Consultation on international requirements for electricity meters

Submission by Dr Martin Gill

The way consumers use electricity has changed. These changes include solar systems, energy efficient appliances and increasing levels of energy storage in both batteries and Electric Vehicles. Despite all these changes electricity meters remain unchanged. Meter reforms to support these changes are overdue.

Summary of Submission

The Australian Energy Market Commission's (AEMC's) 2012 Power of Choice metering reforms recognised the way Australians use electricity was changing. These reforms intended to support greater uptake of onsite generation and storage and to allow consumers to offer demand response services. To date the only outcome of the AEMC metering reforms has been to increase the cost of metering.

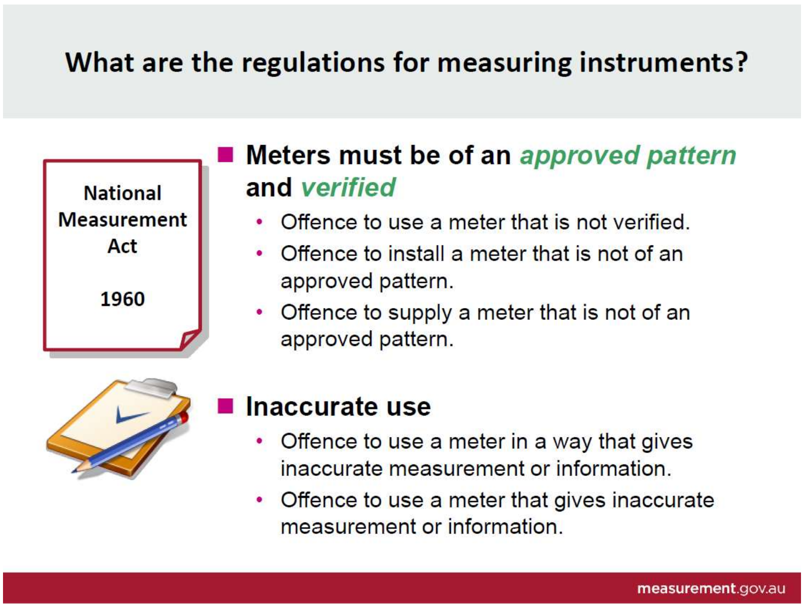
What the AEMC failed to understand was electricity meters are covered by Australia's National Measurement Act. Under this act detailed testing must be performed on any electricity meter used to bill consumers. The problem is current testing ensures only high cost inflexible metering solutions can be used. The flexible, low cost, metering solutions needed to support our energy future, cannot be approved. Without this approval the meters cannot be used to bill consumers.

The approval process is supposed to ensure consumer bills are accurate, unfortunately it fails to do this. Independent testing confirms unacceptably large meter measurement errors when approved meters are connected to modern appliances. The issue has been traced to increasing levels of harmonics, with observed measurement differences exceeding 500%. The conclusion is laboratory accuracy testing, as specified in the current approval process, is woefully inadequate and needs to be updated.

So Australia's meter approval process should be reviewed. The review should urgently address measurement errors due to harmonics. Such a review also presents an opportunity to relax current restrictions, allowing the use of low cost flexible metering solutions the AEMC envisioned as part of its Power of Choice reforms.

Introduction

Australia's National Measurement Act establishes a framework for the regulation of measuring instruments. The Act requires all measuring instruments used for trade to be verified and pattern approved. These approvals are managed by the National Measurement Institute (NMI).



For electricity meters the approvals process requires the meter manufacturer submit documentation showing they have tested their meter as detailed in NMI M6 Parts 1 and 2 [Ref 1]. NMI M6 makes extensive use of Australian metering standards, which are themselves based on International metering standards. The validation is supposed to ensure meters are both safe and accurate. Only once approved can the electricity meter be installed and used to bill consumers.

The NMI has released a consultation paper [Ref 2] which asks several questions. Answers are provided in the following sections.

Should electricity meters used for trade measure energy associated with the fundamental only, or including harmonics?

Background to the question

Recent laboratory testing has revealed significant deficiencies in the accuracy of approved electricity meters. Of particular concern is meter measurement errors caused by the presence of harmonics. Unfortunately restricting measurements to the fundamental does not ensure meter accuracy.

For clarity the response is separated into several different topics:

- Meter measurement errors caused by the presence of harmonics
- Social equity issues caused by harmonics
- Historical measurements
- Reference standards used to check meter accuracy

Meter Measurement Errors

Leferink et al [Ref 3] tested a range of meters claiming to be “2% accurate”. Using a light dimmer they showed measurement differences between the various meters could exceed 500%. It is impossible for meters to be “2% accurate” while measurement differences exceed 500%! The measurement errors highlight current accuracy testing is inadequate.

In another test [Ref 4] a range of “2% accurate meters” were used to measure the electricity use of a variable speed pool pump. This testing also showed measurement errors approaching 500%. The testing is highly relevant for the 10% of Australian households with a pool or spa, with recent changes effectively mandating the installation of variable speed pool pumps.

The testing shows the electricity bill for two identical consumers could differ by as much as 500% despite both using exactly the same appliances in exactly the same manner. This is in no way complaint with the goals of the National Measurement Act.

The claimed “2% meter accuracy” is based on testing detailed in the existing NMI pattern approval documentation. The problem is this testing applies waveforms unrelated to the electricity use of modern domestic appliances. Using the meters to measure the electricity use of modern appliances results in large differences. These measurement differences fall well outside the claimed meter accuracy and well outside reasonable limits.

Consumers reluctantly accept published vehicle fuel consumption figures are unrealistic. The reason is because vehicle testing is largely unrelated to real world driving, for example the testing does not include vehicle weight or aerodynamics. Unsurprisingly real world vehicle fuel consumption (and emission) figures are far greater.

Similarly electricity meter accuracy testing is conducted using conditions not observed in the real world. When real world loads are applied to the meters the measurement differences can exceed 500%. The only reason nothing has been done to address this unacceptable situation is energy use is invisible. Consumers are unaware their bills are being calculated using increasingly unreliable measurement devices.

The situation is only going to get worse. Government energy efficiency initiatives mean modern appliances use less energy than the ones they replace. Testing shows large measurement differences when existing electricity meters are used to measure energy efficient appliances, for example the 500% measurement differences observed for energy efficient pool pumps. The issue needs to be fixed.

Social Equity Issues created by harmonics

The first use of domestic electricity was incandescent lighting. Electricity passing through the resistive filament resulted in useful light. Harmonics simply meant the light glowed brighter so benefitted the consumer. Billing consumers for harmonics seemed reasonable.

Soon consumers started using electricity to run motors, for example in washing machines. Here the situation was totally different. Harmonics reduce the efficiency of electric motors meaning consumers use more electricity. Consumers ended up paying more despite receiving no benefits, a situation which continues today. Billing consumers for harmonic content is unreasonable.

A slightly imperfect analogy is selling goods by nett weight vs gross weight. Consumers benefit from the actual weight of the goods (nett weight) not from the packaging (gross weight). When it comes to electricity the vast majority of consumer appliances only benefit from the fundamental. Harmonics are just the packaging wrapped around the useful fundamental. Charging consumers for harmonics, when they do not benefit, is wrong.

Relevant to this discussion is the source of harmonics. Modern appliances no longer use constant current, instead they rapidly turn the current on and off which generates harmonics. (Other standards define the maximum level of harmonics an appliance can generate) As energy efficient appliances are installed the level of harmonics across modern distribution networks is increasing. As a result the impact of harmonics on consumer bills is also increasing. Reports of significant bill increases after an electronic meter is installed are easily found.

This bring us to another socially unacceptable outcome. Consumers who generate harmonics which flow to the network can lower their electricity bill. Neighbouring consumers who subsequently absorb the harmonics, end up paying more. So those consumers who create the problem pay less, while those who help reduce the problem (by absorbing the harmonics) end up paying more. This is unacceptable.

At least one international technical committee agrees billing consumers for harmonics is questionable. After discussing the source of harmonics, AS62053 Part 24 [Ref 5] states "This makes billing for harmonic current controversial".

Historical Measurements

Traditionally consumers were not billed for harmonics. During the 20th Century domestic electricity use was measured using electro-mechanical meters. These meters are essentially an electric motor where the speed is proportional to electricity use. A dial counts the number of times the motor rotates giving the value used to bill consumers. Of relevance to this discussion is electro-mechanical meters did not measure harmonics.

As the price of electronic meters fell they replaced electro-mechanical meters. Unlike the meters they replaced, electronic meters do measure harmonics. Unfortunately until Leferink et al investigated the huge measurement differences no one stopped to consider if electronic meters ***should*** include harmonics.

The metering industry's response to Leferink et al's work is to claim it is too expensive to exclude harmonics from the measurements. This is exposed as false by noting the addition of a low pass filter to the voltage and current sampling circuits could significantly reduce the impact of harmonics on meter measurements. The filters act like the inertia of the motor in the electro-mechanical meter. The cost of this filtering comes to a few cents.

In fact for most electronic meters there is no additional cost to limit the effect of harmonics. For example Berisford [Ref 6] showed a minor upgrade to the meter firmware (the software run by the meter) avoids measurement differences caused by harmonics. Minor firmware upgrades have virtually no effect on the cost of the meter.

The problem is measurements made by some electronic meters are being adversely affected by harmonics. The simple solution is to ensure meter measurements are less sensitive to harmonic content, for example by ensuring the performance of electronic meters is similar to the electro-mechanical meters they are replacing. Designing electronic meters with lower sensitivity to harmonics is possible at virtually no cost. *This is not the same as requiring fundamental only measurements*.

Reference standards used to check meter accuracy

Laboratory testing of electricity meters involves applying (unrealistic) voltage and current waveforms and comparing measurements made by the meter to measurements made by a reference standard. The "rule of thumb" used to select a reference standard is it should be 10 times more accurate than the meter being tested. The focus on the accuracy of the reference standard misses the difference between "meter accuracy" and "meter measurement errors", especially when harmonics are present.

The following example discusses an actual event. Customer acceptance testing of a batch of meters showed measurement differences fell outside the meter's claimed accuracy when harmonics were present. Research revealed two reference standards implemented different measurement algorithms. Despite each reference standard being certified as "highly accurate" there remained measurement differences. The point is even highly accurate meters can produce "measurement differences".

Australia's National Measurement Act requires quantities used for trade be checked. For example the NMI regularly checks the accuracy of fuel pumps [Ref 7]. Checks compare the amount of fuel dispensed against a standard litre. The same standard litre is used regardless of the type of fuel being dispensed (E10, R95, Diesel, etc). In the above example the problem was created because metering standards fail to define a single standard value. Depending on the harmonic content, the standard value can change. The uncertainty this creates does not support the intent of Australia's National Measurement Act.

Laboratory accuracy testing of electricity meters does not apply actual appliance waveforms. The vast majority of test waveforms contain no harmonics. Internationally this oversight is being addressed with a number of test waveforms being implemented, including the (OIML) Quadriform Waveform and the (ANSI) Pulsed Waveform. Further research to define additional test waveforms is currently underway. As harmonic content of test waveforms increases, the measurement differences created by the failure to define a single reference value will also increase.

International research to develop realistic test waveforms will exacerbate the NMI's current failure to define a single reference value when harmonics are present. A simple method, already adopted in AS62053 Part 24 [Ref 5], is to specify fundamental only measurements. Fundamental only measurements give the same answer regardless of the harmonic content or internal algorithms.

Summary: Should meters make fundamental only measurements?

Two meters with a tested accuracy of 2% measure exactly the same amount of electricity. One meter reads 500% more than the other. As a result of the difference one consumer pays 50 times more than the other. This is a clear failure of Australia's National Measurement Act.

"It is an offence to use a meter that gives inaccurate measurements" Phillip Mitchell 12th May 2016

The intention of the National Measurement Act is to ensure consumer electricity bills accurately reflect their actual electricity use. The problem is multiple laboratories have confirmed metering of modern appliances can result in meter measurement differences exceeding 500%, e.g. when measuring the energy use of variable speed pool pumps [Ref 4].

Fundamental only measurements do not address the identified problem

While implementing fundamental only measurements in electricity meters can be seen as socially equitable, aligning with historical metering practices, and can be implemented at virtually no cost, it does not address the identified problem. If current unrealistic meter testing continues to be utilised to approve these meters, then two meters measuring exactly the same consumer load will still be able to show unacceptably large measurement differences. Laboratory testing of meter accuracy must be made relevant to the loads they will actually measure.

This involves applying test waveforms resembling actual appliance loads, specifically waveforms containing harmonics. This immediately creates a separate (but related) issue, defining a single reference value to be used to check the meter measurements. Aligning all metering standards with the existing AS62053 Part 24 [Ref 5] suggests all reference values should be calculated using fundamental only measurements.

As the level of harmonics across electricity networks continues to rise the problem of measurement errors will get worse. Using unreliable measurements to bill consumers does not align with the National Measurement Act. The NMI needs to find a solution before inaccurate meter measurements become a major consumer issue.

Should there be any additional or special requirements for electric vehicle charging stations?

Background to the question

The vast majority of consumers will be billed to charge their Electric Vehicle (EV). The metering is therefore covered under the National Measurements Act.

Billing the owner of the EV charger (energy supplied to the charger)

This is the traditional use of electricity metering. The electricity meter measures the amount of energy supplied (either to individual chargers or multiple chargers) and the readings are used to bill the owner/operator of the EV charger.

While this is the traditional use of electricity metering there are issues. Electricity bills are no longer calculated from readings taken from the display of the meter, instead they are calculated from remotely read interval data. The NMI M6 approval process does not apply any testing of this interval data. Consumer bills are now routinely calculated on the basis of untested quantities, an apparent breach of Australia's National Measurement Act.

Billing the owner of the EV (energy supplied to the vehicle)

One vehicle per utility connection point

There is a difference between the amount of electricity supplied to the EV charger and the amount of energy supplied to the vehicle. The difference is due to losses through the EV charger. Losses mean the amount of energy supplied to the vehicle is less than the amount of energy supplied to the charger. For slow speed chargers losses are likely to be small and may not justify the installation of separate metering on the customer side of the charger.

Losses will also incur internal to the vehicle, including losses through the in-vehicle charger and energy used by battery cooling to avoid battery damage during charging. It is reasonable for the vehicle owner to pay for these losses.

Multiple vehicles per utility connection point

Multiple EV chargers offered by the same owner/operator are likely to have a single utility meter measuring the use of all connected chargers. This utility meter cannot be used to estimate bills for users of individual chargers. Instead each charger must be separately metered. These individual meters are used to bill consumers so each must be pattern approved.

These meters must be integrated into the selected EV charger operator's billing solution. The bill is then calculated using energy readings taken at the start and end of charging. There will always be delays between energy flow through the meter and when that energy appears in the registers. This delay is untested and undocumented. The maximum delay should be documented, to ensure EV charger billing solutions wait the appropriate time to ensure consumer bills are accurate.

To allow integration within the EV charger the form of these meters may also differ. Greater flexibility may be required, for example do the meters require a physical display (discussed in the next section).

It is also noted the conversion of the incoming a.c. to the d.c. used to charge the batteries can generate harmonics. This makes it vitally important meters used to measure EV charging remain accurate in the presence of harmonics (as discussed at length above).

Billing for controlled charging

The recent COAG decision to mandate all EV chargers allow distribution businesses to control when the EV can be charged is also a consideration. Traditionally consumers have been offered a lower price for choosing to give distributors control of when their appliances can use electricity, for example off peak hot water heaters. Lower pricing requires separate measurement of the energy use of the EV charger. Installing the additional wiring necessary to bring a separate circuit back to the property boundary increases installation costs. This cost could be avoided if distributed metering solutions were allowed.

For example consider if each EV chargers contained its own meter able to be read over the customer provided WiFi connection. The consumer shares this data with their electricity retailer who provides a rebate to account for the lower price of controlled EV charging. This is far cheaper than installing a separate AEMC contestable meter. The problem then becomes the in charger meter is unlikely to pass current NMI pattern approval requirements.

Vehicle to Grid

The recent COAG decision to mandate all EV chargers support Vehicle-to-Grid operation should also be considered. The COAG decision means on command the EV battery is used to supply energy back to the grid. All meters used to measure EV charging should be tested to confirm their accuracy for energy flows both to, and from, the EV.

Fast Chargers

Fast EV chargers use direct current (not a.c.) While the consultation paper only considers a.c. charging it is noted consumers will be billed. This suggests an urgent need to develop testing standards and pattern approval requirements for d.c. metering.

Should there be any additional or special requirements for smart street lighting?

Background to the question

The integration of metering into various devices, including street lights, offers advantages.

Benefits of smart street lights

Smart street lighting offers multiple benefits. Often using energy efficient LED bulbs the lights use significantly less electricity. Monitoring of light output ensures constant light even when individual LEDs fail and allows light output to be adjusted depending on background illumination (dawn, dusk, full moon, etc). Some can be integrated with motion sensors to dim the lights when not required (e.g. no traffic). Long lifetime and lower maintenance costs mean smart street lighting should be encouraged.

Metering of existing street lights

Most electricity used by street lighting is ‘measured’ using a Type 7 meter. In common with most things detailed in the AEMC’s National Electricity Rules this is highly misleading, because Type 7 meters do not exist. Instead the Type 7 meter formalises often wild guesses about the amount of electricity street lighting uses. Finding other examples where Australia’s National Measurement Act allows consumers to be billed on the basis of wild guesses is difficult.

Some smart street lights measure their own electricity use. Using these measurement is better than the Type 7 guesses. As soon as the internal measurement is used for billing it is covered by NMI pattern approval requirements including the full range of testing detailed in the existing NMI M6 pattern approval documentation. This testing may be impossible where the meter is integrated with the light's control circuit. In particular specified test currents cannot be applied to the meter. One solution is to require street light manufacturers incorporate a meter module which can be removed for testing. This is likely to increase the cost of the street light (for little benefit).

Other appliances with inbuilt metering

It is not only smart street lights where inbuilt metering is unable to comply with existing pattern approval requirements. Most solar inverters measure the amount of electricity they have generated (allowing consumers to monitor system performance). Smart battery storage systems measure both the amount of electricity they consume and supply. Some air-conditioners include metering to help consumers manage heating/cooling costs (and also to provide self-diagnostics). The point is none of these meters could receive NMI approval. It is difficult to justify banning the use of these measurements when some of these inbuilt meters are based on exactly the same commercially available metering chips used in pattern approved meters.

Should meters be permitted to use remote display? What additional or special requirements should apply to remote displays ~~and meters with modular components~~?

Background to the question

Pattern approval currently requires all electricity meters be fitted with a display. The display is intended to allow consumers to check their meter. Allowing alternative displays may allow more flexible metering.

Are meter displays used during NMI testing?

The vast majority of NMI meter accuracy testing is conducted by checking a flashing test LED provided on the meter. NMI testing does not refer to the meter display.

AEMC smart meter mandate

The AEMC has mandated the rollout of smart meters to all Australian households. The vast majority of these smart meters are remotely read. Even those AEMC smart meters not using remote communications collect 288 separate readings every day. This huge amount of data can only be downloaded from the meter using a handheld reader. Hence meter displays are no longer used by utilities.

Lessons from existing remote displays – Standards and Availability

The vast majority of Victoria's Advanced Meters support a remote display. These remote displays are intended to allow consumers to reduce their electricity use and costs. The displays use direct access to values stored in the customer's electricity meter. To ensure compatibility all Victorian meters use the same wireless standard ensuring any compliant display can be connected.

The selected standard has been superseded. Electricity meters typically last 15 years making it difficult to predict which interfaces will still be readily available (and/or backwards compatible) with the offered interface. This raises a significant question: "If a meter only offers a remote display and a suitable display is no longer available, then does the meter need to be replaced?" The intent of the existing requirement suggests the answer is yes.

Security

Many utility provided remote displays include security. The security restricts who can access the information. Arriving at the right amount of security will prove to be a complex topic. Some authorisation will be required to connect a remote display. The ability to remove a remote display may also be necessary (e.g. on consumer move out).

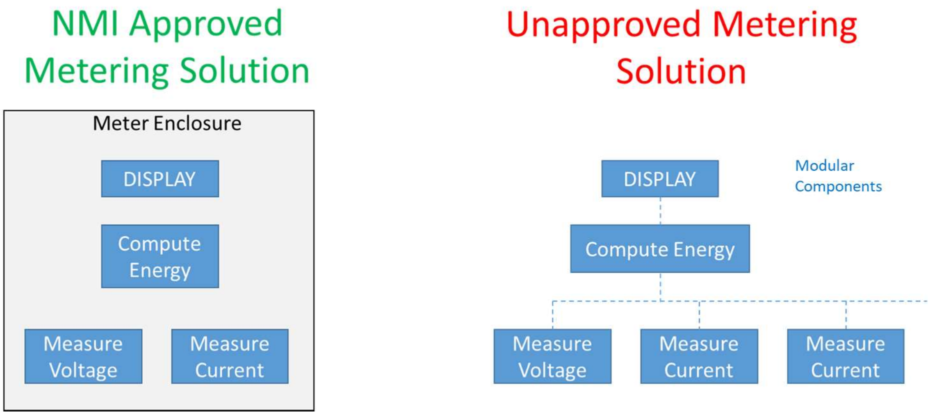
The transfer of data between the meter and approved displays should also be considered. Some will claim all information transmitted between the remote display and the meter must be protected while others will note some existing meter protocols allow unrestricted access to displayed values (typically meter serial number and total kWh).

What additional or special requirements should apply to ~~remote displays and~~ meters with modular components?

Background to the question

The efficient management of distributed energy resources requires distributed metering solutions.

While flexible metering solutions can be built to pass accuracy testing, physical differences mean they do not comply with the rigid NMI "pattern" and therefore cannot be approved for billing purposes.



Why are meters with modular components required?

Historically consumers had one electricity meter. The meter measured the current use of the household. In the 1960's many households installed an off peak hot water heater, requiring the installation of a second meter. When electronic meters became available meter manufacturers offered a single meter able to separately measure household energy use and hot water use. The "two meters in one" offered a cheaper metering solution than two separate meters.

The rapidly evolving energy future sees consumers installing solar systems: measurement of solar output requires a meter able to monitor three separate loads. Adding battery storage increases the number of separate measurements to four. The arrival of their electric vehicle requires a meter making five separate measurements. Participating in the demand response market requires (at least) six separate measurements (discussed in the next section). So Australia's energy future requires cost effective metering of multiple devices and appliances. Existing pattern approvals are too inflexible to cost effectively deliver this future. It can be delivered using modular metering.

Example: Our future demand response market

The recent COAG decision to mandate the provision of demand response capabilities in all air-conditioners, pool pumps, hot water heaters and EV chargers is relevant. The COAG decision supports Australia's future demand response market. This future demand response market is also supported by the AEMC who have amended the rules to allow demand response to be bid directly into Australia's Energy Market. The critical point is in this market consumer bills will be calculated using the amount of demand response consumers provide. Since billing is involved, the metering is covered under the National Measurement Act. Measurement devices require NMI pattern approval.

An ARENA funded study [Ref 8] found it is not possible to use the existing utility meter (installed at the connection point) to estimate the demand response of individual appliances. Accurate measurement therefore requires the electricity use of each appliance bid into the market be measured separately. Under the existing NMI approvals this is prohibitively expensive. Costs would include installing additional AEMC smart meters and major household rewiring so each appliance can be measured. Modular metering offers a means of avoiding these costs.

This becomes even more costly and expensive when one considers the AEMC intends to allow multiple market participants to reward consumers for offering demand response. Earlier decisions by the AEMC found each market participant must install their own NMI pattern approved meter at the customer connection point. Once again modular metering offers a more cost effective solution.

Finally additional metering costs might be totally avoided if metering already built into the appliances could be used. For example Australia's air-conditioner demand response standard (AS4755.3.1:2014) requires the air-conditioner to 'halve consumption on demand'. Compliance requires the air-conditioner to measure its energy use and modified energy use. Access to this existing measurement avoids unnecessary duplication of metering (and the ARENA study suggests is far more accurate).

Conclusion

In 2012 the Australian Energy Market Commission (AEMC) realised the way Australians use and generate electricity had changed. Their Power of Choice metering reforms intended to support this rapidly changing energy landscape. The only outcome of their reforms has been to make electricity meters significantly more expensive.

For once the AEMC cannot be held solely responsible for increasing Australian electricity costs. Some of the increased costs are a direct result of the draconian pattern approval processes enforced by Australia's National Measurement Institute (NMI).

While the NMI claims these draconian measures are implemented to ensure electricity bills are calculated using validated devices the truth is the rules fail this simple test. When measuring the energy consumption of modern appliances meter measurement errors have been shown to exceed 500%. Consumer electricity bills are then calculated using these highly unreliable measurements. This does not align with the intent of Australia's National Measurement Act.

That the NMI's current meter approvals process fails to ensure measurement accuracy indicates a major review of the entire process should be undertaken. In addition to addressing meter measurement errors the review should consider how current limitations fail to support Australia's future metering requirements and how limitations imposed by NMI requirements are increasing metering costs.

Citation

Please accurately attribute all quotes and references to this submission. It would be appreciated if references also included the author's website drmartingill.com.au.

Comments or Questions?

The author is happy to receive comments or questions about this submission. He can be contacted at
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References

1. Department of Industry, Science, Energy and Resources, Pattern Approval Requirements for Utility (Electricity) Meters Part 1 and Part 2

2. National Measurement Institute, Consultation on international requirements for electricity meters 3rd Working Draft of OIML R 46 Electrical energy meters – alternating current (a.c.), February 2020

3. Frank Leferink, Cees Keyer and Anton Melentjev, Static Energy Meter Errors Caused by Conducted Electromagnetic Interference, December 2017

4. Bas ten Have, Tom Hartman, Niek Moonen, Cees Keyer and Frank Leferink, Faulty Readings of Static Energy Meters Caused by Conducted Electromagnetic Interference from a Water Pump, April 2019

5. AS62053 Electricity Metering Equipment (a.c.) Part 24 Static meters for reactive energy at fundamental frequency (classes 0.5 S, 1 S and 1)

6. Andrew J Berisford, A Smarter Meter: IEEE-1459 Power Definitions in an Off-the-Shelf Smart Meter

7. Malcolm Sutton, Petrol bowser audit reveals under-pouring, Government authority issues fines, December 2019

8. Baselining the ARENA-AEMO Demand Response RERT Trial, September 2019

About Dr Martin Gill

Dr Martin Gill is an independent consultant specialising in the provision of consumer advice based on a deep understanding of the Australian energy industry and strong analytical skills. As a consultant he has prepared advice for consumer advocates, government regulators, electricity distributors, electricity retailers, asset operators and equipment vendors.

He currently represents the interests of consumers on a range of Standards Australia committees including metering, renewable power systems, battery storage, electric vehicles and demand management.

Dr Gill is a metering expert. During the National Smart Metering Program he facilitated the development of a specification for Australian smart meters. Innovative metering products developed by his teams have been externally recognised with the Green Globe Award, NSW Government's Premier's Award and Best New Product by the Australian Electrical and Electronics Manufacturers Association.