University of Wollongong: Submission to AER Issues Paper - Reviewing the Service Target Performance Incentive Scheme and Establishing a new Distribution Reliability Measures Guidelines

The Australian Power Quality and Reliability Centre (APQRC) at the University of Wollongong (UOW) appreciates the opportunity to provide a submission to the Australian Energy Regulator's (AER) Issues Paper, released in January 2017 (ref. no. 60666) which signals an intention to review the Service Target Performance Incentive Scheme (STPIS) and establish a Distribution Reliability Measures Guideline. Established in 1986, The APQRC is a centre of excellence for research, education and consulting in distribution and transmission system power quality, reliability and renewable energy systems. The strengths of the APQRC include wide ranging expertise in both power systems and customer loads, strong contacts with industry and knowledge of international research efforts. The APQRC operates a modern laboratory with equipment and instrumentation necessary to undertake a range of investigations into both power systems and equipment behaviour.

In addition to research activities, the APQRC offers a consultancy service as well as continuing education courses and has expertise and experience in the following areas: -

- Power Quality – modelling and analysis, standards, instrumentation, monitoring, reporting, improvement, equipment behaviour
- Distribution system reliability
- Renewable energy systems

INTRODUCTION

This submission is directed towards the inclusion of power quality (PQ) parameters[1] and respective assessment procedures within the STPIS framework and as such, specifically addresses *Section 8: Future of STPIS* in the Issues Paper. For the past two decades, UOW has worked closely with Australian Electricity Distribution Network Service Providers in the field of power quality and have been prominent contributors to Standards Australia and international organisations such as IEC and Cigre and as such is in a very strong position to make this submission.

It is noted that Section 4 of the 2009 Electricity Distribution Network Service Provider Service Target Performance Incentive Scheme is dedicated to power quality, however, no requirements are specified. It is understood that the inclusion of power quality in performance incentive scheme was discussed between the AER and some Victorian DNSPs in 2009, but the AER considered that insufficient power quality monitoring infrastructure existed in order to properly implement a scheme. Since 2009, power quality infrastructure has progressed significantly in quantity and capability. This includes the installation of significant numbers of dedicated power quality monitoring devices coupled with the widespread deployment of smart metering devices that have some limited power quality monitoring capability. Combined with the rapid take up of renewable energy generation as well as the expected rapid take up of energy storage systems, which may result in customers now being less susceptible to supply outages (as foreshadowed in the Issues Paper), means that there may be an opportunity to begin the process of implementing a scheme for incentivising management of power quality.

[1] The term power quality is preferred to the broader quality of supply in this document. This is due to the fact that in many cases Quality of Supply covers three areas: customer service, continuity of supply (i.e. reliability) and power quality (also known as voltage quality) as per the description given in [1] based on the Council of European Regulators (CEER) Working Group.

Specific responses to the questions presented in Section 8 of the Issues Paper are outlined in Section 2. This is followed in Section 3 by a general commentary related to power quality monitoring and the economic impact on consumers, based on the experience gained by UOW through the implementation and operation of a national power quality survey, an auditing project that has been in operation since 2002, along with other associated applied research programs. Finally, a high level proposal, outlining the mechanisms by which a scheme to manage power quality could be implemented is presented.

SPECIFIC REPONSES TO QUESTIONS

Q23. *In what way could the STPIS be changed to reflect the needs of consumers with storage or other similar technologies?*

As the Issues Paper rightly identifies, there has been a proliferation of solar PV systems installed over the last decade. A significant number of these installations are small scale domestic systems (rooftop solar), generally less than 5 kW in capacity. Also asserted in the Issues Paper is a prediction that energy storage will become much more prevalent which can be noted as a reasonable assumption. Increased penetration of renewable and dispersed generation with or without energy storage has the potential to both improve and/or deteriorate power quality. There are many instances that can be cited where small scale PV has contributed to voltage rise in domestic installations and in low voltage distribution networks. At the other end of the capacity spectrum, there is evidence of large solar farms causing voltage fluctuations and hence flicker on medium voltage networks. Inverters used for integration of renewable energy have the potential to be of great benefit to control power quality if they are controlled appropriately.

The combination of significantly increased local generation along with local energy storage at domestic consumer premises (which are the bulk of customers contributing to the increase), results in an electricity consumer with differing expectations with respect to the electricity distribution network continuity of supply. However, with respect to the power quality delivered to these customers whilst they are grid connected, their needs remain equivalent to or may even exceed those of all consumers across the entire supply network. Value can be derived from the grid by using it as an energy trading platform supported by incentives (e.g. local demand response, pool price response, frequency support etc.). There are many instances of consumers with local generation wishing to export power to electricity networks who are unable to do so due to voltage levels which are not compatible with generator (e.g. solar PV inverter) protection constraints. Generators which are unable to export power due to unacceptable PQ disturbances levels causing protective limit trips and thus not allowing high value energy trades to take place represent a direct loss of potential income to the customer. In addition, there have been instances of consumers wishing to connect generation who have been prevented from doing so by electricity suppliers due to network constraints related to power quality. Further, ensuring that customer distributed generation can operate and be called upon reliably will be increasingly important to overall grid security (e.g. Virtual Power Plants). LV voltage management under a range of operating conditions is necessary for this.

The technology associated with the provision of off-grid capability (i.e. PV plus storage) has the capacity to change the power quality characteristics of the low voltage grid to which they are connected; it can contribute to a deterioration of power quality as well as be sensitive to such a deterioration. In this regard, including power quality components in the STPIS framework would be a positive mechanism for ensuring that all consumers retain adequate power quality in the evolving distribution network.

In summary, the inclusion of a power quality component to STPIS may better reflect the changing requirements of consumers with local generation and/or energy storage.

Q26. *Should the AER move away from service quality measures mainly based on SAIDI and SAIFI measures? If not, how do we know when we have reached that point? What other measures should be considered?*

As opposed to moving away from measures mainly based on reliability indices such as SAIDI and SAIFI, the AER may wish to consider retaining these measures in conjunction with additional power quality measures which may better reflect customer needs as addressed in the response to Q23. If power quality measures are to be considered, in the first instance, it is recommended that these measures include steady state voltage variations and voltage sags (with the intention of introducing other prominent power quality parameters - harmonics, voltage unbalance, voltage fluctuations progressively). It has to be noted that monitoring of voltage sags usually require dedicated high end instrumentation and not all smart meters may be able to capture them, and hence it may not be possible to report on the same for all networks. Further, the reliability indices such as SAIDI and SAIFI capture network fault data which have links with voltage sags. The above two measures are recommended for the following reasons:

- They are basic power quality parameters that are easy to understand and measure.
- They are the power quality parameters for which most data is potentially available, being measured by all power quality monitoring devices as well as a significant proportion of smart metering devices.
- There is compelling evidence to suggest that voltage sags have the greatest economic impact of all power quality parameters on consumers, in particular those in the industrial and commercial sectors. Furthermore, there is also evidence that there are many voltage sags in the network that are equivalent to an interruption based on the effect on customer equipment.
- There is evidence and ongoing research indicating that improper steady state voltage levels can have significant impacts on consumer equipment efficiency, lifespan and energy consumption.
- As noted previously, steady state voltage variations can also have significant impacts on integration of renewable energy.

General Commentary on Quality of Supply Monitoring

Through the operation of the Long Term National Power Quality Survey (LTNPQS), now called the Power Quality Compliance Audit (PQCA), in conjunction with Australian Distribution Network Service Providers (DNSPs), UOW has gained considerable insight into the power quality monitoring capability of DNSPs as well as actively assisting in the design and implementation of monitoring and reporting schemes. Extensive research has also been undertaken into power quality data summarisation and indices (as in the case of reliability), power quality monitoring methodologies and respective benchmarking.

There has been a significant increase in the level of power quality infrastructure deployed over the past decade. Most DNSPs now have automated, permanent power quality monitoring infrastructure to some degree, with the general preference for permanent monitoring at zone substations as well as large customer locations. Until recently, little infrastructure was available in low voltage networks. The rollout of smart revenue devices with some power quality monitoring capability has addressed this lack of infrastructure in low voltage networks and has resulted in a step change in the number of devices with the potential to supply power quality data. This is particularly the case in Victoria where smart revenue meters were rolled out to all consumers. Additionally, levels of smart revenue meters in other states continue to increase. Notwithstanding the issues confronting DNSPs related to the ownership of data from smart revenue devices (whether it be the retailer or the DNSP), it is becoming more and more likely that sufficient power quality monitoring devices are deployed in networks to provide adequate data to assess the power quality performance of networks.

Along with vastly increased numbers of monitoring devices, there is now a comprehensive suite of Australian standards and guidelines which outline the methodologies to be used for monitoring, analysis and assessment of power quality data. In addition, the LTNPQS and PQCA projects undertaken in conjunction with Australian DNSPs and the Energy Networks Association (ENA) have allowed the development of power quality monitoring, analysis and reporting methodologies which are technically sound and well accepted by the industry. More recently, research undertakings at UOW have established robust methods to determine overall network power quality performance based on sampled data. This includes projection of actual network performance from sampled data and identification of an optimum number of sites which are required for prediction of network performance with acceptable levels of accuracy.

General Commentary on Economic Impact of Quality of Supply

The economic impact due to power quality disturbances is wide and varied. In some cases the impact of the disturbance is immediately obvious through equipment damage and/or loss of process production. This is particularly the case for voltage sags, interruptions and transients. In other cases, the impact of the disturbance may be aging of equipment that will not be noticed for some years, if at all (i.e. the consumer has little or no idea that the device has failed prematurely). In other cases, disturbances lead to unexpected losses, including additional demand and consumption which just become part of the everyday costs of doing business and are not considered further.

The literature is in general agreement with regard to the cost components that are affected by power quality disturbances (i.e. components where expenditure may need to be made, or financial burdens may be felt, due to poor power quality). In general, the literature divides the cost parameters of power quality into three categories; direct costs, indirect costs and social costs. In most literature, direct costs are those that can be easily measured such as waste of material and downtime while indirect costs are more difficult to define and include factors such as loss of reputation and loss of supply chain orders. Social costs are even more difficult to define and include personnel health and safety concerns. In [1], the economic costs of power quality of are divided into three broad categories as follows:

Direct economic impacts

- Loss of production
- Unrecoverable downtime and resources
- Process restart costs
- Spoilage of semi-finished production
- Equipment damage
- Direct costs associated with human health and safety
- Financial penalties incurred through non-fulfilment of contracts
- Environmental financial penalties
- Utility costs associated with the interruption

Indirect economic impacts

- The costs to an organisation of revenue/income being postponed

- The financial cost of loss of market share
- The cost of restoring brand equity

Social economic impacts

- Uncomfortable building temperatures which may reduce efficiency, health or safety
- Personal injury or fear
- Possible need to evacuate nearby buildings as a result of a failure of industrial safety

As discussed previously, if power quality measures are to be included in STPIS it is recommended that these be steady state voltage variations and voltage sags. Additional information concerning the economic impact of these two parameters specifically is given below.

1.1 Steady State Voltage Variation

The costs associated with steady state voltage variation are generally related to loss of equipment life caused by premature aging of equipment due to high steady state voltage levels (overvoltage). Equipment insulation and capacitors are particularly sensitive to voltage levels. For undervoltage, equipment may draw additional current which in turn stresses components. For instance, in [1], for over or under voltage, the main issues are identified are loss of life of equipment, additional equipment energy usage and possible device maloperation.

A less well understood and difficult cost associated with high voltage levels may be the cost related to the additional energy which is consumed by equipment at high steady state voltage levels. Equipment is designed to operate most efficiently at a given voltage level. Operating equipment at voltage levels above this will reduce efficiency and result in wasted energy (in the equipment and the supply network). There is considerable evidence [2], [3] which indicates that a reduction in voltage levels will result in reduced electricity demand and hence reduced energy bills for consumers.

1.2 Voltage Sags

For voltage sags, if the sag is long enough or deep enough it can have a similar impact to an interruption. Even sags which are not particularly severe may result in the tripping of a sensitive piece of equipment. If this piece of equipment is part of a primary control system, the tripping may result in the loss of a whole production facility. In [4] it is stated that a 1 s power failure or, very deep sags, lead to a 1- 30 min. process interruption for 56% of customers. For industrial customers, it is stated that the average process outage time after a 1 s power failure is 21 minutes. As another example, Figure 0.1 shows outage durations for a 1 s power failure.

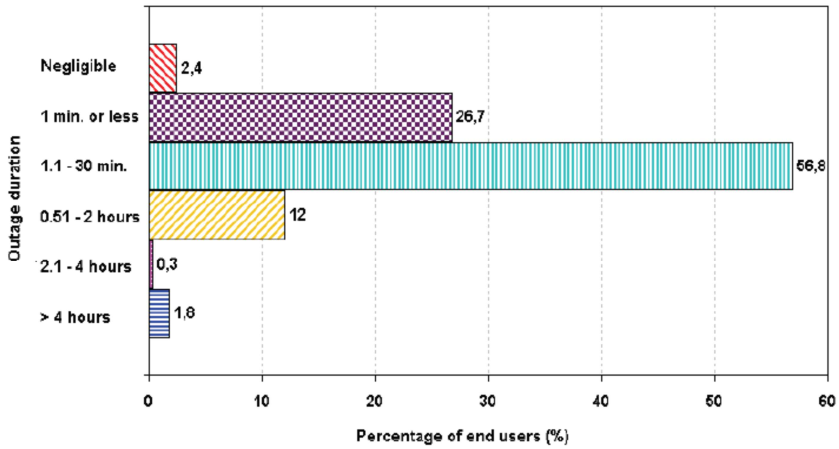

Figure 0.1: Outage Duration for a 1s Power Failure [5]

Figure 0.2, taken from [6], shows the breakup of costs due to voltage sags for different industries. It can be seen that work in progress and equipment damage costs tend to dominate.

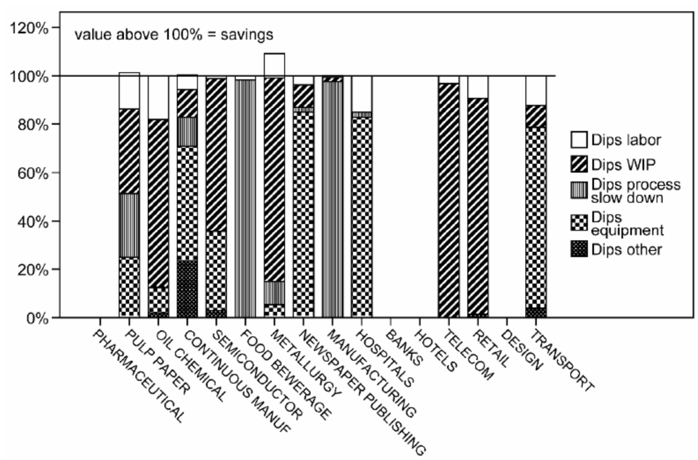

Figure 0.2: Breakup of Costs due to Voltage Sags [6]

All literature reviewed to date is in agreement that voltage sags is the power quality parameter which is responsible for the overall greatest cost to consumers [4], [7], [8], [9], [10].

POWER QUALITY MANAGEMENT PROPOSAL

The AER may wish to consider inclusion of power quality in STPIS through a staged process including trials. A possible three stage implementation is outlined here.

1.3 Stage 1 – Identification of Appropriate Measures and Assessment

Stage 1 would involve the identification of the necessary power quality monitoring and assessment methodologies. This stage would consist of the following:

- Identification of the appropriate power quality parameters to be included in any scheme. It is proposed that, in the first instance, these be steady state voltage variation and voltage sags[2].
- Identification of the appropriate assessment methodologies and indices for each included power quality parameter. Australian standards and international best practice can be drawn from in this regard. Methodologies for steady state voltage are generally well accepted and understood. Additional work may be required to determine appropriate indices for voltage sags.
- Identification of appropriate methodologies for the selection of sites as well as monitoring of power quality.
- Determination of the appropriate methodology for determining the power quality performance for an entire distribution network.

1.4 Stage 2 – Trial Measurement and Assessment

Stage 2 would involve application of the methodologies in Stage 1. DNSPs could perform measurement and assessment over a minimum 12 month period to familiarise themselves with the scheme and ensure that adequate infrastructure is in place without being concerned about financial implications. At the end of this stage appropriate performance targets could be determined. Appropriate penalties and incentives for performance could be assessed in parallel with trial monitoring and assessment of power quality performance.

1.5 Stage 3 – Trial Full Scheme Deployment

In Stage 3, the full scheme including incentives/penalties would be deployed as a trial to better understand the workings of the scheme and any issues associated with it. In this trial although the penalties and incentives would be in place, they would not be levied. If the trial is successful, the scheme could then go 'live'.

CONCLUSION

This submission is directed towards the inclusion of power quality parameters and respective assessment procedures within the STPIS framework and as such, specifically addresses *Section 8: Future of STPIS* in the Issues Paper.

Decentralisation of generating resources and the prevalence of energy storage devices will mean that, for many customers, grid interruptions may no longer have as significant an impact from an energy security perspective, yet, as detailed in this document, power quality continues to be important. For large customers, the impact of voltage sags will remain to be the main power quality issue for quite some time. For all customers, having a reliable and in-specification supply is paramount to protect the investment in end use equipment and network infrastructure that are linked to the existence of equipment and supply network standards. Therefore, power quality monitoring and reporting is a natural extension to the current STPIS framework which at the present covers reliability and customer service components but not power quality. Inclusion of power quality will result in a STPIS scheme which manages the full breadth of quality of supply.

The inclusion of an incentive scheme within STPIS that encourages power quality management in distribution networks is a way of recognising the importance of ensuring the quality of electricity delivered to customers while the network and its components are optimally utilised, thus bringing

---

[2] As stated earlier in Section 2 under Q26, some care is required in the incorporation of voltage sags as a power quality measure.

benefits to the wider community. In this regard it is vital that various power quality parameters remain within the stipulated specifications.

With the above in view, this submission proposes a staged approach for the inclusion of power quality in the STPIS framework.

References

[1] Angelo Baggini (ed), "*Handbook of Power Quality"*. West Sussex, England: John Wiley & Sons, 2008.

[2] Pacific Northwest National Laboratory, "*Evaluation of Conservation Voltage Reduction (CVR) on a National Level*", Report Prepared for US Department of Energy, 2010.

[3] Peter Fairley, An Easy Smart-Grid Upgrade Saves Power, *IEEE Spectrum*, vol. October 2010, Issue. 2010, pp.

[4] David Lineweber, Shawn McNulty, "*The Cost of Power Disturbances to Industrial & Digital Economy Companies*", Report Prepared for EPRI's Consortium for Electric Infrastructure for a Digital Society (CEIDS), June 29, 2001.

[5] Sharmistha Bhattacharyya, Sjef Cobben, "*Consequences of Poor Power Quality – An Overview*", Webpage, last accessed 14th February, 2017, Available: http://www.intechopen.com/books/power-quality/consequences-of-poor-power-quality-an-overview.

[6] Jonathan Manson, Roman Targosz, "*European Power Quality Survey Report*", Report Prepared for Leonardo Energy, November, 2008.

[7] Andreas Eberhard (ed), "*Power Quality"*. Rijeka, Croatia: InTech, 2011.

[8] H. De Keulenaer, "*The hidden cost of poor power quality*", Report Prepared for Leonardo Energy, European Copper Institue, October, 2003.

[9] R. Targosz, J. Manson, "*Pan-European power quality survey*", Electrical Power Quality and Utilisation, 2007. EPQU 2007. 9th International Conference on, 9-11 Oct. 2007, 2007, pp. 1-6.

[10] R. Barr, V.J. Gosbell, S. Perera, "*The Customer Benefits of High Reliability and High Power Quality*", EESA Electricity 2005 Conference, Brighton-le-Sands, NSW, Australia, November, 2005.

Appendix A: Further Information About the Power Quality Compliance Audit (PQCA)

The Power Quality Compliance Audit (PQCA), formerly known as the Long Term National Power Quality Survey (LTNPQS), is a world leading power quality monitoring, analysis and reporting project involving the majority of Australian DNSPs. The project which has been developed in conjunction with the ENA and DNSP participants involves submission of data by the participating utilities to the University of Wollongong who prepare annual reports on the data using the novel and innovative analysis and reporting methods developed specifically for the project.

Benefits of the PQCA to participants have included:

- Analysis and reporting of PQ data and compliance determination is performed by an independent body using world leading techniques.
- Alleviation of the need to maintain complex PQ data storage, analysis and reporting systems. PQ data will be reported using the very latest techniques by world leading experts using methodologies that have been developed over many years.
- The ability to compare network performance with peers across a range of site characteristics. Determine whether PQ strategies are working. Decide where scarce resources should be allocated.
- Access to a very large repository of PQ data and expertise.
- Assistance with customer education. Data can be used to indicate how performance compares with industry best practice.
- Identification of the economic impacts of power quality both to the network and customers.

Major findings of the PQCA to date include:

- Identification of the PQ issues of most concern for distribution networks.
- A greater awareness of PQ issues within participant networks including assessment and control.
- Development of sophisticated and novel analysis and reporting methods including benchmarking.
- Better understanding of PQ disturbance behaviour
    - Acknowledgement that harmonic levels are not a major concern, being smaller than reported overseas in both magnitude and rate of growth.
    - Confirmation that network voltage sag behaviour of networks cannot meet equipment immunity.
    - Realisation that present methods of measuring unbalance are unsatisfactory.
- Significant advances in the understanding of PQ monitoring methodology including sampling and application of statistical methods for performance estimation.

Much like standards, the PQCA is a ‘living’ project. PQ indices and reporting methods have evolved over time for a range of reasons. These include developments in reporting and analysis gained through research, changes in the requirements of industry and standards/codes. Access to a vast repository of data has allowed significant ongoing research to be conducted into power quality monitoring and reporting. A significant number of research outputs are the direct result of the LTNPQS/PQCA project. These include:

1. Sean Elphick, Vic Smith, Vic Gosbell, Sarath Perera, Phil Ciufo, Gerrard Drury, “Characteristics of power quality disturbances in Australia: voltage dips at low-voltage sites”, IET Generation, Transmission & Distribution, DOI: 10.1049/iet-gtd.2015.0556

2. Sean Elphick, Vic Gosbell, Vic Smith, Gerrard Drury, Robert Barr, “Assessing Network Compliance for Power Quality Performance”, Proc. 16th IEEE International Conference on Harmonics and Quality of Power ICHQP 2014, 25 - 28 May 2014, Bucharest, Romania, Paper No. 83.

3. Elphick, S., Smith, V., Gosbell, V. & Perera, S., “Characteristics of power quality disturbances in Australia: Voltage harmonics”, Australian Journal of Electrical & Electronics Engineering, Vol. 10, No. 4, 2013.

4. Sean Elphick, Vic Smith, Vic Gosbell, Robert Barr, "Characteristics of Power quality Disturbance Levels in Australia", Proc. 15th IEEE International Conference on Harmonics and Quality of Power ICHQP 2012, 17 - 20 June 2012, Hong Kong, Paper No. 61.

5. Sean Elphick, Vic Gosbell, Vic Smith, Robert Barr, “The Australian Long Term Power Quality Survey Project Update”, Proc. 14th IEEE Conference on Harmonics and Quality of Power ICHQP 2010, 26 - 29 September 2010, Bergamo, Italy, Paper 936

6. Ian Gibb, Sean Elphick, Vic Smith, Vic Gosbell, Robert Barr, “The Long Term National Power Quality Survey – Benefits, Opportunities and Future Directions”, Energy21C 2009, 10th International Electricity and Gas Networks Conference and Exhibition, 6 – 9 September 2009, Melbourne

7. Sean Elphick, Vic Gosbell, Robert Barr, "The Australian Long Term Power Quality Monitoring Project", Proc. 13th IEEE Conference on Harmonics and Quality of Power ICHQP 2008, 28 September - 1 October 2008, Wollongong, Australia, Paper 1042

8. Sean Elphick, Vic Gosbell, Vic Smith, Neil Browne, “Appropriate Power Quality Standards for the National Electricity Rules (NER)”, Energy NSW 2008, EESA NSW Chapter, 29 - 31 October 2008, Sydney, Australia

9. S. Elphick, V. Gosbell, S. Perera, "The Effect of Data Aggregation Interval on Voltage Results", Proceedings of AUPEC2007, 10-12 December 2007, Perth, Paper 15-02

10. S. Elphick, V. Gosbell, "The Variation of Power Quality Indices due to Data Analysis Procedure", Proceedings of AUPEC2007, 10-12 December 2007, Perth, Paper 15-03

11. V. Gosbell, S. Elphick, R. Barr, D. Urquhart, P. Wong, "The Australian Long Term National Power Quality Survey", Energy21C, 9th International Transmission and Distribution Conference and Exhibition, 11-14 November 2007, Sydney, Australia

12. S. Elphick, V. Gosbell, R. Barr, "The Statistical Behaviour of Voltage at LV Sites", Energy NSW 2007, EESA NSW Chapter, 12-14 September 2007, Sydney, Australia

13. S. Elphick, V. Gosbell, R. Barr, "The Australian Power Quality Monitoring Project", EEA Annual Conference, Auckland, NZ, June 2006

14. S. Elphick, V. Gosbell, "The Need for Greater Standardisation in Utility Power Quality Measurements", Proc. 6th Biennial Conference of Metrology Society of Australia, Canberra, Australia, October 2005, pp. 148-153

15. S. Elphick, V. Gosbell, R. Barr, “Reporting and Benchmarking Indices for Power Quality Surveys”, Proc. AUPEC04, 26-29 September 2004, Brisbane, Australia, Paper 132.

16. M. Peard, S. Elphick, V. Smith, V. Gosbell, D. Robinson, "Data Management for Large Scale Power Quality Surveys", Proc. AUPEC04, 26-29 September 2004, Brisbane, Australia, Paper 133.