



Measurement and Technical Transmission Standards in Australia

A Submission from the National Measurement Institute to the Reliability Panel's Review of Technical Standards June 2008

1. Introduction

The Issues Paper of the Australian Energy Market Commission Reliability Panel's Technical Standards Review set out the scope of the Review in accordance with Section 38 of the National Electricity Rules (NER). The Issues Paper, however, acknowledged that the term *technical standards* is not defined in the NER.¹

Metrology (i.e. measurement science) is an essential part of standards that are used to provide consistency to the quality and performance of processes and services. Physical measurement underpins technological activities and is the basis on which technical standards are designed and the integrity of products and services assured. Indeed, accurate measurement of electrical quantities such as voltage, current, resistance and capacitance underpins most areas of industry, research and everyday life. Yet, accurate measurement is regularly taken for granted, especially when electrical quantities are involved.

The National Measurement Institute (NMI) administers the *National Measurement Act 1960* which together with its subordinate legislation and regulations sets out a framework for measurements conducted in Australia. Under Section 10 of the Act, measurements can be substantiated in law by relating them, through a continuous chain of calibrations with known uncertainties, to the national (primary) standards of measurement held by NMI, and through them to internationally accepted units of measurement. A measurement made according to this process is said to be 'traceable'. Measurements that are not traceable to national or international standards cannot be regarded as beyond doubt, since their accuracy and their uncertainty cannot be substantiated technically.

NMI provides electrical testing, measurement and calibration services to support a wide range of clients including the Australian power industry. In order for electrical measurements used for trade, regulation or enforcement to be recognised under Australian law, they should ideally be compliant with Section 10 of the National Measurement Act and consequently be based on internationally accepted reference standards and protocols. NMI maintains substantial infrastructure for these services because our output must be scaled over widely varying voltages, resistances, capacitances and currents, measured at frequencies from direct current to 40 Gigahertz or higher.

This submission paper is restricted to presenting NMI's concerns about technical aspects of the metrological situation applying to high-voltage transmission in Australia's National Electricity Market (NEM) and its implications for transmission technical standards. The following questions are specifically addressed:

- 1) Are there barriers to accurate future measurements which underpin the technical standards of high-voltage transmission services?
- 2) Do new measurement standards or procedures need to be developed for transmission services?

2. Measurement and its Relation to Transmission Systems

The Reliability Panel in its 2007 review of electricity market performance acknowledged that in order to meet power system security standards, a number of technical requirements *must be*

satisfied including technical standards, frequency operating standards, equipment ratings, system voltage limits, system stability criteria, and generator performance standards (where “security” relates to operation of the power system within its technical limits).²

Each Australian State has a transmission system that differs due to its sources of electricity, physical size, and location of generation relative to load centres. Five of these transmission systems are now interconnected forming the NEM. Such interconnection creates new problems and places demands on each transmission system not previously encountered in Australia before the creation of the NEM. One such problem is the accurate measurement of physical quantities when electricity passes from one transmission system to another. This problem was clearly stated in a 2002 U.S. report on transmission interconnection:

... it is necessary to precisely measure how much power is being exported or imported by an area to know whether the area is balancing its generation and load. Gathering this information requires that every line or transformer connecting an area to any other area be accurately metered and monitored ...³

Accurate measurement of electrical quantities and time underpins the technical standards necessary for maintaining continuous and reliable transmission services and is the means by which compliance with those standards is ascertained. This was also acknowledged by the Reliability Panel in its 2007 review:

Transferring large amounts of electricity between generators and consumers over a wide area presents technical challenges to the power system’s stability. One of NEMMCO’s [National Electricity Market Management Company’s] core obligations, therefore, is to ensure that stability is maintained. The primary means of doing this is to carry out detailed technical analysis of *threats* to stability. Under the Rules, generators and TNSPs [Transmission Network Service Providers] monitor indicators of system instability and report their findings to NEMMCO. NEMMCO then analyses the data to determine whether the standards have been met. NEMMCO also uses this data to confirm and report on the correct operation of protection and control systems.⁴

A further difficulty for the NEM is that the majority of the transmission assets in Australia have been in constant use for over 30 years. The next ten years will present significant new challenges for Australian transmission systems, as the current configuration adjusts to changes in supply and demand. At the very least, these transmission networks will require major capacity enhancements. Also, in the near future, the greater proportion of transmission assets will come to the end of their useful lives and will need to be replaced.⁵ The replacement of these assets will go hand-in-hand with the installation and calibration of new classes of electrical measurement systems involving technologies which are being widely introduced into electric power industries worldwide. The maintenance and development of Australian test and calibration facilities is an essential part of the process of replacing and upgrading infrastructure.

3. Barriers to Accurate Measurement in High-Voltage Transmission Services

As described above, there will be significant challenges for transmission systems in Australia plus the necessary replacement of the majority of transmission assets over the next decade. Changes to existing infrastructure and the advent of new transmission lines within the NEM’s transmission networks will demand additional high-voltage metering and calibration services. Before the establishment of the NEM, little metering at the high voltages used for long distance transmission was undertaken. However, the operation of the NEM has necessitated an increase in high voltage metering and related services. This is because the NEM draws

electrical energy from many suppliers across eastern and central Australia to a common electricity 'pool' and does so at purchase (i.e. monetary) rates that vary throughout each day. The electricity suppliers are then paid according to information gained from high-voltage metering. For such purposes, high-voltage measurements in Australia are required to be accurate to within $\pm 1\%$.⁶ The potential risk of failure of NEM trading will be significantly increased without an appropriate level of measurement accuracy, since accurate measurement is the basis of the NEM's payment system.

The demand for metering at high voltages and related services can only increase in future with on-going augmentation, as the old transmission assets are replaced with new ones, and as the NEM expands in capacity and geographic size. As part of NMI's obligation to assist Australian industry to utilise measurement techniques and promote best practice in measurement, NMI has been maintaining a close scrutiny of new high-voltage metering technologies that are appearing on the world market.

The measurement of high voltages on an electrical system is usually done with capacitive coupled voltage transformers (CCVTs). A CCVT is a type of reliable, high-accuracy transformer used for quality metering and protection in high-voltage circuits. (Capacitive coupling refers to the transfer of energy by means of a capacitor placed in series with a magnetic voltage transformer.) The capacitor part of a CCVT has an expected drift of several percent over a few years. Some CCVTs can develop measurement errors of as much as 3% over a year, so that regular calibration and a good understanding of instrument characteristics is required to maintain the desired $\pm 1\%$ measurement accuracy. NMI can calibrate known systems from working standards that are eventually traceable to measurement standards maintained at NMI.

The situation is not the same with the measurement of high-voltage electric current. This is measured with current transformers (CTs), usually of the magnetic type. A current transformer provides a current in its secondary winding which is proportional to the current flowing in its primary winding. Current transformers are commonly used in metering and protective relaying where they facilitate the safe measurement of large currents in the presence of high voltages. Magnetic high-voltage CTs are normally calibrated at low voltage, at mains frequency, with an assumption that their errors at high voltage are similar, if internal shielding is in place. There is a growing need to determine the errors of CTs at high voltage, due to the electrical loads generating high harmonic content (higher frequencies) in the current on the transmission system. CT calibration at high voltage and at a broad range of frequencies may be done with Electronic Current Transformers (ECTs) which incorporate clamp-on Rogowski coils. A Rogowski coil is a single coil electrical device for measuring alternating currents or high speed current pulses. The output of the coil is usually connected to an electrical (or electronic) integrator circuit in order to provide an output signal that is proportional to current.

Electronic Current Transformers (ECT) are finding an increasing number of applications for the measurement of electric current in the electric utilities and power industries in Australia and overseas. In addition to precision current measurements, ECTs must operate on high-voltage conductors. They need to be stable over a wide range of environmental factors while maintaining a long term stability of their measurement accuracy. However, phase errors can increase and noise can corrupt the precision current measurement capability of the coils.⁷

NMI does not presently have detailed knowledge of the unique testing and calibration methodologies for calibrating clamp-on Rogowski coils. Such knowledge is essential to ensuring that traceable and accurate measurements of current are being performed.

Several new types of clamp-on, high-voltage current transformers of the magnetic type have also been developed overseas. These transmit the current reading to a pick-up unit by radio signals. Manufacturers have claimed that such a device could be used to calibrate (or recalibrate) *in-situ* current transformers. In order to use these, NMI would need to devise a way to calibrate such devices at high voltage, so that their measurements would be fully traceable to the national measurement standards. At the present time, traceability would be via calibrations at low voltage and there is as yet no accepted procedure for calibrating clamp-on high-voltage current transformers. Such a procedure would have to be developed by NMI, possibly in collaboration with other (overseas) measurement institutes. The accuracy with which Rogowski coil-based systems can be calibrated, and consequently their suitability for their intended function, is presently not clear.

New measurement devices called ‘optical voltage transformers’ and ‘optical current transformers’ are also being introduced into electric power industries. These transmit the value of a measurement as a signal in an optical fibre. Optical current transformers, utilise the magneto-optical effect (Faraday Effect). They may provide improved transient response, improved dynamic range, low temperature coefficient and higher accuracy than conventional current transformers. However, the outputs of these devices are much smaller than conventional units. This will require NMI to develop new methods for testing these devices.

4. Ensuring the Stability of NEM Transmission and Improving its Technical Standards

It is useful for comparative purposes to take account of what has been done in North America since the NEM has much in common with the North American transmission grid. The North American grid really consists of four large grids, each primarily a synchronous alternating current system that has evolved from local electric supply systems into a set of interconnected large-scale power grids. These grids transmit wholesale electricity over distances similar to those in the NEM, from one region (and/or company) to another with transmission infrastructure of a similar age to the NEM. Given the similarities of the North American transmission grid, Australia can expect similar types of problems to befall the NEM.

There are concerns in North America that the structure, size, age and capacity of their grid has (and will) lead to major technical and reliability problems as noted in a recent review article:

It is inevitable that an electrical grid built on such a huge scale in a patchwork manner over 100 years will have reliability issues... In addition to mechanical failures, overloading a line can create power supply instabilities such as phase or voltage fluctuations. For an ac power grid to remain stable, the frequency and phase of all power generation units must remain synchronous within narrow limits.⁸

The importance of these problems and the future challenges presented by the North American transmission grid is taken so seriously that the U.S. Congress established a transmission reliability program. The U.S. Transmission Reliability Program is designed to support a national laboratory/ electricity industry partnership to develop technologies that will improve the reliability of electricity delivery infrastructure. This program has proved highly successful.⁹

New high-voltage metering technologies are progressively being introduced into world markets and will inevitably be incorporated into the NEM by individual companies. This may constitute a technical barrier to accurate measurement in transmission services as, without appropriate calibration methods, any measurements made with these new high-voltage metering technologies would not be traceable to Australian national measurement standards.

As stated earlier, physical measurement underpins technical standards and to ensure that measurement standards contribute to achieving an effective national electricity transmission network in the future, Australia would be well advised to follow the North American lead in electricity transmission. In light of the problems likely to arise with the NEM's transmission assets over the next decade and the technical measurement difficulties outlined above, NMI advocates that a minimal program of research and development be conducted which is tailored to the needs of the NEM's transmission infrastructure and in support of better technical standards. In particular, the following actions are recommended as a matter of priority:

- essential data should be assembled on what high-voltage calibration/ verification standards and calibration procedures will be needed for the future stable operation of the NEM; and
- development of the various high-voltage measurement standards and procedures required for the NEM.

Although these technical matters fall within NMI's capabilities, the required studies and associated research has not been conducted so far. This is because the amount of high-voltage research that can be undertaken by NMI is limited by competing priorities within NMI. We also note that no requests for this research have yet been received from the electricity industry.

5. Concluding Remarks

Measurement and testing is critically important to the successful implementation of technical standards, but is often overlooked or taken for granted. This oversight can lead to significant additional expenses and other adverse consequences over time. Therefore, in the process of establishing a national framework for electricity transmission technical standards, existing measurement and testing capabilities, and the cost of establishing relevant new capabilities and infrastructure, should be considered in detail. NMI would be glad to provide further input and support.

¹ *Issues Paper - Reliability Panel Technical Standards Review* (Australian Energy Market Commission, 9 May 2008) p.7.

² *Annual Electricity Market Performance Review 2007 Final Report* (Australian Energy Market Commission, February 2008) p.46.

³ Alvarado, F. and Oren, S., 'Transmission System Operation and Interconnection' in *National Transmission Grid Study Issue Papers* (U.S. Department of Energy, Washington D.C., May 2002) p.A4.

⁴ *Annual Electricity Market Performance Review 2007 Final Report* (Australian Energy Market Commission, February 2008) pp.56-57.

⁵ Council of Australian Governments, *Australia's Infrastructure National Overview Report* (April 2007) p.27.

⁶ AS 1931.2—1996, 'High-voltage test techniques Part 2: Measuring systems', *Standards Australia*.

⁷ See, for example, <http://store.ncsli.org/Rogowski-Coil_Based_Systems_t_P1006.cfm>

⁸ Amin, M. and Stringer, J., 'The Electric Power Grid: Today and Tomorrow', *MRS (Materials Research Society) Bulletin* **33** (April 2008) p.402.

⁹ See: U.S. Department of Energy Transmission Reliability webpage <<http://www.oe.energy.gov/transmission.htm>> and *Transmission Reliability Program Peer Review Final Report* (U.S. Department of Energy, Washington D.C., October 2005). Available at: [www.oe.energy.gov/DocumentsandMedia/Peer_Review_2005_transmission_Peer_Review_report\(1\).pdf](http://www.oe.energy.gov/DocumentsandMedia/Peer_Review_2005_transmission_Peer_Review_report(1).pdf)
