Network Monitoring and Smart meters

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Abstract

There is much discussion nationally on the introduction of smart meters to allow customers and network businesses to better manage the usage of electricity

These smart meters typically have the capability to monitor various power quality parameters at the metered site. This can be used for the benefit of the customer and also to assist the network business to better manage network power quality.

This paper investigates the management of power quality parameters captured by smart meters and explores the challenges, the advantages and disadvantages of using smart meters with a view to encouraging further debate on this issue.

1. Introduction

Tamworth became the first town in Australia to light its streets using electricity on 9th November 1888 and it wasn't until 1904 that Sydney caught up [1]. Supply became available to the general Tamworth public towards the end of 1907 at a rate of sixpence per unit for lighting and fourpence per unit for power and heating. The first electricity meters for Tamworth (see Figure 1) cost in the order of £3/10/-.

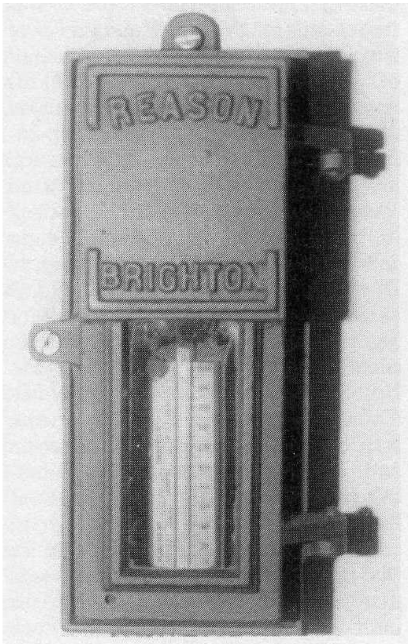

Figure 1 - Reason brand electrolytic direct current meter. C. 1907.
Source: City of Light [1]

Metering has made many advances over the years from DC electrolytic, commutator or mercury motor meters to induction disc meters for AC. Pre 1950's, the rotating disc was supported by a pivot at the top and a single jewel type of bearing at the bottom. This was superseded by the double jewel and ball bearing in the 1950's, then by magnetic floatation in the 1960's. It was stated in 1971 that "The new bearing arrangements together with the introduction of magnetically stable steels for brake magnets will no doubt considerably improve the stability and extend the maintenance period of meters" [2]. Many of the meters installed using this technology in the 1970's are still in service today e.g. Email's M1 meter.

Demand management and load shedding principles have been in vogue since the early days of the industry in Australia. In 1920, when problems with the electricity plant could not be resolved quickly, notice to Tamworth electricity customers to cut demand was by way of an advertisement in the "Tamworth Daily Observer". The advertisement required various classes of customers to curb electricity usage during various parts of the day. This form of notice to customers has been replaced with SMS messages requiring certain customers to cut demand within a few hours.

Electricity meters have evolved to high tech, fully electronic, smart meters with no moving parts and in house displays. Smart meters should have a life expectancy of approximately 10 years but some may fail prematurely due to component failure, lightning or sustained overvoltage. The technology of the meter is likely to be superseded before it is even installed.

The Council of Australian Governments (COAG) endorsed a national roll out of smart meters in April 2007 and there have been many discussions about the advantages and disadvantages of this roll out since then. Whilst the Ministerial Council of Energy's (MCE) Regulatory Impact Statement lists "Quality of supply and outage detection to improve consumer supply services" in its national minimum functionality and an 'other' objective as "Promoting the long term interests of electricity consumers with regard to the price, quality, security and reliability of electricity", little has been discussed on how to monitor power quality, other than the likelihood of savings, due to avoided investigations into voltage and quality complaints [3]. This paper focuses on the "how to" of smart metering for managing power quality and loss of supply, to help 'iron out' some of the issues and promote further discussion on the topic.

2. Smart Meter Monitoring Programme

The basic elements of a smart meter monitoring programme are shown in Figure 2. It includes smart meters, a means of communication, a power quality data warehouse and a data mining/ reporting tool. The means of communication could include fixed telephone lines, mobile phones, power line carrier, radio, fibre optic, or a combination of these.

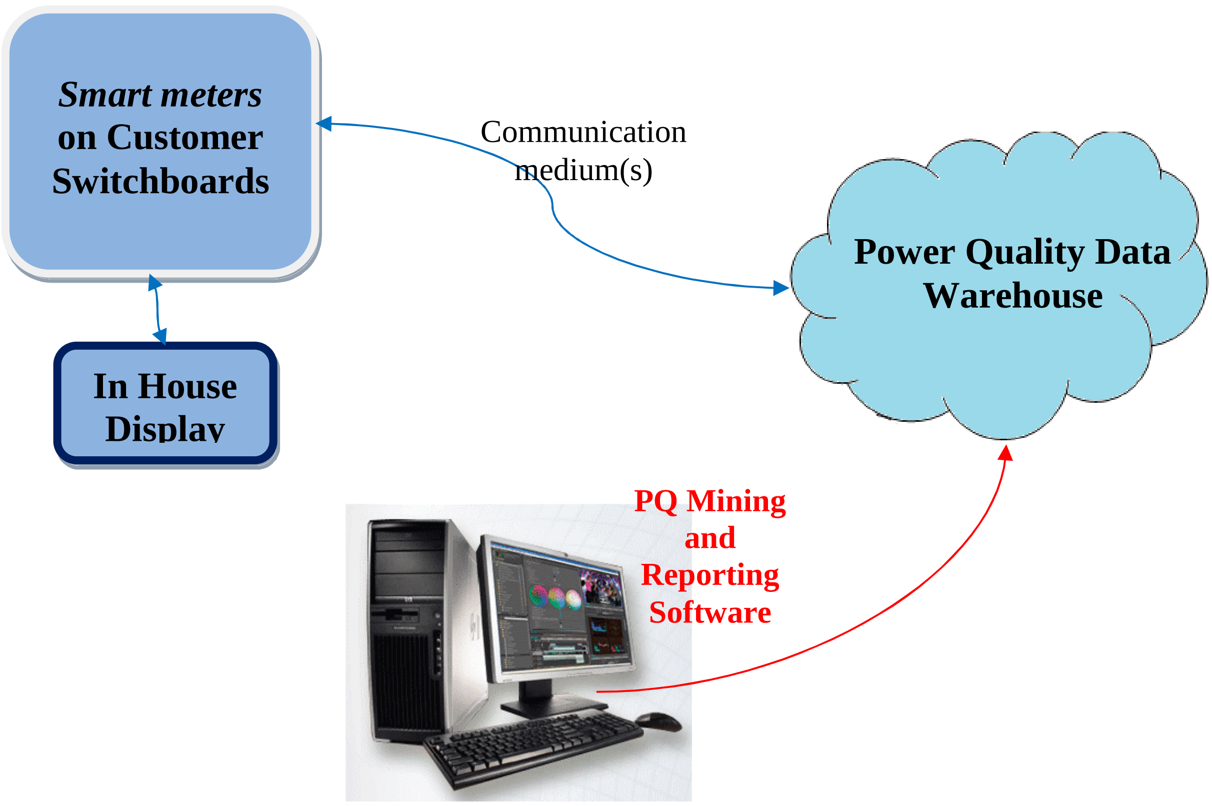

Figure 2 – Smart meter Monitoring Programme

The meters chosen must be capable of recording the parameters using capture methodology as detailed in Section 3.

The communications of data represents a significant cost and consequently the choice of communication needs to be reliable and cost effective. This paper does not address this subject area.

The data warehouse must be an effective and secure means of storing data from all meters for the monitoring period. Because of the large quantities of data, the warehouse must also allow easy retrieval of data for mining and reporting. The quantity of data stored will be dependent upon the transmitted data and is discussed in Section 3.

The mining and reporting tool must be capable of identifying sites that do not meet the requirements of Australian Standards, legislation and/or the National Electricity Rules. Sites outside standard should be listed in order of severity and those with common connectivity grouped together. This will allow those areas of the network with wide spread problems to be identified and overall solutions implemented rather than solutions site by site, saving time and money and giving speedy results. Mining and reporting software will need to be developed as available proprietary software is in its infancy.

Data collected from sites needs to be analysed to identify sites that have poor power quality caused by the customer themselves. The network business may need to make contact with the customer so they understand their responsibilities, particularly if they are impacting on the power quality of other customers.

3. Power Quality Data Capture

This section will look at what power quality parameters should be recorded and how the data could be captured. Parameters required for energy usage and revenue purposes will not be discussed.

Present smart meters that capture power quality data have concentrated on transmitting all data such as 10 minute data for voltage, voltage unbalance or positive and negative sequence voltages and total harmonic distortion, as well as sag/swell and loss of supply event data. Each smart meter using this methodology would capture approximately 12 kilobytes of data/day resulting in 5 megabytes/year. A typical distributor with say 750,000 customers could therefore expect 3.75 terabytes of data/year. This is a massive amount of data to store and then to mine. Not only is there data storage costs but the data must first be sent from the smart meter to the Power Quality Data Warehouse and the data transfer costs/meter is likely to be in the order of $60/year and a total of $45M/year for a distributor with 750,000 customers/smart meters. This calculation assumes a connection to every house and current pricing which is unlikely to be the case in the future. This level of operating expenditure would assist in cost justifying the installation and use of power line carrier and data concentrators.

A more sensible and realistic option is for each smart meter to report by exception in real time or using power quality indices for each site, perhaps on a weekly basis. In this scenario the meter is doing much of the processing and preventing massive amounts of data being needlessly transmitted to the warehouse. Those sites teetering on the edge of a power quality limit could be in constant communication, if reporting by exception, and increase communication costs dramatically for that site. Reporting by indices therefore provides a more sensible option.

Loss of supply data can be used to identify areas of no supply on the network as they occur. This will allow the likely protective device to be identified and speedier restoration of supply to be effected. This is great in theory but if 20,000 customers are without supply, then there will be 20,000 smart meters trying to contact the Power Quality Data Warehouse at the same time. In the event of such large outages, modems or other communication devices are likely to jam with the number of devices attempting data transfer and the volume of data.

This can be better managed by only allowing meters at strategic locations (where existing SCADA systems do not provide full network coverage notification of outages as there is no need for duplication of systems) to send notification of outages. These meters will need Uninterruptible Power Supplies (UPS's) to be able to communicate at the onset of an outage. The UPS's would then need batteries replaced every couple of years which will add a significant cost. This is another reason to only have selected units able to dial in for outages.

Before Power Quality indices are reported by the smart meter, Australian Standards, legislation and the National Electricity Rules need to be consistent in requirements for the various Power Quality parameters. Queensland is still legislated for a 240 volt nominal supply voltage whilst many states have renamed their nominal at 230 volts they still follow the same basic range of voltage i.e. 230 volts, +10%, -2% which almost equates to 240 volts, ±6%. Most states have therefore not adopted the allowable lower threshold allowed by AS60038 which will defer the need to upgrade parts of the network as loads increase. Also, most distributors will be still operating towards the higher end of the allowable voltage range so as to minimise loses and maintain voltages within the previous 240 volt standard allowable voltage range.

The Energy Networks Association's (ENA) Reliability and Power Quality Working Group (R&PQWG) have been developing a Power Quality standard for voltage which is the most basic requirement for power quality. Even the voltage range and the amount of time outside standard is still in discussion.

Power Quality indices that could be reported on a weekly basis or if thresholds are exceeded. These include the following:

- V_{99} and $V_{1.0}$ for the percentile values of the upper and lower voltage range or as determine by the ENA's R&PQWG, by standards and/or National Electricity Rules;

- 99 and 95 probability values for 10 minute values of voltage unbalance and total harmonic distortion;

- The number of swells outside the National Electricity Rules swell curve (Figure S5.1a.1 of the National Electricity Rules);

- In lieu of any national standard for sags, the Wollongong University Sag Index could be used to report sags. The smart meter would analyse sags, tabulate and report the index;

- MAIFI and/or MAIFIe. Both indices have their advantages and so the reporting of both may be preferable.

Comprehensive power quality indices can be provided for the first time for individual customers, LV feeders, distribution transformers, MV feeders, Zone Substations and/or on a whole company or Australia wide basis.

4. Other Opportunities

4.1. Power Factor

Power factor, whilst not a power quality parameter as such, at the customer premise, if poor, can unnecessarily increase network losses and greenhouse gases and may overload networks and reduce voltage levels and network capacity reserves to unacceptable levels. Power factor data is likely to be collected as part of the revenue data anyway and could then be analysed by the power quality data mining tool. Those customers not fulfilling their obligations under local service rules and/or National Electricity Rules should be asked to rectify their breach of contracts.

Penalty tariffs for poor power factor should be mandatory in all states to give incentives for businesses to improve and maintain their power factor at more acceptable levels - Queensland is one notable example where penalty tariffs do not apply. National bodies responsible for greenhouse gas abatements should seek to make penalty tariffs a requirement.

4.2. Customer Load Data

Customer kVA or current (amperes) data could be collected for each customer. This data could be used to determine if transformers or LV mains are overloaded or out of balance. It may be difficult for most distributors to determine if individual phases are overloaded as the customer's connection phase will probably be unknown and hence kVA would be a more practical parameter to collect. However, distributors could commence recording the phase each customer is connected to, if they are not already doing so, so that they can use the data from smart meters for better network load balancing. This type of data would need to be collected from all customers, summated by LV feeder or transformer and perhaps even by medium voltage feeder where present SCADA systems do not collect load data at medium voltages. Summation at higher levels would not generally be needed due to duplication by SCADA.

The benefits of this approach would seek to prevent overloading of networks and the subsequent reduction in voltage drop and to minimise outages from the overload. But this approach would require large quantities of data to be collected and analysed on a continuing basis. However, excessive voltage drop is a good indicator of overloading and analysis of voltage levels is likely to be an adequate tool to prevent overloading.

4.3. Reliability Statistics

The accuracy of reliability indices such as SAIDI and SAIFI is dependent on:

- The availability of SCADA for network protection equipment (non-existent in many rural areas);
- Contact by customers with outages in areas without SCADA or for parts of the network such as blown primary or secondary fuses for distribution transformers.

Smart metering offers the opportunity to provide accurate and comprehensive reliability statistics or as a check for existing data capture methods for all distributors, including rural distributors. This is dependent upon all customers receiving smart meters with remote communications, which may not be the case as some rural customers may not have a economic means of communication.

Also, network reliability statistics will be polluted slightly by customers that overload their system and cause a service fuse to blow (as this outage will be recorded by the smart meter).

Reporting by the smart meter for outages would need to be in the form of indices such as SAIDI and SAIFI or excessive quantities of data would again need to be transmitted.

5. Benefits and Liabilities for Networks

Certainly having a smart meter on every customer's installation with Power Quality monitoring capability has advantages for the network business such as:

- The network business can better understand what is happening on its network;
- It can prioritise remediation work with a great deal more certainty because it knows where the worst areas of supply are located;
- Overloading can be minimised by monitoring of voltage levels;
- The network business does not need to be purely reactive to customer complaints;
- Trends, such as increases in harmonics, can be identified as data is collected over several years.
- Faulty equipment, such as a defective voltage regulator, can be identified from the change in voltage levels from the norm;
- Even with SCADA pockets of the network can remain unknowingly without power after a major event such as a storm. Comprehensive smart metering can help to identify these areas;
- Comprehensive power quality indices could be provided to regulators to assure that power quality is being managed adequately.

One problem with monitoring customer power quality is those customers who have long consumer mains and/or motor starting issues would log events by the smart meter not indicative of how the network is performing. Sustained voltage and voltage dip problems for these customers are their responsibility.

No doubt an intelligent grid should know power quality parameters at the customer's point of supply but this would be an additional unnecessary expense to monitor all customers at this location. An intelligent grid could, if given the data at the point of supply, could make adjustments to voltage levels that benefit the majority of customers instead of using open loop voltage control as presently occurs. This is easily stated but the algorithm needed for the controlling voltage regulation relay will be quite complex and costly to develop. The use of customer smart meters for network voltage control becomes even more complex given the pollution of the supply by the customer's equipment and loads.

For this reason additional monitors need to be installed at locations which give data more indicative of how the medium voltage is performing. Monitoring units could be installed towards the end of feeders as close as is practical to the terminals of unloaded or lightly loaded distribution transformers.

If customer smart meters are installed, the data from the customer meter can be compared with the data from the distribution transformer meter to identify the source of problems such as inadequate low voltage mains and sags caused by customer loads. This, however, would be a rare situation as the network monitor would be located only at select locations.

The data manager/reporting tool must be able to identify customer data against a point on a hierarchical network so that analysis can be carried out.

The cost of operating a smart meter network monitoring will no doubt add to the operating cost of the network businesses. Ultimately customers pay for this increase in customer service.

6. Benefits and Liabilities for Customers

The obvious benefits to customers of a Smart Meter Monitoring Programme include longer appliance and equipment life through better management of network power quality. There is possibly some reduction in electronic equipment imports and national savings through this improvement but this would be difficult to quantify. Regardless of this, a considerable amount of customer appliances and equipment outlive the technology and many customers seek to upgrade long before the equipment dies.

Most customers do not even think about power quality until something goes wrong. Then they may not relate the damaged equipment to poor network power quality. The question then remains whether customers should have access to power quality data on a real time or summary basis on their remote consoles inside their premise. Many qualified and experienced people within the electricity business have little idea about power quality, so how can the average customer make an assessment of their power quality and whether problems relate to the network or from issues within their premise. Even electrical contractors ring distributors about poor voltage quality when the supply voltage is still within limits.

The authors believe that it is probably more appropriate for distributors to manage power quality than to give the domestic customer confusing and complicated data that they have no comprehension of.

It may be appropriate to provide data, such as power quality indices, to business customers to allow analysis of the impacts of the power quality on their business and if “toughening” of equipment is required either on retrofit basis or to allow development of specifications for new equipment. But unless businesses have technical staff then the same applies as for domestic customers in restricting the information. The data should be provided if requested by customers and the Freedom of Information legislation in each state would ensure this occurs.

Customers will ultimately pay for the additional costs of a Smart Meter Monitoring System.

7. Set-up Costs

It seems Australia is getting smart meters whether we want or need them. The expense of the meters themselves is therefore not relevant to this paper. The cost of a Power Quality Data Warehouse will depend on the quantities of data to be stored. Using exception or indices reporting, it is considered that the quantities of data to be transmitted and stored would only be a small percent of collecting all available data.

A philosophy for archiving data needs to be adopted and must include common table structures. This will allow reports to run in reasonable times and reduce active storage space. Some indices need to be kept to allow reporting on trends.

A mining tool must be developed either by each distributor or a more sensible approach would be to do this on a national basis to minimise costs. The cost for each distributor could be in the order of $100k. The disadvantage of this approach is that it would stifle innovation of each of the distributors. However, the formation of a user group would allow innovation to flow across all distribution businesses.

All in all, the set up costs for a Smart Meter Monitoring Programme are really rather minimal given the meters are going to be installed anyway.

8. Operating and Maintenance Costs

Whilst set up costs are minimal, the cost of operating a system and a return on investment are much more involved. Each distributor will probably need at least one network monitoring programme administrator to maintain the system and compile reports for the distributor to rectify abnormal situations. Whilst the rectification of abnormal situations should be a normal part of running the business, there will be additional costs by way of the network administrator to identify those customers that are causing themselves problems and to tag or remove these customers from the list of problem sites caused by network issues. The identification of such customers is likely to require a site visit from a Power Quality Technician and the cost of such investigations are likely to offset any savings that are likely through reduced power quality complaint investigations by using of smart meters to better manage the network.

Traditional induction disc revenue meters have given very reliable service with few failures (any failures are generally caused by lightning) with many meters lasting in excess of 50 years. Smart meters are far less robust due to their internal electronics and are more prone to problems associated with sustained or transient overvoltage. Much of Australia is rural based and lightning damage can be a considerable problem, particularly on overhead networks which is the norm in rural areas. The cost of replacing a damaged smart meter in rural areas can be considerable due to distances to the site.

It does seem reasonable due to the increased sensitivity of smart meters and likelihood of damage from lightning, that any specification for smart meters should include a requirement for transient protection. Surge filter protection could be provided for the meter power supply but is more expensive than metal oxide varistor protection. However, it may be appropriate due to economies of scale of the large numbers of smart meters to be manufactured and installed.

The operating costs of the data warehouse and mining tools, once developed, is envisaged to be similar to the normal operating costs for other IT systems.

9. Other Issues

The weather has a large influence on power quality problems. Lightning increases the number of voltage sags on the network and the load increases significantly in hot weather due to increases in the use of air conditioning resulting in additional voltage drop. For these reasons weather information should be stored but will be difficult to correlate to power quality issues across wide, diverse networks.

10. Summary

- Smart meters are coming and distributors can make use of them to better manage the network to deliver a more reliable, quality electricity supply by collecting and analysing power quality and reliability data;
- A Smart Meter Monitoring Programme includes:
  - smart meters with a means of remote communication;
  - a power quality data warehouse;
  - a data mining/reporting tool.
- The power quality warehouse will need common table structures to allow the use of a common or proprietary mining tool;
- A data mining tool will need to be developed with distributors working together to achieve this;
- Smart meter specifications should include transient/surge filter protection and that meters process the data into indices rather than transferring masses of data;
- Reporting by exception should be included in smart meter specifications where levels exceed threshold for a set periods of time;
- Reporting by indices will minimise the quantities of data to be transmitted and stored and hence minimise costs;
- Distributors, Standards Australia, Energy Networks Association and Regulators need to work together to develop effective standards and indices that reflect power quality. Australian Standards, legislation and the National Electricity Rules need to be consistent;
- Meters at strategic locations can be used to supplement SCADA systems to send notification of outages and to complement power quality data collected from customer smart meters;
- Sites outside standard should be listed in order of severity and those with common connectivity grouped together. This will allow those areas of the network with wide spread problems to be identified and overall solutions implemented rather than solutions site by site;
- Smart meters monitoring customers who have long consumer mains and/or motor starting issues would log events not indicative of how the network is performing. Data collected from these sites needs to be identified and flagged;

- Penalty tariffs for poor power factor should be mandatory in all states. Smart meters can be used to assist in controlling power factor. Thereby reducing waste and greenhouse gases and deferring network upgrades;
- Distributors should manage customer power quality rather than giving the domestic customer confusing and complicated data from the smart meter that they have no understanding of;
- Business customers should have access to data such as power indices to allow analysis of the impacts of power quality on their business/equipment and to allow “toughening” of equipment or to allow equipment specifications to be developed.

11. References

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[3] Standing Committee of Officials of the Ministerial Council on Energy, April 2008. Cost-Benefit Analysis of Options for a National Smart meter Roll-Out (Phase Two – Regional and Detailed Analyses) Consultation Regulatory Impact Statement.