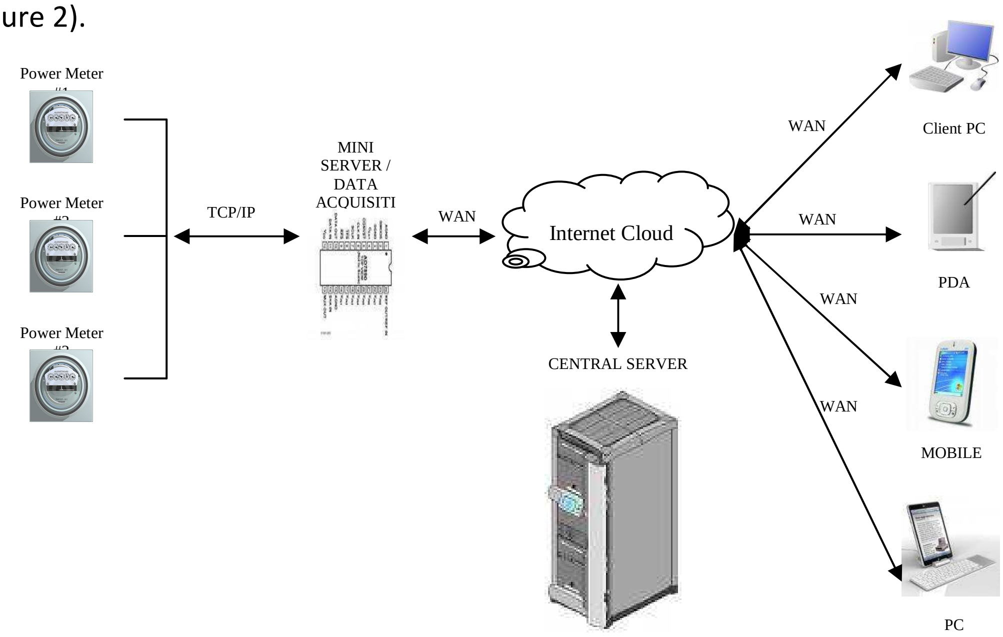

Figure 2 - PQ Monitoring System

3. Presentation of information in a user-friendly format. Information such as the PQ parameters, various types of electrical costs, the amount of power usage, consumption patterns, etc should be included.

4. Proactive identification of conditions and events that could potentially cause problems and alert users to address the issues before problems set in.

5. The ability of the system intelligence to evaluate disturbances in accordance with the set limits must be distributed among the respective components of the PQ system.

6. All equipment, communication devices and software involved in PQ monitoring need to be scalable to handle hundreds of points and still remain manageable.

7. Information on the set limits has to be available for other systems and end users.

8. The PQ monitoring system has to be flexible, able to adapt accordingly to user preferences and the latest standards.

Features of iQpm

The standard features of iQpm can be used as a reference guide for others intending to develop a PQ monitoring system. iQpm is able to track the following in real time:

- Energy Usage (monitored every second)
- Energy Cost (based on hourly to yearly consumption cost)
- Cost Comparison and Trending (includes graphical presentations
  - trending from day to year profiles, on real and reactive power and energy)
- Voltage Regulation and Imbalance
- Frequency
- Voltage Harmonic Distortion
- Current Harmonic Distortion
- Max 3 Phase Voltage Unbalance
- Max 3 Phase Current Unbalance
- Apparent Power (kVA)
- Real Power (kW)
- Reactive Power (kVAR)
- Power Factor

An important feature of iQpm is the default setting of limits (Figure 3), alerting users to adopt corrective actions. The limits proposed by iQpm conform with IEEE 519 and is recommended for the user as an initial setting. Such limits are set well below the point of failure. Once historical data is available, these limits may be tightened or loosened as appropriate by the user.

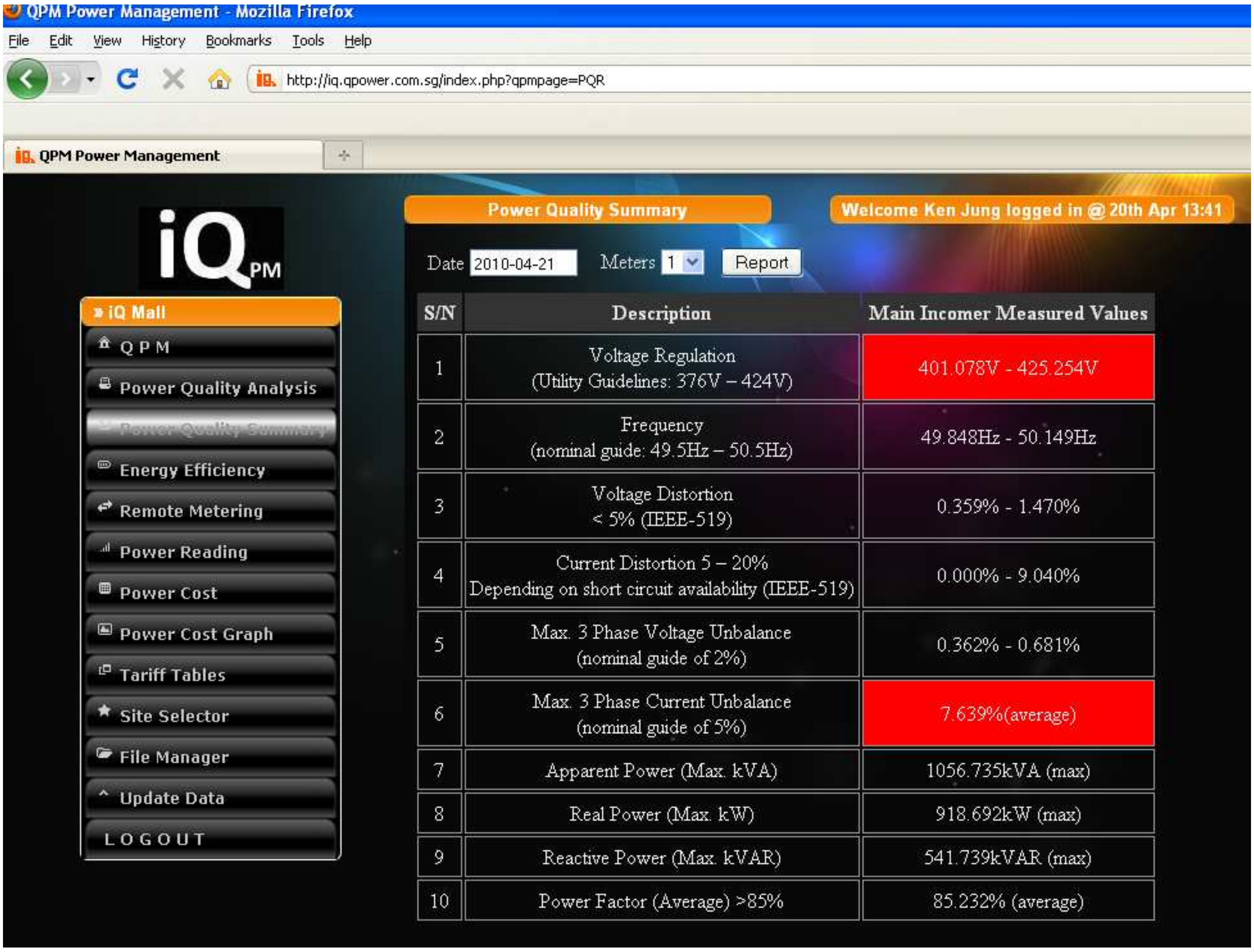

Figure 3 – PQ Summary Report

New information tabs can also be added and could incorporate electrical drawings, reports, maintenance schedule, contracts, contact list, standard operating procedures on power failure, invoices, quotations and purchase orders.
Other optional features of iQpm include:-

- Alert Feature (For System Fault, Over-Voltage or Current, etc)
- Temperature and Humidity Monitoring
- Leakage Current
- Energy Consumption Per Floor Area
- CO_2 and Carbon generated (Carbon Footprint)
- Waveform Monitoring
- E-billing

Some examples of how the above parameters may be displayed on screen can be found in Figures 4 – 10.

Figure 4 shows the Phase Voltage Unbalance Profile in a 3-phase system. Significant phase voltage differences point to a defect in a load or a system problem. If not rectified, it can lead to poor equipment performance or premature failure due to mechanical stress in motors. This can arise from abnormally high motor currents and low torque output.

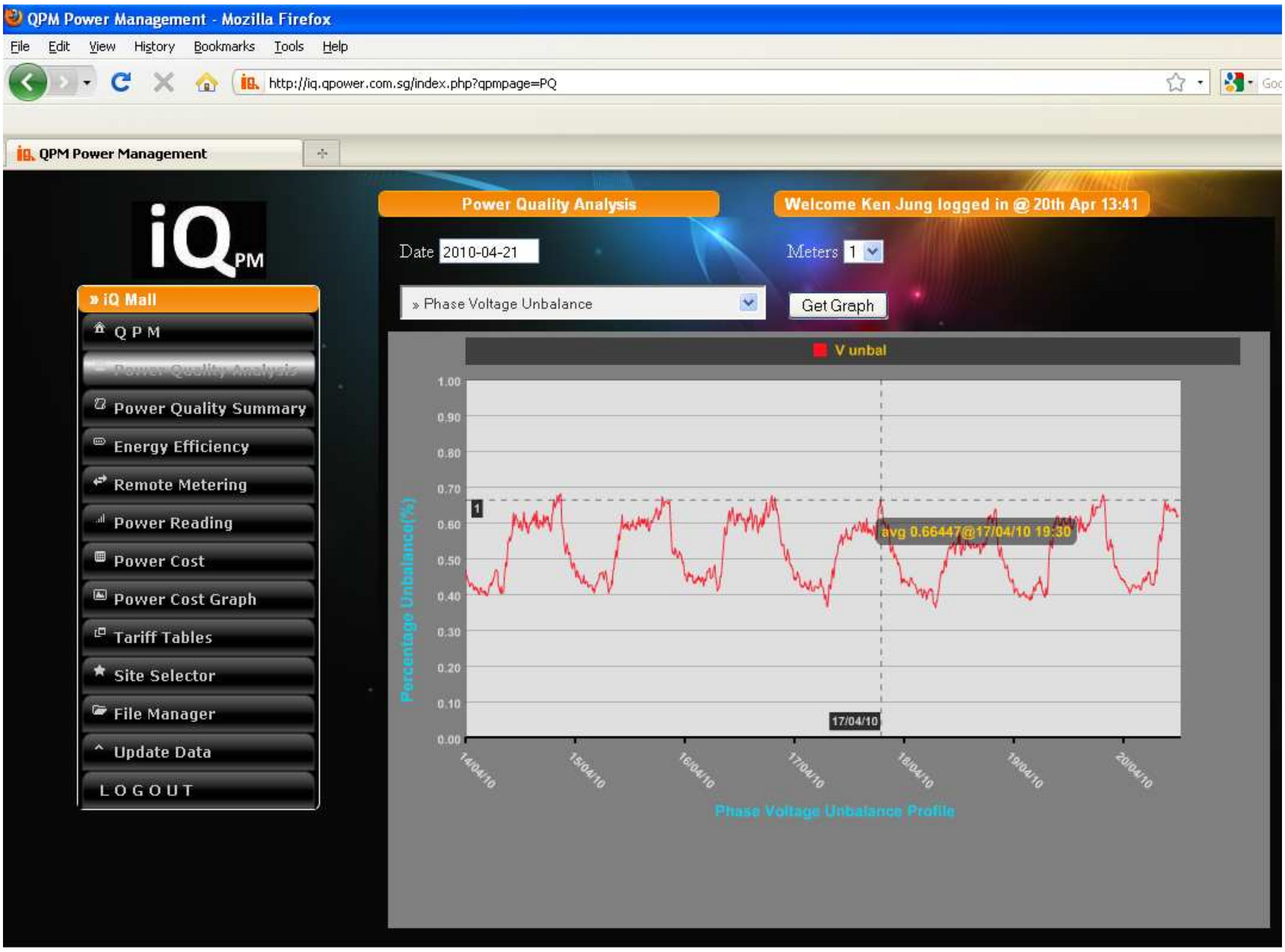

Figure 4 – Phase Voltage Unbalance Profile

Figure 5 highlights the Phase Voltage Percentage Total Harmonics Distortion Profile. Distortion can result when loads are added or removed from the system. It is a good practice to check the harmonics regularly as it can cause heating and reduce the life of motor windings and transformers. It can also result in excessive neutral current, increased probability of voltage sags and reduced transformer efficiency.

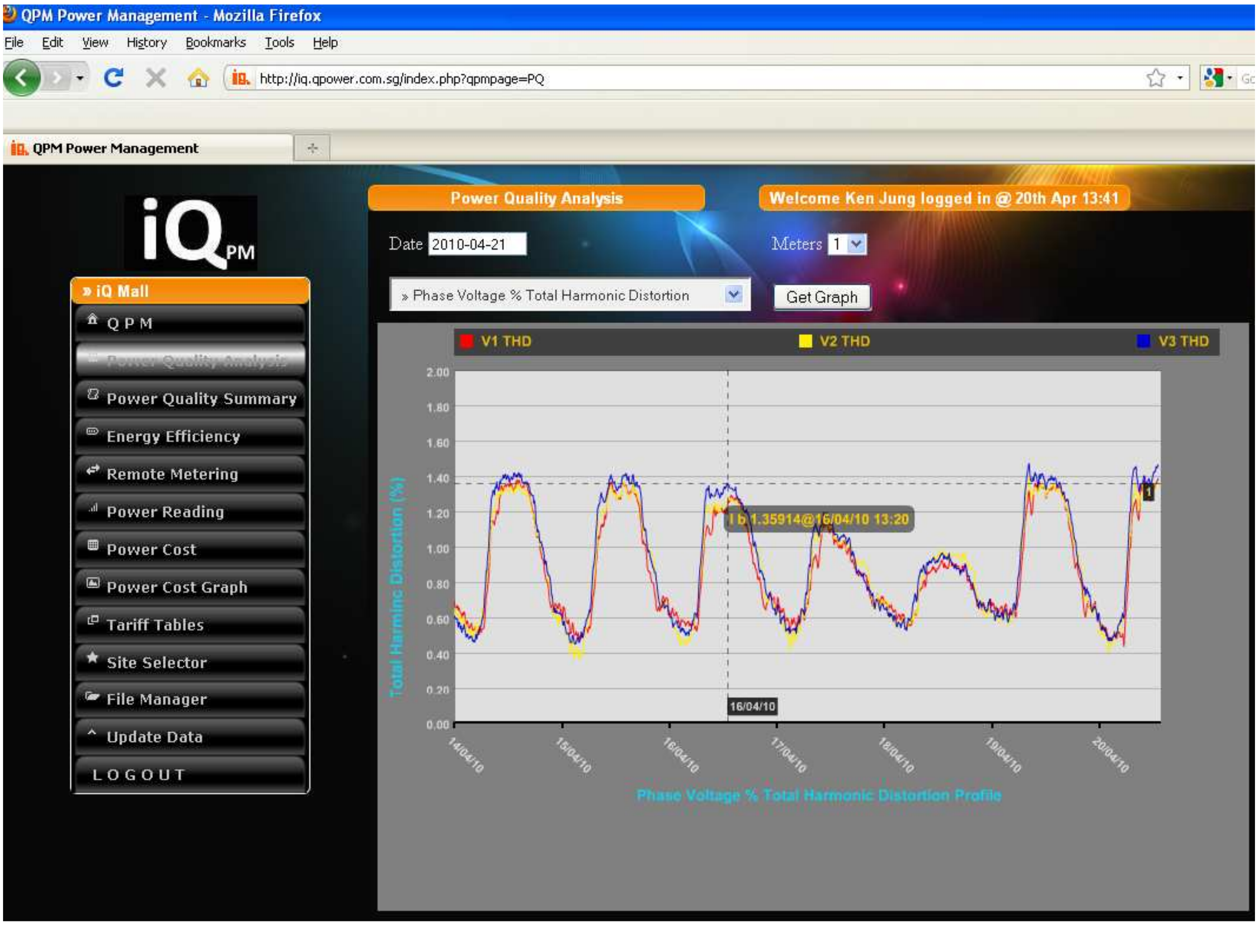

Figure 5 – Phase Voltage % Total Harmonics Distortion Profile

Figure 6 displays the Energy And Demand Profile. The daily breakdown energy demand load profile for 7-days is displayed. There is a variety of physical and behavioural factors that determine an energy demand load profile. Monitoring of this profile serves to facilitate the design of conservation measures and optimal energy allocation.

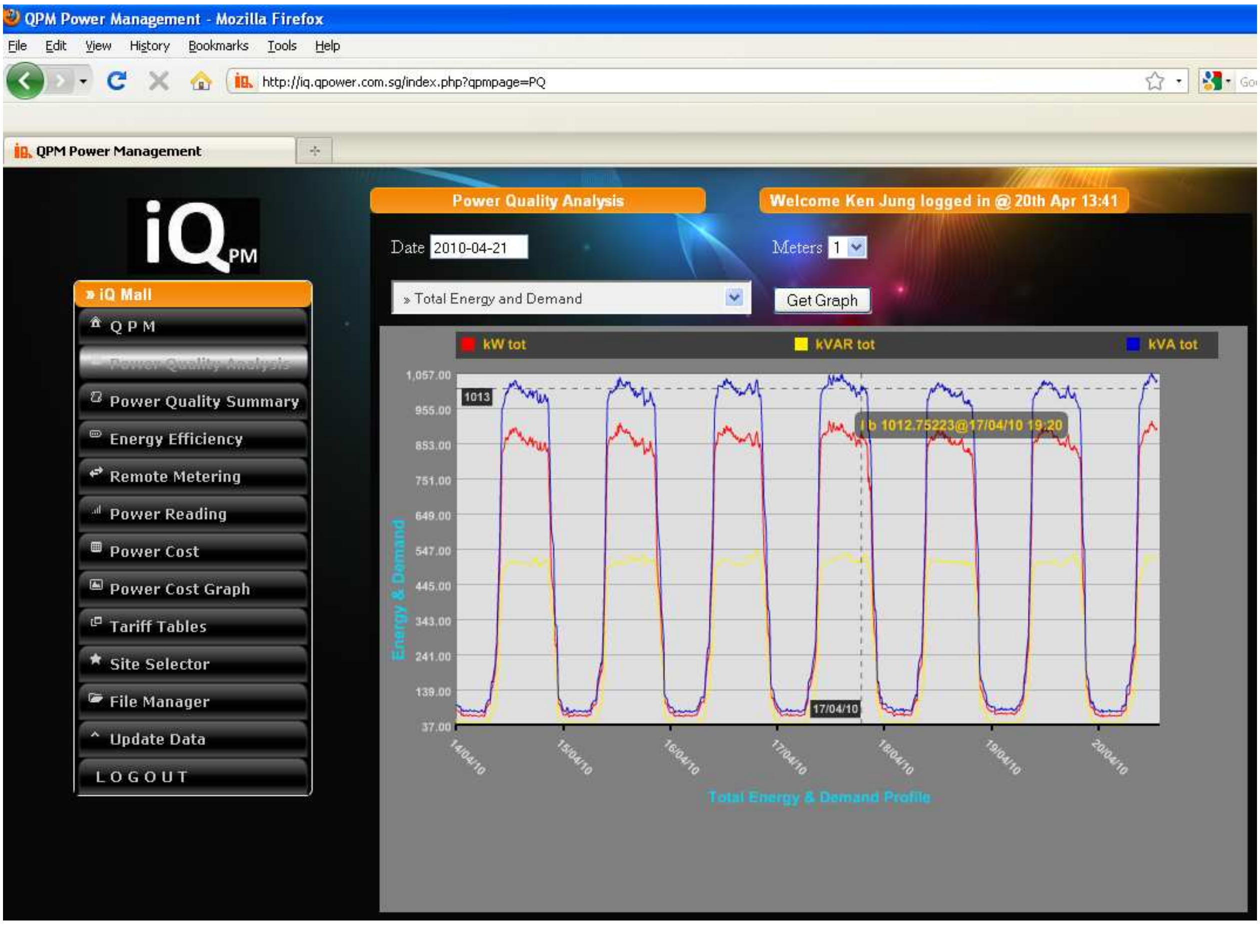

Figure 6 – Energy & Demand Profile

Figure 7 depicts the Phase To Phase Voltage Profile. Based on the profile monitored, information can be gathered on whether voltage changes are within set limits. Voltage can then be regulated either up or down to bring it within the limits.

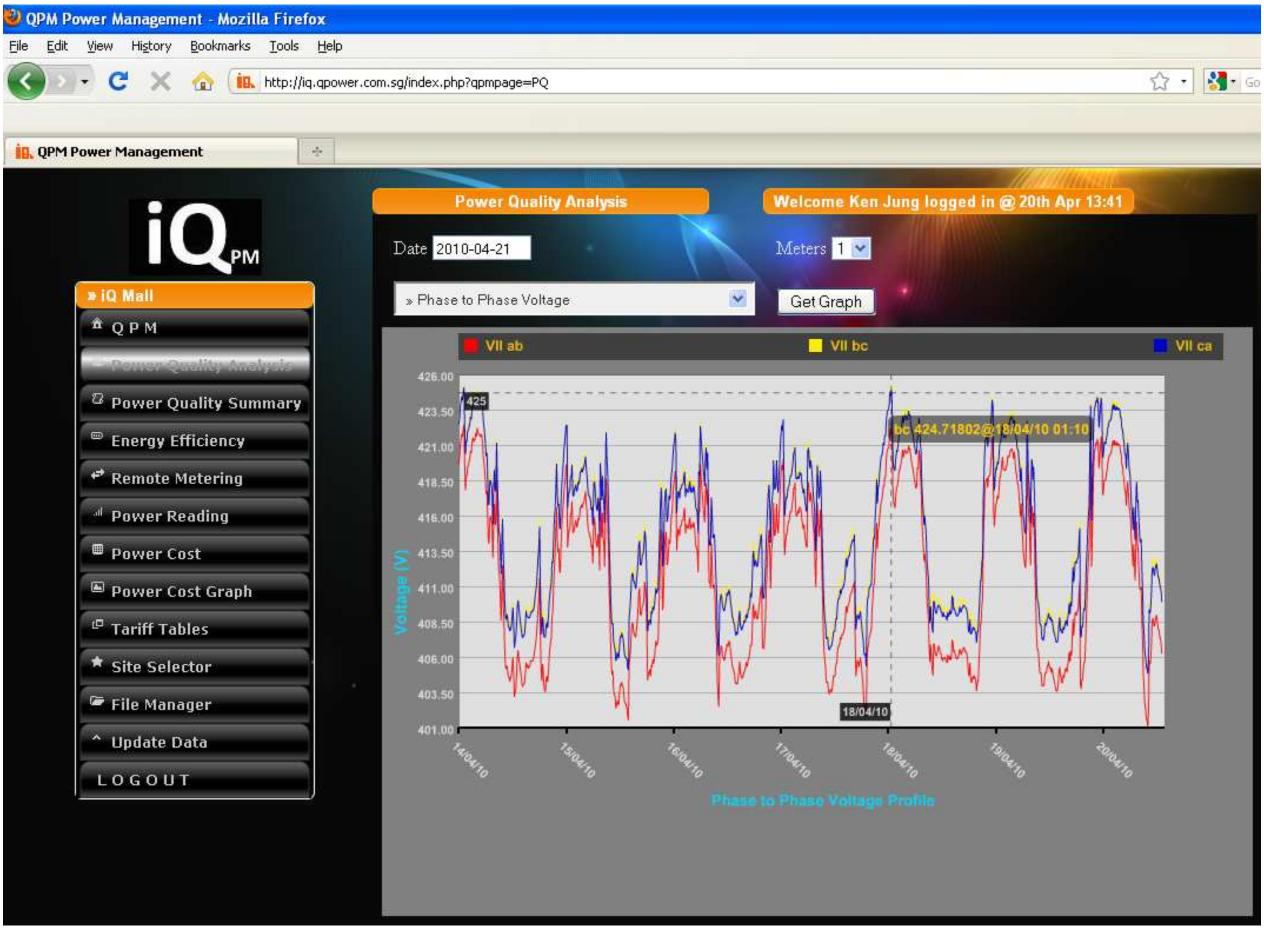

Figure 7 – Phase to Phase Voltage Profile

Figure 8 shows the Red Phase Current Total Harmonic Distortion Histogram. This histogram displays the 7-day current total harmonic distortion measurements with statistics for the red phase or the other phases selected.

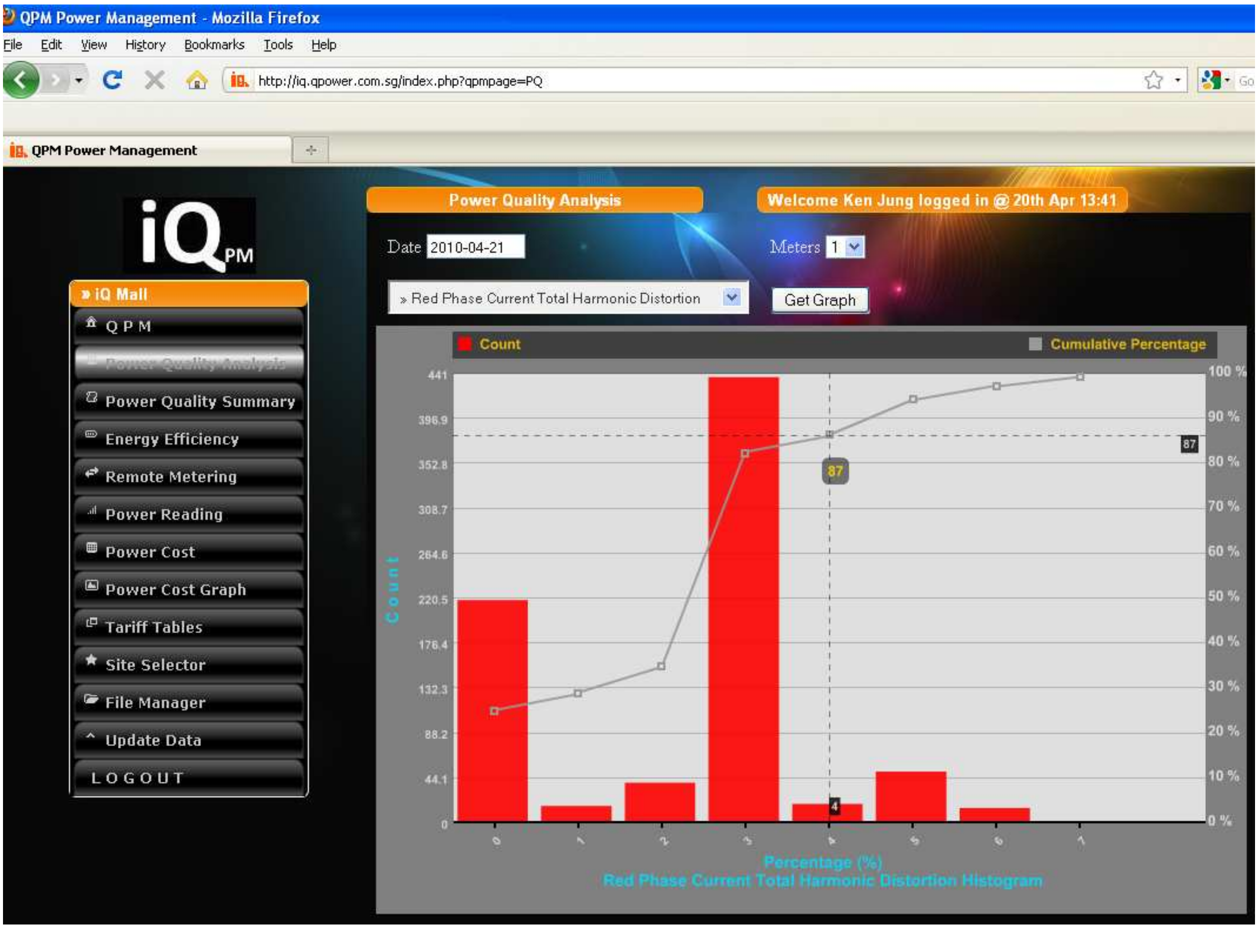

Figure 8 – Red Phase Current Total Harmonic Distortion Histogram

With such features incorporated in a PQ monitoring system, organisations would be better positioned to take immediate actions to avert downtime, reduce wastage, minimise costs and reallocate resources.

Conclusion

Current trend in PQ monitoring focuses on providing web-based access to a real-time power quality monitoring system. Expanded use of TCP/IP networking will aid in providing access to information from facilities located at different sites. This enables a multinational company to leverage on cross-border engineering resources and facilitate corporate energy management. Future trends point towards a system that is able to perform power quality diagnosis with fault location and disturbance analysis capabilities.

iQpm is in the commercialisation phase and has received accolades from potential partners. However, with perpetual advancement in technology, there is always room for improvement. We envisage that power quality monitoring will go wireless (using Mobile Monitoring Agent Technology) in the near future. New features are likely to include remote data analysis via artificial agent technology, real-time data access via mobile telecommunication devices, real time fault and waveform analysers, load and forecasting management, as well as demand side option programme (using fuzzy logic). With soft computing, problems associated with complex balancing between electricity production and capacity generation can be more readily addressed.

Bibliography

[1] Modbus-IDA. *Modbus Application Protocol Specification V1.1a*, June 2004.

Available at http://www.modbus.org

[2] Modbus-IDA. *Modbus over Serial Line: Specification and Implementation Guide V1.0*, December 2002. Available at http://www.modbus.org

[3] Badrul H Chowdhury, "Power Quality," *IEEE Potentials*, vol. 20, Issue 2, pp 5-11, April-May 2001

[4] Mark McGranaghan, "Trends in Power Quality Monitoring," *IEEE Power Engineering Review*, Vol 21, Issue 10, pp 3-9, 21, Oct. 2001

[5] Jos Arrillaga, Math H. J. Bollen, Neville R. Watson, "Power Quality Following Deregulation," *Proceedings of IEEE*, Vol 88, Issue 2, pp 246-261, Feb 2000

[6] S Chen, C L Zhang, and Y Z Liu, “A multi-channel monitoring system for system-wide power quality measurements,” in *Proc. 2000 4th Int.Conf. Power System Technology*, pp 953–958

[7] Afroz K Khan, "Monitoring Power for the Future," *Power Engineering Journal*, Vol 15, Issue 2, pp 81-85, 21, April 2001

[8] Gregory B Rauch, D Daniel Sabin, et al, "Implementing System-wide Power Quality Monitoring Plans," in *Proc. 1996 IEEE Power Engineering Society Transmission and Distribution Conf.*, pp 37-44

[9] Christopher J Melhorn, Mark F McGranaghan, "Interpretation and Analysis of Power Quality Measurements," *IEEE Trans. Industry Applications,* Vol 31, No. 6, pp 1363-1370, Nov-Dec 1995

Article contributed by Dr Henry Wong Chuen Yuen and Mr Ken Jung of Quality Power Management Pte Ltd. Dr Wong is a member of ISPE, MIET, IEEE (USA) and is also a Chartered Engineer - Stage 2, IEEE. Founder of Quality Power Management Pte Ltd and Jung Power Management Pte Ltd, Ken Jung is a member of the Association of Professional Engineers of the Province of Ontario, Canada (APEO), Singapore Professional Engineers Board and Chartered Engineers of the United Kingdom. He is also an Authorised High Voltage Switching Engineer (AHVSE) with Energy Market Authority (EMA). Ken graduated from the University of Toronto with a Bachelor of Applied Science (BA Sc) in Electrical Engineering.

Quality Power Management Pte Ltd (QPM) provides comprehensive and integrated solutions for the development of electrical power quality needs. Its customer base includes high tech industrial and multinational commercial, residential and government bodies.

Quality Power Management Pte Ltd
16 Boon Lay Way, #01-43 TradeHub21, Singapore 609965
Tel (65) 6795 4666 Fax (65) 6795 4222 www.qpower.com.sg