PQA NEWSLETTER

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Electricity Quality – Are We Getting What We Pay For?

Summary

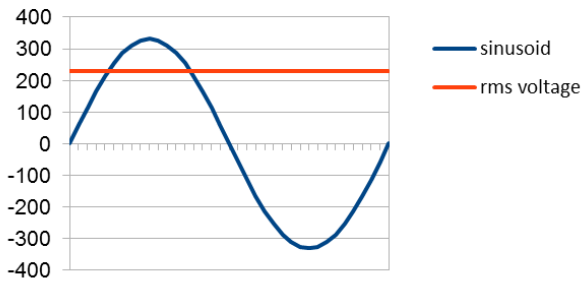
It is universally acknowledged that we are paying quite a lot for our electricity. Are we getting what we pay for? This article describes why there is a price to pay for power quality and exposes the risks we may be taking.

High Quality Electricity - Why do we want it?

Most of our household electrical appliances, lights, storage heaters and motors are designed to operate at a particular voltage. If the provided voltage deviates too far from the design voltage, the equipment could operate inefficiently, not do the job it is intended to do, have a shorter life than expected or even fail in an unsafe manner. These implications range from inconvenience to greater cost and even risk to personal safety. For those with generation systems such as rooftop photovoltaics, income could be limited due to inverter tripping if the voltage is not as expected.

What do we want?

Ideally the supply voltage should perfectly match the equipment design voltage. What is the design voltage? Most equipment sold in Australia is designed around Australian Standards. (For voltages, the Australian Standard is AS60038.) For single-phase low voltage 50 Hz alternating current equipment as used in most households, 230 V is the rated voltage. We also want the voltage waveform to be sinusoidal without too much distortion and to not fluctuate too much. If we have a 3 phase supply, we want all 3 phases to be more or less equal in magnitude and evenly spaced in time. If not, 3 phase motors could overheat. There are Australian standards which specify acceptable levels for distortion, fluctuation and difference in magnitude and phase angle across phases



When do we want it?

Uniform voltage all the time would be ideal. Realistically 98 per cent of the time has been adopted as a reasonable expectation for steady state voltage. To achieve this, Australian Standard AS61000.3.100 created the terms

V1% and V99% to describe the lower and upper steady state voltage limits respectively to be achieved at customer connection points.

Where do we want it?

Ideally every power point should receive the same voltage. However, all conductors exhibit some impedance to current flow and that means a voltage drop along the conductor – be it cable or overhead line. The standards prescribe voltage at customer connection points. The Wiring Rules ensure the voltage drop throughout the premises is not excessive.

How well do we do?

Do power systems deliver this voltage? The short answer to this is no. However, the full story is quite complex. It involves a long history of different laws, codes and regulations. Electricity suppliers endeavour to give their customers the equipment rated voltage most of the time. However, just as the water pressure to your garden hose varies throughout the day and from summer to winter, so voltage varies according to usage, generation and weather patterns. Also the voltage at the power point in the lounge room may differ from the voltage at the pool pump in the backyard. To add to the confusion, things happen on the electricity network to cause the voltage to fluctuate and the waveform to distort. This can be the result of other customers' equipment or network operators' equipment. It can be deliberate or inadvertent. Some utilities deliberately distort the waveform slightly in order to send control signals, such as those that turn on hot water systems or street lights. Customers with arc furnaces or air conditioners can cause voltage fluctuations which affect not only themselves but other customers as well.

The Power Quality Compliance Audit conducted by Power Quality Australia collects data from many sites in utilities around the country. It shows that the median high voltage (or V99%) for the average utility's sites was about 251 V last year, while the median low voltage (or V1%) for the average utility's sites was 240 V. 95% of sites for the average utility had a low voltage (V1%) of more than 230 V. In other words, voltages at measured sites are consistently high compared to the equipment rated voltage.

Conclusion

If you consider that electricity is a product, then the bottom line is surely the right product at the right time and the right price. The right product is perfect voltage all the time. Achieving this could be expensive. Imperfect voltage some of the time would be cheaper and may be acceptable to most customers. The electricity companies argue that if prices do not rise then quality of supply will fall. The Regulator is required to prescribe the level of service that a customer can reasonably expect. To use a motor car analogy, do we want a top of the line model with heated leather seats and breathtaking performance or a no frills model that is cheap to run? Alternatively, if electricity is a service, do we want to travel 1st class, business class or budget economy? In a country like Australia, there must be a minimum acceptable quality of supply. However in order to make a decision, the customer needs to know what is on offer and how much it costs. Are we getting what we pay for? Only some of the time – and that is costing us money.

Addendum - Why supply voltages do not match equipment rated voltages

This involves history, politics, economics and technical stuff.

History

Historically the United Kingdom had a lot to do with it. In order to beat the French, England sent a motley assortment of felons by boat to Australia and claimed it as their own penal colony. The English ships were allowed to stay and the Westminster system was brought to Australia. Once electricity was invented we were pretty much tied to all things British. Long before joining the European Union, the UK used 240 V as their nominal voltage. As Australia's power system was based on the UK system, we also used 240 V. In Europe there were 220 V, 230 V and 240 V systems. The International Electrotechnical Commission (IEC) has tried to standardise things and adopted 230 V some years ago. Australia Standards have followed IEC and also adopted 230 V. The expectation is that countries will gradually adjust their systems to align with the 230 V standard. There are some difficulties doing this. For example in Queensland the state legislation prescribes 240 V as the nominal voltage. So even if they wanted to align with international and Australian Standards, Queensland utilities are still tied to Queensland's laws.

Technical Stuff

In designing their LV networks, electricity network operators allowed for a voltage drop through their system. In order to ensure the customer furthest from the source of supply received adequate voltage at times of peak load, the voltage at the terminals of the distribution transformer has traditionally been set high. This means that customers close to the transformer receive higher voltage at times of peak load. At times of light load, all customers may well receive high voltage as there is little voltage drop along the feeder. Nowadays, at times of peak generation by rooftop PV, the voltage may even rise along the feeder.

Politics

In Australia according to the constitution, various responsibilities belong to the Commonwealth and others belong to the states. State governments have responsibility for electricity supply. However with the establishment of the National Electricity Market, National Electricity Rules have been developed on top of state requirements. (The National Electricity Market applies to NSW, QLD, SA, Tasmania and Victoria.) National Electricity Law was established in 1994 and revised in 2005. The National Electricity Rules are enforced by the Australian Energy Market Commission and the Australian Energy Regulator.

In some states voltage requirements are quite specific. In particular, Queensland Electricity Law says that electricity for general supply must be alternating current having a nominal frequency of 50 Hz, and the standard voltage for electricity supplied at low voltage from a 3-phase system must be 240 V between a phase conductor and neutral conductor. The allowable margin in this 2006 law is 6% more or less than the standard voltage. A degree of interpretation is required if this law is to be enforced. It is generally assumed that the voltage waveform is sinusoidal, and that the root mean square (rms) value is the standard voltage. Temporary excursions can and do occur and it is unreasonable to expect the voltage to remain within the margins for all customers all of the time. Cars hit power poles, cables fail, transformers can explode. But what is reasonable? Is 7% high for some of the time for some customers acceptable? Does the waveform have to be sinusoidal or is it OK if some customer's equipment distorts the waveform?

Economics

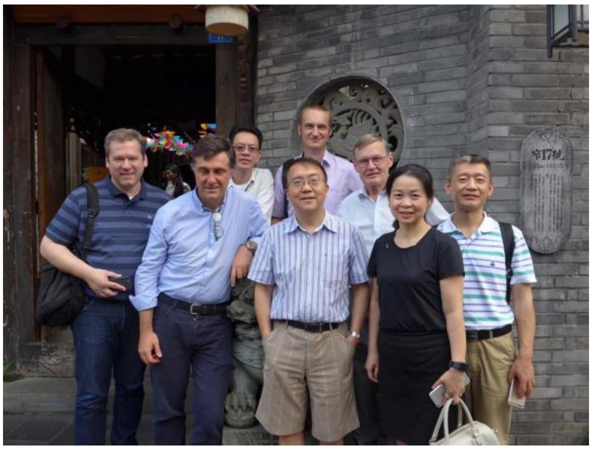
As demonstrated in South Australia recently, it is not always possible to have electricity. When we do have it, it may not be perfect. It may not even be within normally accepted limits. By spending more money on our networks we can get better quality voltage. Do we want to spend more? That is debatable. Before having that debate we should at least know what we are getting. To know that we need to monitor the voltage on our networks. Utilities can manage voltage drop and voltage levels but there is a cost. Thicker conductors and shorter distances between transformers can help reduce voltage drop. Adjusting transformer taps can lower voltage but it needs to be carefully managed.

International Workshop on Harmonic Detection

Prof Vic Gosbell Represents Australia on Expert Panel

IEC standards give guidelines for allocating harmonic current emission to large customers, but they do not detail the assessment of compliance. This is a very difficult problem because the harmonic current drawn by an installation is a combination of two effects: non-linear loads (and capacitors) within the installation and background harmonics in the power system due to other customers. Over the last couple of decades, there have been several papers suggesting various techniques that might be used to separate the customer and power system contributions to the harmonic levels at the point of connection, but none has been accepted as a final satisfactory solution.

This problem is sufficiently important that CIGRE and CIRED have set up a joint working group - JWG 4.42 "Continuous assessment of low order emissions from customer installations" - due to report at the end of 2018. In association with this working group, Profs Yang & Xiao of Sechuan University invited several international experts to a workshop held in Chengdu in late June. The workshop was led by Prof Wilsun Xu, Editor-in-Chief of the IEEE Transactions on Power Delivery, and included experts from Slovenia, Italy and Poland as well as Vic Gosbell from the Australian Power Quality and Reliability Centre. A day was devoted to individual presentations on current research followed by a two day brainstorming session.



Experts at the recent International Workshop on Harmonic Detection

The main result from the workshop arose out of recent successful attempts to identify customer harmonic currents and equivalent harmonic impedances using modern transducers and digital signal processing techniques. A proposed method is to determine for an installation how far its behaviour deviates from that of a pure resistor then to determine suitable penalty factors to measure this. This might become a basis for harmonic assessment or alternatively a method for billing customers for harmonic rights. If the second idea can be established, it will remove the need to determine customer allocations since that will be looked after by a "harmonic emissions market".

The proposal looks promising but needs to be confirmed. There will need to be many simulation studies to examine the details and show that the result follows expectations for changes both within and outside the customer installation. A final report is expected from the simulation studies later this year.

Power Quality (PQ) Allocation Workshop

Experts Gather at the University of Wollongong

The Australian Power Quality and Reliability Centre (APQRC) hosted a one day Power

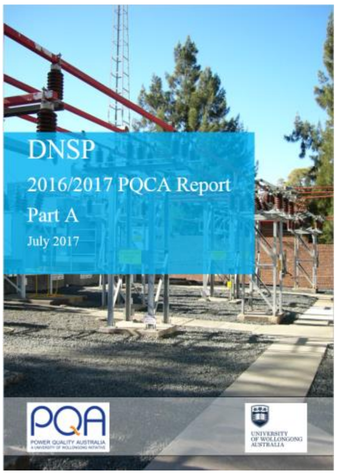
Quality (PQ) allocation workshop on the 7th August 2017 at the Sustainable Buildings Research Centre (SBRC). The workshop was aimed at transmission and sub-transmission voltage and discussed the methodologies available and their limitations for allocation of harmonics, flicker and unbalance. The running of the workshop was motivated by the challenges that are facing many electricity network providers due to the increasing number of large renewable energy generators (mostly solar farms) that are being connected at voltages up to 132kV. In particular harmonic allocation was given significant emphasis covering the new 'head room approach'. The uncertainty associated in the connection of distributed generation systems was emphasised using a probabilistic approach. Flicker and voltage unbalance allocation was also covered considering the methodologies that are already described in the ENA Power Quality Guidelines. The workshop was concluded with a discussion session which was aimed at gathering PQ allocation issues of concern from the nearly 20 participants who came from transmission and distribution network service providers in NSW, Queensland, Victoria and Tasmania.

PQCA Update

Innovation and Expansion

With the close of the financial year on 30th June 2017, collection of data for the 2016/2017 PQCA reports has begun in earnest. PQCA staff are now busy collecting data from participants, performing analysis and producing reports. With more and more participants including smart meter data in their PQCA reporting, it is expected that site numbers will increase significantly this year. This leads to better value for the individual participant as well as improved benchmarking. After over 15 years of operation, there is now a very large repository of power quality data maintained by PQA for the benefit of individual PQCA participants along with the electricity supply industry as a whole.

In terms of reporting, participants will notice some significant changes to the visual presentation of reports this year. Considerable development has been undertaken to make reports an even more holistic review of participant PQ performance. This includes additional analysis and commentary on performance. In addition, report layout has been refreshed and a modern visual aesthetic adopted whilst still maintaining the underlying technical and analytic rigour which has been a hallmark of the project to date.



PQA has also been supervising development of an enhanced web based reporting system. Once online, this system will be significantly more functional than the current offering and will give participants a more modern and flexible web based reporting experience. In other exciting news, PQA staff are also working to deliver our very first reports to transmission operators. Engagement with transmission operators represents a significant evolution of the PQCA and PQA staff are working closely with transmission system PQ experts to ensure that the PQCA is of as much benefit to their businesses as it has been to distribution operators over an extended period of time.

PQCA System Upgrade

PQCA now with extra crunch

The final report for the pilot study that was the forerunner of the PQCA was published in 2001. That study included 70 sites. Fifteen years later the 2015/2016 PQCA included over 9,000 sites. Over the years the accumulated data has grown to over 1.5 billion records with 85% of those added in the last 5 years. Recent growth in supplied data is largely due to participants starting to supply large quantities of data from smart meters. The accumulation of data and the exponential increase in data over recent years has seen a need for the PQCA systems to be upgraded. However the upgrade is not only catering for increased requirements for data storage, but with the latest hardware and updated software also comes a performance increase in processing power. The new hardware is a latest model Dell PowerEdge R730 with 5 times the RAM and almost twice the disk capacity as the current system, and will also include an update to a later version of the MS SQL Server database software. As the current system is now several years old and at its capacity, the upgrade will enable PQA to continue processing and analysing the increasing data being supplied by participants and delivering the PQCA reports that are keeping the participants and industry informed about the ongoing state of PQ in Australian electricity networks.

Joint PhD Program

Program established to attract international research students

After considerable effort, the APQRC has initiated a joint PhD program with a number of international institutions. This program has already attracted students from Austria, India and Sri Lanka to undertake research projects of strategic value to the Australian Power Quality and Reliability Centre and the wider Australian power engineering industry. These joint PhD students will be completing half of their studies in their home institution and the remaining half at the University of Wollongong where the tuition fees are waived and a living allowance is paid. Upon completion, they will receive a joint award from their home institution and University of Wollongong. Several more students are expected to arrive in 2018 to complete their studies at UOW. This scheme will help bolster the research programs at the APQRC. For further information on this program Dr Ashish Agalgaonkar (ashish@uow.edu.au) of APQRC can be contacted.

Upcoming CPD Courses

Quality of Electrical Supply	19-20 April 2018
Advanced Quality of Electrical Supply	12-13 July 2018
Renewable Energy & Distributed Generation	27-28 September 2018

For information on upcoming training courses visit www.elec.uow.edu.au/apqrc/training.

Have you considered our modular Master of Electrical Power Engineering (MEPE) program? Click here for more information.

Looking for Further Information?

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