Chapter 4

The Post Carbon City and Smart Metering

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Additional information is available at the end of the chapter

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Abstract

Buildings and districts are an appropriate focus for smart metering infrastructure in the urban environment. While properties and buildings have traditionally been metered for revenue recovery purposes, energy management of these buildings has not been available. In the way we account for money, we should account for energy; energy in its own right carries a direct cost with it to the end user. Along with carrying a cost, energy also carries carbon emissions. Smart meters are a vital component to the making and management of post carbon cities and can be used to monitor not only electricity use but also water and gas consumption. Energy Management Systems combined with structured metering also enable consumers with renewable energy generation such as photovoltaic (PV) panels to monitor their own generation, consumption, import and export. As battery storage becomes integrated with renewable energy generation, consumers will have the ability to consume cheaper renewable energy than can be bought from the grid and sell energy back to the grid at the most economically viable times. While uncertainty surrounds the grid and its impact on rising electricity prices, smart metering, intelligent control systems and utilities offering consumers more amenities and the ability for consumers to participate in the wholesale market will ensure the smart grid can contribute to future carbon neutral urban environments.

Keywords: smart meter, smart grid, post carbon city, renewable energy, energy use, water use, buildings, districts

1. Introduction

Traditionally meters have been used for revenue recovery on utility scale distribution networks with meters read manually on a monthly basis. Meters and data only accounted for a single direction of energy flow. Smart meters measure a spectrum of energy consumption information at intervals and communicate the information to the utility remotely. They are effective tools for gathering of data, monitoring long-term trends and responding short term or live events or incentives mechanisms such as demand-side management both locally and remotely. New technology in smart meters enables the measurement of two-way energy flows [1]. Monitoring of data allows for a higher degree of control on energy use, which will be important in the emerging post carbon urban environments [2] with the impact of distributed renewable energy generation, battery storage and electric vehicles as well as feedback on energy use patterns to consumers.

Buildings and districts are an appropriate focus for smart metering infrastructure in the urban environment. While properties and buildings have traditionally been metered for revenue recovery purposes, energy management of these buildings has not been available. In the way we account for money, we should account for energy; energy in its own right carries a direct cost with it to the end user. Along with carrying a cost, energy also carries carbon emissions. Smart meters are a vital component to the making and management of post carbon urban environments [3].

Smart meter requires accessible communications for robust data availability and storage to enable advanced architecture and applications. Preferably, it is best to use a smart meter with multiple communication ports (at a minimum Modbus, TCP/IP, IR). Smart meters need to be installed and calibrated to national peak measurement body standards (e.g. in Australia, the National Measurement Institution or NMI) to enable utility billing. The smart meter should have a configurable program to optimise data measured and collected to meet the requirements of application (i.e. within the South West Interconnected System (SWIS), demand intervals have been extended from a 15-min period to a 30-min period).

The meter should have the ability to bring in additional data sources (i.e. water, air, gas, electric and steam, WAGES) through either direct pulse inputs or through a local wireless communication protocol such as Zigbee and its appropriate sub-meter hardware. In addition, smart meters should have configurable on board logging that enables backup of meter data locally if communications or power failures occur, which can cause loss of data and revenue. Meters and data collection needs to adhere to legislation on data collection and usage. Consumers' data are typically protected, and permission is required to use it (check your local laws and regulations to ensure compliance).

In this chapter, we will describe smart meter architecture and management systems for buildings and district energy and water use, and then, we will provide two case studies as to how this is applied in practice. The latter is done with specific industry focus and products.

2. Smart meter architecture

Smart meter architecture needs multiple levels providing multiple points of reconciliation. Hierarchies should inform the levels of consumption and more importantly demand within the distribution network and for total and isolated services (i.e. Internal/External Lighting, Mechanical services, power etc.). Smart meters should separately meter all generation inputs into the system (i.e. renewable energy, Co/Tri-generation). Using hybrid communication architecture will bring in meters at the lowest cost and highest data reliability. (Direct meter to TCP/IP; Meter via Modbus to gateway to TCP/IP; Gateway to enable localised data logging [where proprietary meter software is not used to pull data logs direct from the meter] and pass through of centralised/decentralised [i.e. cloud based] software packages to contact meters/gateway to collate data).

Accuracy of data is important for smart metering metrology characteristics. International standards assist to ensure accurate measurements. Varying reference conditions such as low loads, poor power factor and/or verification of meter accuracy affect performance outcomes. Accuracy standards such as Class 0.5S to AS/IEC 62053-22 improve levels of reliability thus ensuring confidence in measurements in varying conditions.

The use of smart meters can leverage off existing WiFi technology networks to reduce costs. GSM technology is expensive and has ongoing running costs (bring data back over TCP/IP backbone; and architecture complies with BEEC/NABERS & Green Star/BREEAM/LEED) (**Figure 1**).

Figure 1. Large building and campus electricity smart meter architecture.

3. Energy management system (EMS)

Centralised energy management systems (EMSs) are used to support the reporting of energy consumption monitoring, a primary requirement as a component of the management cycle for feedback and continual improvement. EMSs directly support the billing and revenue recovery from end-use consumers. It allows customers to understand where the costs are allocated from their bill and therefore where energy and cost savings can be made. EMSs assist the implementation of demand-side management, often with alarms linked to either a manual intervention or more preferable automated actions implemented through the building management system (BMS).

Demand and particularly the capacity charge of the bill is the most effective way to reduce energy consumption (predictive based upon historical consumption and ambient conditions particularly for the Perth climate as HVAC often accounts for ~40% of a sites consumption). EMSs can set benchmarks for energy savings, enable forecasting, ensure benchmarks are achieved and energy efficiency measures are tracked and continue to perform as installed and commissioned.

Dashboards are typically used as a primary method to advise building occupants on a live basis when demand-side management is in effect and what measures are being undertaken. This is particularly important to manage stakeholder expectations during these critical demand management events where large amounts of money can be saved on capacity charges. The capacity charges are price signals from the utilities to reduce peak demand of the site when the grid is at maximum demand.

There are several key demand-side management measures to be communicated to building occupants. One example is reducing the lighting demand in a staged process, with the lowest level not to significantly affect work and in line with occupational health and safety. Another example is expanding set point ranges for thermal comfort to reduce pressure on the chilled water supply and the need to turn on additional chilled water supply to cope with escalating demand. A change in the global set point of buildings of 2–3°C during demand events when the external ambient temperature is >38°C for a period of 2–5 h would likely not negatively affect occupant comfort. An additional measure would be the shutting of a building CHW supply or air-conditioning entirely for 30 min periods. The Australian National University in Canberra using SATEC meters have successfully trialled this technique to manage the load. They advised that ambient temperatures did not escalate and stayed within 1°C. An important benefit is reduced fan and pump power and energy use of mechanical services. Buildings could run on a cyclical demand management process, depending upon the event in question. Another example is the pre-cooling of buildings before 8 am during periods of consecutive 38°C ambient temperatures. (See the CIBSE Energy Efficiency in Buildings for more tested ideas as well as for pros and cons) [4].

4. Integrated and distributed renewable energy systems in buildings

Smart meters are integral to integrated and distributed renewable energy systems in buildings. If an existing building is considering renewable energy, smart meter data can be analysed to size the system to produce the greatest benefits to the owner/occupier. Demand profile in the form of 15 or 30 min interval data can be used to determine seasonal consumption patterns, base and peak loads. Renewable energy production can then be modelled on an equivalent 15 or 30 min interval data and compared on a temperature and humidity normalised basis to the predictive model to gauge the optimal pairing of renewable production to consumption behaviour.

While smart meters provide accurate data, in general unless the occupier is planning on going carbon neutral or implementing battery storage, renewable energy should only ever be sized to 70–75% of average daily load on the normalised comparison data. This provides a buffer to enable future energy efficiencies to reduce the overall consumption of the premises. However, this needs to be optimised with the degradation of PV and other renewable energies over the life cycle of the system, typically 20–30 years for PV.

With the introduction of energy storage, buildings are now able to more effectively utilise their renewable energy production and target energy generated to best meet their own needs. The largest benefit to large consumers is the ability to target market signals such as demand-side management programs and to reduce their own capacity charges. Other benefits offered include the ability to store the energy rather than export it to the grid often for little or no rebate from the utility supplier. Meters form an integral part in the monitoring and management integrated renewable energy and storage systems. Live data inform all decision making and supports tuning of these management systems to improve performance and reduce both carbon emissions [5] and consumers' bills.

5. Residential smart metering

Traditional residential metering has involved an electricity, gas and water meter, which is read on a monthly, bimonthly, quarterly or biannual basis. This standard of data does not provide sufficient detail of consumption patterns to enable energy or water management [6]. It is vital that utilities and embedded network owners provide consumers access to live and/or 15–30 min interval data [7]. The data should be easily accessible either by an in-home display (IHD), mobile application or website [8].

Consumers are then informed on a real-time basis of how their behaviour contributes to their utility bills and are empowered to manage their own utility bills [9]. In Australia, residential electricity prices have increased 60–80% over the past 10 years, which has put extra additional strain on consumers' budgets, in particular pensioners and low-income households, the most vulnerable to fluctuations in the community. Data should be easily accessible and easily configurable at the tip of a finger for consumers, particularly for those who are not technology literate or who do not have access to the internet, a computer or smart phone. In this latter case, affordable IHDs would be the best solution [8].

Utilities and energy service companies can then configure the data to provide useful feedback to consumers in water and energy efficiency and savings programs. This can be done through the IHDs, online programs, smart phone apps or over-the-phone coaching programs [3].

The typical structure, applications and interactions of residential smart metering are laid out in **Figure 2**.

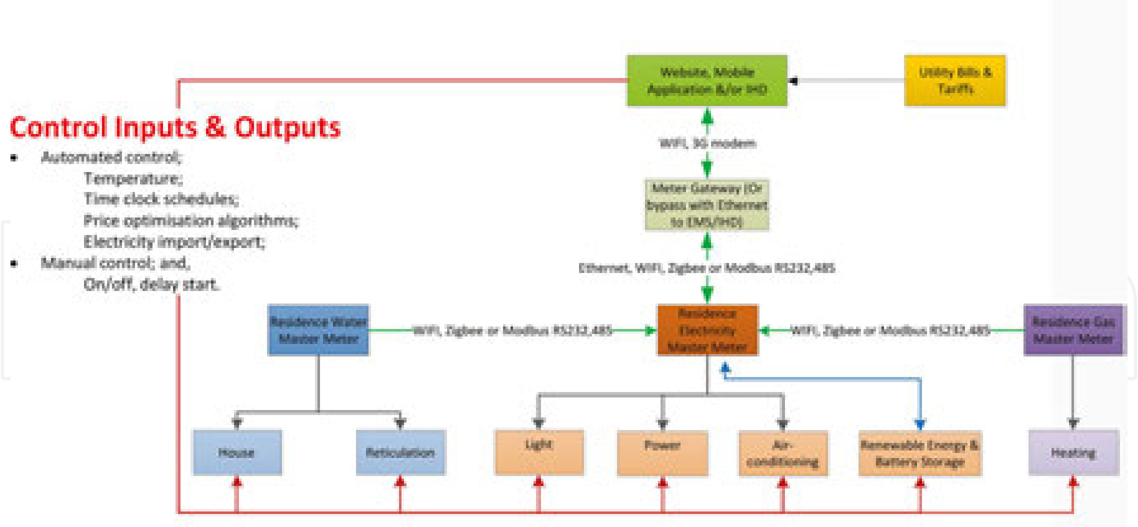

Figure 2. Typical residential smart meter architecture and applications.

6. Case studies

In this section, we introduce two case studies that show how the above principles are applied in practice at two very different locations. Case study 1 is in Perth, Western Australia on the Murdoch University Campus where the Carbon View Smart Meter Project was implemented and provides a commercial/institutional example. The second case study is described in Central Park, Sydney, New South Wales, Australia. This is an inner city mixed use development and this provides a residential apartment example.

In both case studies, the same types of meters have been used, being the SATEC EM 133 smart meter, in very different applications. The difference at each site is the programming. Although at Murdoch University the SATEC meters were programmed for a 15-min demand interval and one decimal place (to account for large users), and the meters at Central Park were programmed for a 30-min demand interval and four decimal places for the smaller residential users. For example, the latter provides significant figures for the water meters down to liters. This is specifically because of the type of pulse output from the water meters at this site.

6.1. Case study 1: Murdoch University campus carbon view smart meter project

Murdoch University has approximately 135,000 m^2 gross floor area (GFA) across 165 buildings on the South Street Campus. The university distributes electricity from the western power grid through two gate feeders through two interconnected HV ring mains at 22 kV with no step down. Each of these independent feeders is metered by western power. The internal distribution network is broken down into two distinct electrical ring mains with a total of 26 substations, which reduce HV (high voltage) to LV (low voltage). The locations and layout of the HV distribution network can be seen in **Figure 3**. Electricity is then reticulated out to the end use either directly or through building's internal LV distribution network at 240/415 V.

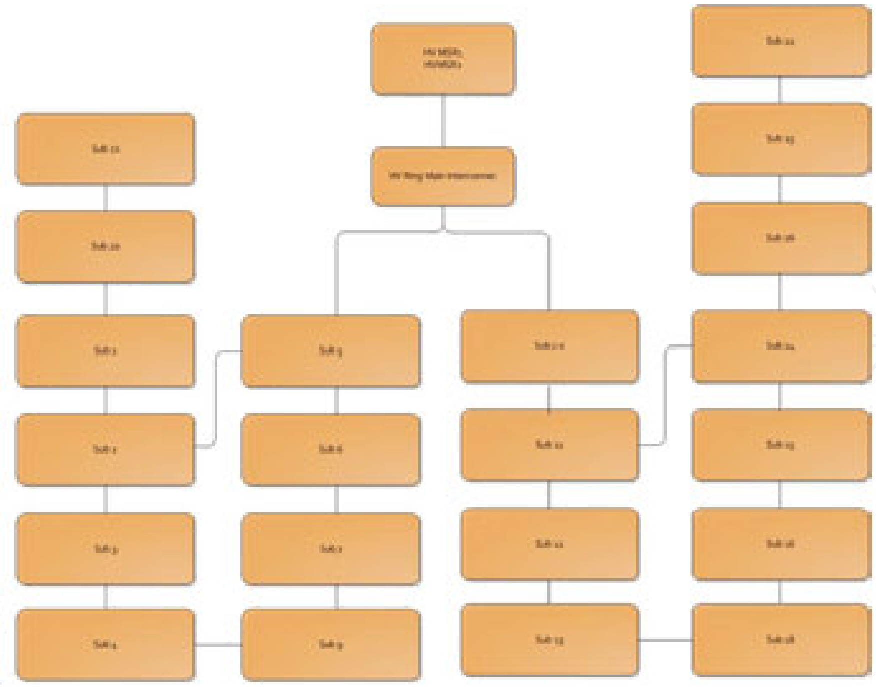

Figure 3. Murdoch University Typical HV Schematic Distribution Single Line Diagram, each ring main has an open point not represented in the diagram which is moved to balance the ring and to enable maintenance.

Murdoch University has recently embarked upon a smart meter roll out to upgrade its existing varied and aging meter embedded network infrastructure. Murdoch University undertook a review of its electricity metering embedded network and found that its old mechanical meters were at end of life and required replacement. After external consultation by JD Shute Pty Ltd, the SATEC EM133 meter was chosen as the universities' meter of choice for all installations as a standardised product. The university initially purchased 200 m to be rolled out from 2015 to replace existing end of life metering which included central chilled water plant and major tenancies.

Figure 4. The SATEC EM133 meter.

A significant amount of work was put in through the consolation phase on the meter selection to ensure that the meter had the capability to meet the needs of the university. One of the primary governing factors as to the choice of the SATEC smart meter was the need for a NMI-approved DIN-rail mount meter. At the time of selection, the SATEC EM133 meter was the first meter on the market available, which met the criteria [10].

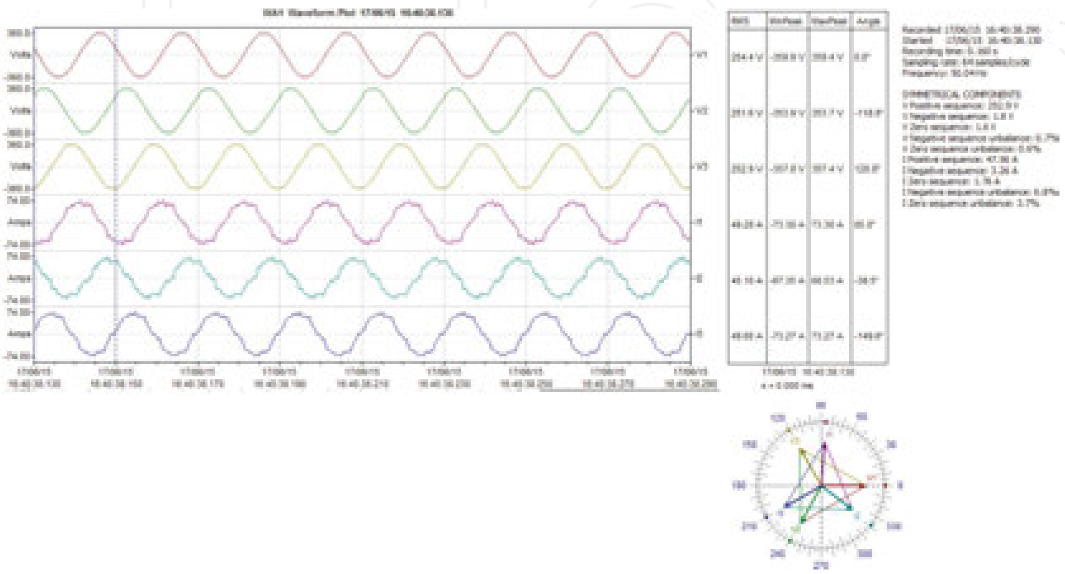

Figure 5. Instantaneous sub-cycle meter analysis and phase rotation vector diagram.

The SATEC EM133 meter, **Figure 4**, provides the university with flexibility as to what information can be programmed, stored and logged locally and at what frequency as well as live Modbus values, which can be pulled from the meter remotely by an EMS. The SATEC meter is provided with free software that provides access to program, interrogate and download data logs. This licence-free power analysis software (PAS) enables a sub-cycle snapshot and phase diagram to be produced (**Figure 5**), which is very useful for commissioning and electrical investigations.

Figure 6. The variety of existing meters installed at Murdoch University.

It is recommended that within DBs that 0–100Amp direct meters are placed between the main switch and the chassis or end use rather than on the source side of the main switch as the entire DB including the other services will have to be isolated should the meter fail or require replacement. Therefore, this configuration of direct connect in line metering significantly reduces the impact and stakeholder engagement for facilities managers during shutdowns.

The alternative CT type meters while they take up a significantly larger amount of space within the DBs due to the installation with Class 0.5 s CTs allow for installed test links to be isolated and the power from the source to the measured load to remain on while the meter is being replaced. CTs are also required for measurement of loads >100 A. The university's choices of CTs for CT type installations are the:

- Type 'S', 200/5 Amp CT 5VA Burden SCT200-IPD; and,
- Type 'T', 800/5 Amp CT 15VA Burden TCT800-IPD.

These CTs are Class 0.5ME2 and 0.5S extended range CTs, which enable the SCT200 CTs to be installed on measurement application up to 400 A loads and the TCT800 CTs to be used on applications up to 1600 A. With the use of extended range CT's, the smart meters are required to be of the extended range design. SATEC's EM133 supports extended range CT's thus compliance to 5A/10A style CTs is assured. The majority of metering hardware is designed as 5A/6A which would not be suitable for extended range CT's.

The third alternative installation methodology used at the university is the SATEC EM 133 meter installed with high-accuracy current sensors (HACS) as the installed equipment is NMI compliant as a Class 1 system. This meter configuration has only recently become available since NMI installation and provides the additional benefit to the university particularly with the ability to use HACS split core CTs on existing electrical infrastructure rather than having to disconnect to slide the IPD CTs over the cables and then re-terminate the cables. The HACS CTs range from 5 to 1200 A with various split core and solid core configurations. HACS CT installations with the EM 133 meter are NMI compliant up to 200 m with the CT wiring only transmitting 40 mA.

When developing a metering architecture and strategy for the existing campus building, it was important to be flexible yet also future proof the strategy for the expansion within the campus. While a significant amount of planning and stakeholder engagement with academics and industry experts took place, changes to the base program still occurred post-installation. The original program had four decimal places and was meant for residential applications, as the base program for the SATEC EM133AR was designed for the Central Park installation measuring water down to 0.0001 kWh intervals. This problem was noticed when regular meter readings of large consumers were lower than the previous read. It was then discovered through the use of the 30-min interval logging that the meter had been clocking at 9999.9999 kWh, which in some instances was every few days. Thanks to historical log files because no data were compromised nor lost in the process.

The MU program has since been tailored for commercial applications and reduced to 1 decimal place. As a result, the largest consumer on campus will clock in around 25 years time rather than have constant clocking in some cases every 2–3 days with large consumers. Choosing this number of decimal places does impact pulse counted units such as water and gas. Water will, therefore, have the lowest resolution down to 0.1, which will equate to 100 L. Gas likewise will clock at 0.1 of an m^3.

Investigations were undertaken to determine the most cost effective and robust connection for the automated meter reading software. Initially, the plan to bring metering online to the BMS utilising the BMS backbone through upgraded PLC in the form of Schneider Automation Servers was not feasible as there was a limitation to the number of Modbus points that could be logged. Another finding was that the automation server would not function as a gateway device to allow other software packages to contact the meter. Therefore, the license free and very useful commissioning and meter management tool PAS could not be used remotely for commissioning, meter data log reclamation, programming and detailed engineering analysis through its sub-cycle waveform capture.

The university meter program supports the functions in **Table 1** in relation to the eight assignable registers within the meter as well as providing time-of-use (TOU) data in line with the Western Australian SWIS grid on peak and off peak tariff times. That TOU billing is represented below:

- On peak—Monday to Friday 8 AM to 10 PM—Tariff 2 (displayed as T2 on meter display); and
- Off peak—Weekends and after hours—Tariff 1 (displayed as T1 on meter display).

The information in **Table 1** is also represented on the meter display and logged daily at the following configurations. Current totals for the target registers are displayed in the meter for all time. The previous and second previous read values at the end of the daily, weekly, monthly and quarterly period are displayed along with the period use consumption values for each target register as sub-menus on the meter display.

Meter program registers	Unit	Source input	Target
Total electricity	kWh	kWh import	Register 1
Phase 1	kWh	kWh L1 import	Register 2
Phase 2	kWh	kWh L2 import	Register 3
Phase 3	kWh	kWh L3 import	Register 4
Kvarh	Kvarh	Kvarh import	Register 5
kVAh	kVAh	kVAh import	Register 6
Gas	m^3	DI1	Register 7
Water	m^3	DI2	Register 8

Table 1. The Murdoch University PAS meter program for assignable registers and time of use logging (TOU).

TCP/IP was then considered against a typical Modbus RS485 meter communication connection to a gateway. While the university would have liked to go direct with the SATEC meter TCP/IP module onto its fiber backbone, the cost per module and per switch was high enough for the university to choose to utilise a hybrid solution to maintain cost-effectiveness across the smart meter roll out.

The university chose the Schneider Com X 510 gateway, which can log up to 30 m, but has been limited to around 12 m due to the number of Modbus points logged and the high polling frequency required. The university is still working on finding the limit to the number of meters per gateway and total distance for RS485 to optimise cost-effectiveness and ensure that live polling is equal to or less than 500 ms. This is particularly the case as the SATEC EM 133 driver being viewed and logged on the Schneider Power Manager Software has not been undertaken before. One of the biggest benefits of choosing the Schneider Com X 510 gateway other than the competitive price was that the software is intrinsically linked and viewed on MU's smart structure building operations (SBO) despite being installed on a standalone server and on a secure VLAN. Therefore, SBO works as a high-level Web integration package for the BMS, EMS and, in the future, the lighting controls of the university, which will all be integrated into a demand-management page on the BMS.

Figure 7. Installed Embedded Network Installations in 2015 at Murdoch University: from top left and left to right each row (a) 9× SATEC EM133 meters installed on main distribution board in one building, (b) chart showing output from the Schneider Electric COM510 energy server webpage, (c) showing the 3× energy servers with ethernet and modbus connections, (d) and (e) showing the EM133 smart meter installation using IPD CTs, test links and voltage fuses.

Building design and specification of meters and electrical installations have varied over 40 years as building codes have changed leading to variation in metering installed across the campus, which can be seen in **Figure 6**. Within buildings, electrical risers, disparate DBs and in slab conduit can limit the ability to run Modbus RS485 cable in an open loop to the nearest Com X 510 device. As a result, meters in this situation are installed with the SATEC EM133 Ethernet module, which can leverage off of the universities' Ethernet network; the Ethernet module that ‘bolts’ onto the side of the SATEC EM133R meter. While this module increases the installation cost of the meter significantly, the meter can still be logged at a high level either by the Com X 510 or at the EMS itself using 4 TCP Sockets. In some locations, the Com X 510 gateways have leveraged off of the universities’ *Eduroam* WiFi network to bring remote sub-stations, which are not connected by the universities’ fibre backbone, such as sub-station 18 in **Figure 3** to provide connectivity and visibility on the EMS. Utilising the universities’ WiFi network for remote sites has resulted in significantly reduced costs to bring these integral parts of the embedded network online. If there will be loss of communications, the biggest benefit of the Com X 510 is that it will log approximately 45 Modbus points at 1 min intervals; these data can then be recalled by the EMS automatically when connectivity is resumed. Installed Com X 510 devices connected through Ethernet are visible in **Figure 7**.

PV and renewable energy metering applications will always be connected through the Ethernet module to ensure the highest resolution for research and to ensure automated protection mechanisms are not affected by network traffic or WIFI outages.

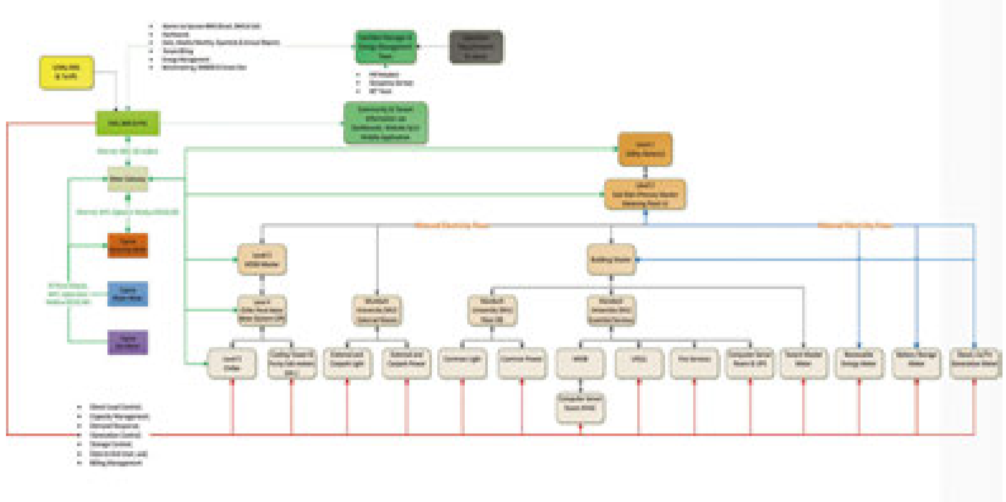

Figure 8. Typical Murdoch University Embedded Meter Network SLD, automated meter reading system and theoretical energy management framework. The arrows depict metered energy flows and type. The 5 level and end use breakdown is important for energy management, NABERS and Green Star.

The embedded network meter hierarchy in **Figure 1** has been adapted and represented along with the individual SLD-type diagram in **Figure 8**, which also displays the communications methodology in place at Murdoch University. The embedded network diagram also shows the breakdown of end use services in line with NABERS and Green Star requirements as well as the interactions between the meters, the EMS and the BMS to form the management feedback loop for the control of consumption and internal and external conditions for occupation and operation of the facility.

The outcome is the system that has live consumption information, internal building feedback from equipment and sensors and building and tenant occupant feedback and room booking information. The deployment of sensors as part of this system must be done in a thoughtful and strategic manner to satisfy feedback requirements and to optimise data collection for this purpose [10]. In the end, this has leveraged existing systems to enable the energy and water efficient operation of the Murdoch University facilities at the lowest operational cost and environmental impact.

6.2. Case study 2: Central Park, Sydney, an inner city residential apartment development

Central Park is an urban village located in Chippendale, Sydney, New South Wales (NSW), Australia, on the former old Kent Brewery site. The $2 billion mixed use development comprises two 5 Star Green Star-rated commercial and residential towers. The SATEC EM133AR meter [11] was chosen by the developer as the best fit for the project. The requirements were for a DIN-mounted Class 0.5 s, according to AS/IEC 62053-22, direct connect meter to be installed within each apartment for the monitoring of multiple electrical sources including hot/cold water usage [12].

Central Park operates a ‘tri-generation system’ and a membrane bio-reactor for the advanced water treatment (recycled water) system to support self-sufficiency and sustainable energy and water consumption. Therefore, fan coil units (FCU) are used instead of individual air-conditioning systems for each residential unit. The objective of measuring cold water and hot water is to allocate the heating/chilling cost to each tenant based on their consumption. The EM133AR was deployed to measure 3x single-phase supplies in each apartment, as well as the cold/hot water. Overall, each meter supports 7x sub-meters per apartment (**Figure 9**):

1. Total electricity;
2. Light + power;
3. FCU #1;
4. FCU #2;
5. FCU #1 + FCU #2;
6. Cold water; and
7. Hot water.

An example of an alternative raw data configuration inputs to the meter and configuration to support the 7x sub-meters per apartment is represented below:

1. Phase 1—light and power (kWh);
2. Phase 2—fan coil unit #1 (kWh);
3. Phase 3—fan coil unit #2 (kWh);
4. Phase 2 + 3—fan coil unit #1 + #2 (kWh);
5. Digital input 1—cold water (kL);
6. Digital input 2—hot water (kL);

7. Digital input 3—recycled or other type water (kL); and
8. Digital input 4—gas meter (m^3).

Figure 9. Meters installed at Central Park: (a) typical complete installation of meters for gas, electricity, hot water, cold water, (b) close up view of the gas and water meters, (c) showing electricity meter EM133AR installed in residential DB with Ethernet output to building IP backbone.

SATEC developed an algorithm specifically for the Central Park project based on the Green Star principles for daily/weekly/monthly reporting. SATEC also added 'quarterly' so that the EM133AR profiles for 'electricity and water' can easily be displayed as 'daily/weekly/monthly/quarterly' and accessible at the meter and at the Modbus/TCP/IP interface levels. The meter was programmed to provide the information over 3× periods, thus available on the meter is profiled:

- Today, yesterday and day prior to yesterday;
- This week, last week and week prior to last week;
- This month, last month and month prior to last month; and
- This quarter, last quarter and quarter prior to last quarter.

The methodology of the in-depth meter program above was designed to comply with the Green Star's Metering and Monitoring Credit. The credit specifies that the Green Star requirements are in line with the CIBSE TM39 Building Energy Metering [4] for best practice in the design of energy metering and sub -metering. Utility meters must meet metering guidelines under the weights and measures legislation, as outlined under the current national measurement regulations.

Non-utility meters (including sub-meters) must follow the same requirements to those described in the most current validating non-utility meters for NABERS ratings protocol, issued by the NSW Office of Environment and Heritage.

The Green Star credit requires all residential premises and tenancies to have their own utility grade meter and access to the meter reliant on accuracy standards. However, points are not awarded to the project without an automated monitoring system installed, which, as a minimum, must be capable of (Green *Star—Design & As Built v1.1 06 Metering and Monitoring*) the below:

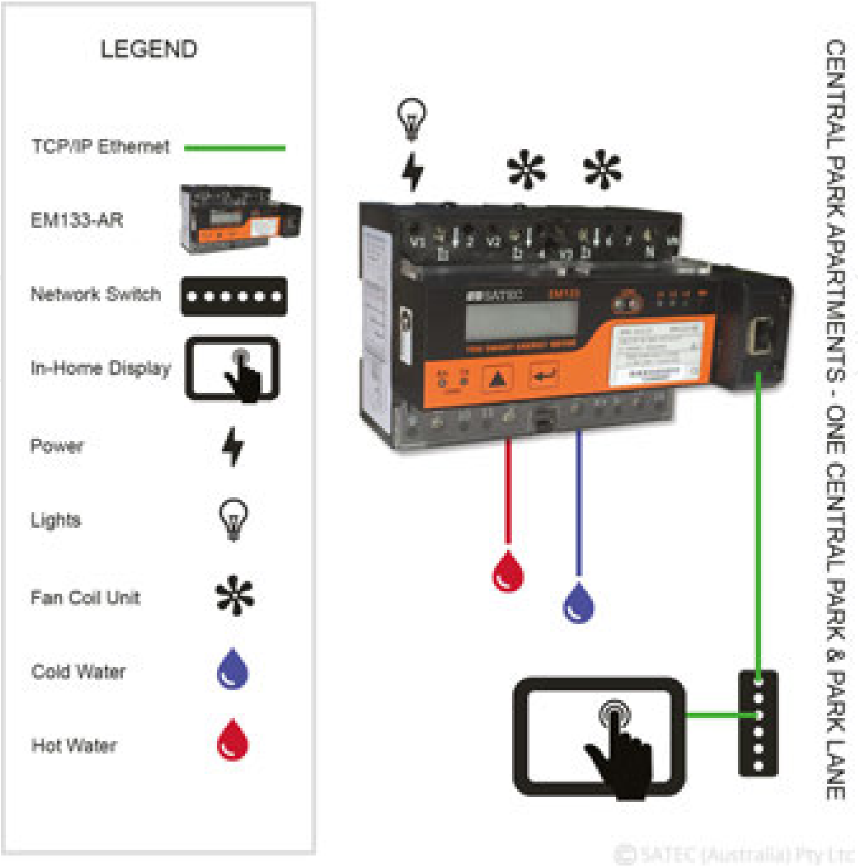

Figure 10. One Central Park & Park Lane design topology.

- Collecting data from all meters;
- Alerting to missing data due to failures;
- Recording and processing of data on energy use or water consumption at user adjustable intervals;
- Raising an alarm when the energy or water use increases beyond certain parameters and automatically and instantly issue an alert the facilities manager;
- Providing a breakdown of the information by building system (mechanical, electrical, etc.), or by space (or by tenanted floor);
- Including the consumption water or energy, the load versus time (load profile), and the power factor (in the case of energy); and
- Producing, as a minimum, a quarterly report that is automatically emailed to the facilities manager responsible for the building.

The SATEC program outlined above provides a virtual utilisation type technique or a distributed logic approach reducing processing power from software platforms particularly for the daily/ weekly/ monthly/ quarterly element. While the program attributes in the meter offer these convenient summaries, real-time data are available through the Modbus register map along with asset information assisting in managing metering assets according to ISO 55000 (**Figures 10–12**).

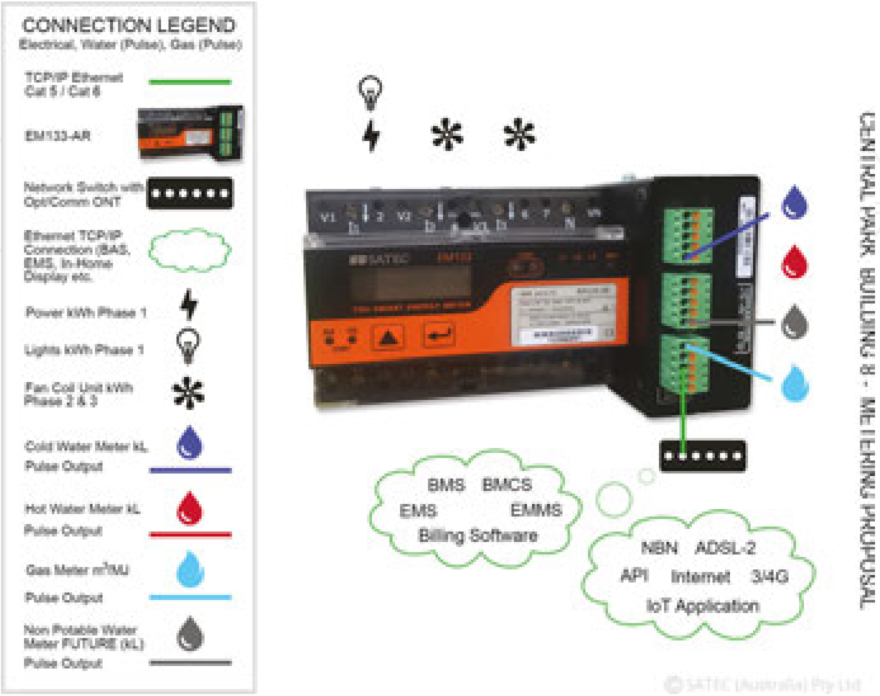

Figure 11. Central Park—Proposed Building 8 Solutions (Mechanical, Electrical, Hydraulic Services).

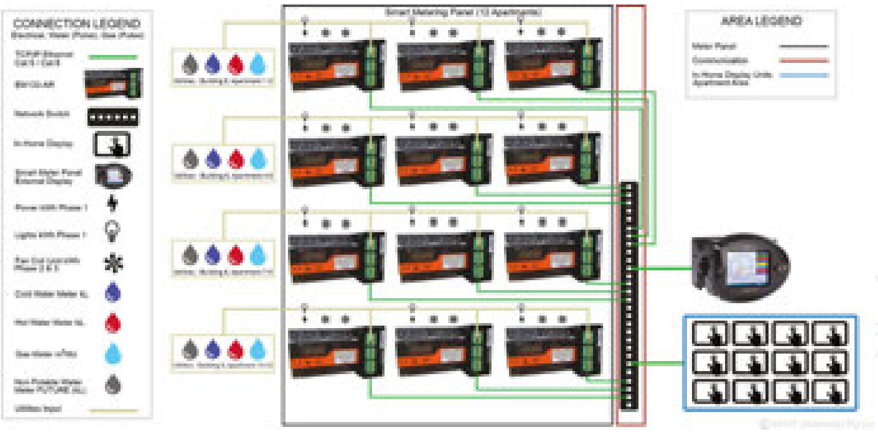

Figure 12. SATEC proposed typical typology for Smart Metering for Central Park Sydney (SATEC EM133AR 'Smart Metering' for Central Park Building 8 Rev 2 04).

The purpose of the embedded network is to allow the developer/owner to have increased financial revenue from their infrastructure. This trend is becoming more popular, as developments and owners are becoming more aware of the benefits that can be gained by owning and operating their utility networks internal to their facilities. This is particularly the case for multi-unit residential developments. SATEC (Australia) Pty Ltd advised that as of December 2015 the embedded network is still not fully operational at Central Park, as the billing provider was not fully utilising the functionality. SATEC (Australia) Pty Ltd further noted that it was possible for them to fully utilise the system, but there were some managerial issues still to overcome.

Common area metering is now more used widely utilised in commercial buildings, mainly due to NABERS and Green Star. Once NABERS became mandatory under the commercial building disclosure legislation at the point of sale, lease or sub-lease for office space greater than 2000 m^2, metering sales and installations increased dramatically according to SATEC (Australia) Pty Ltd. Comparing to New Zealand, where NABERS is voluntary, fewer owners install embedded network metering systems than Australia. The CBD legislation is under review by the federal government with the recommendation that the threshold of 2000 m^2 be reduced to 1000 m^2, which will further drive the installation of these embedded meter networks from A grade buildings into B and C grades building stock within Australia. The Green Building Council has linked NABERS and Green Star ratings directly to the improvement in return on assets calculations, as specifically expressed in a meeting in Christchurch.

While NABERS energy and water assessments require 12 months of utility meter readings for the building for a whole building reading, a base building rating requires 12 months of tenant meter data to subtract from the buildings total consumption. The outcome is the base building consumption, which is the standardised based upon the climate using the postcode, net lettable area (NLA) and occupancy data to provide the final NABERS energy base building rating.

Alternatively, Green Star requires under Section 6.0.1 Metering Distinct Uses or Floors of its Design & As Built v1.1 rating tool that metering shall be provided to allow for monitoring of the relevant areas or functions of the project. Stating that in most cases floor-by-floor metering will suffice if the entire floor has a single use and that if a floor has multiple uses, the different uses shall be metered. Therefore, should a floor be composed of office space and a seminar room, both spaces shall be separately sub-metered. If a floor has multiple tenants or owners, each tenancy or property shall also be separately sub-metered.

Green Star also has specific requirements where an energy load for a single item exceeds 5% of the total energy use for the building, or 100 kW, it must be independently metered. Supplementary equipment can also be installed on the same measured circuit as the major use item. However, the total combined energy use of any systems connected to the major use item must not contribute more than 10 kVA to the overall energy use.

Examples of systems that are considered to be common uses for energy are provided by the Green Star rating tool, but are not limited to:

- Chillers;
- Air handling units, fans and humidification;
- Server and computer equipment;
- Water reuse systems;
- Kitchen plant and equipment;

- Specialist lighting for stages, etc.; and
- Specialist equipment.

Embedded networks within Australian buildings will gradually change, with the market competition reviews being conducted by the Australian Energy Market Commission (AEMC) and the Western Australia (WA) stand-alone grid known as the South West Interconnected System (SWIS) being harmonised into the national management framework under changes being made out of the WA Electricity Market Review in particular.

The outcomes of that will be increased competition in metering to be more likely, and advanced metering will be used instead of low-cost metering. The ability for consumers to 'opt-out' of the embedded network, or meter churn, will be a big issue in the future. One way of overcoming this is to leverage improved communication such as Ethernet (TCP/IP). Ethernet is a 'multi-master' communications platform and widely used throughout many industries.

Metrology measuring devices have improved from RS232 communications, which are an example of 1:1 relationships. The communications or RS232 are most demonstrated in networks whereby remote communications is leveraged by modems supporting—2/3G, 4G, GPRS, etc. Metering encompasses further complicated communication networks such as RS485 (e.g. daisy-chain) topology configurations. In particular, Modbus RTU protocol delivered over RS485 methods could limit physical connections with respect to individual modern digital metering systems.

Methods over TCP/IP leverage improved communication methods. For example, a typical 'modem/meter relationship' is limited to a 1:32 ratio in respect to a Modbus RTU protocol implementation. Ethernet leverages modern improvements in communication methods allowing for improved transparent communication methods. The National Broadband Network (NBN) in Australia will inhibit a transition to a modern information enabled generation.

At Central Park in Sydney, Ethernet is used on all meters. The meter has data logging and event logging, as well as a daily/weekly/monthly/quarterly profile. Developed for Green Star reporting principles, the benefit is now the meter is 'the data server'. It performs the 'distributed logic' and alleviates the burden from any given control system such as the building management system (BMS) or building management control system (BMCS). It allows for more efficient communications and works to guarantee that all profiled data are done by the physics of the real-time clock, compared to a traditional 'polling system'.

A traditional 'polling system' is unable to assemble all data correctly across these many meters. Central Park in Sydney has more than 1500 m or devices installed in the digital metering network. Each meter has 7×7× sub-meters per apartment which equates to 10,500 sub-meters on a digital network. The main benefit of Ethernet is the multi-master support. The SATEC TCP/IP module has four TCP sockets available for different software systems to consume the data from the meters simultaneously, which cannot be done with traditional RS485/RS232 communication topologies.

In the case of 'meter churn', or a consumer replacing their respective meter used for trade purposes such as 'billing', future communication developments will enhance the overall consumer experience respective to regional Internet capabilities. Overall 'meter churn' within the Australian jurisdiction, or others, can be improved exponentially, and with effective methods , the overall efficiencies and flexibility in network design improve the following:

- BMS, BMCS, and EMS;
- Billing system;
- In-home display, and;
- Metering programming software (E.g. Power Analysis Software—PAS).

In the future, should a consumer choose to opt-out of the embedded network, an energy retailer could easily access the data directly from the meter through use of TCP/IP Ethernet communications. If ADSL, ADSL+, GPRS, NBN or 2/3/4G are required, then it is with TCP/IP communications whereby enhancements can be made. A simple 'port forward' is managed though IT layers proving a clear and transparent visualisation of the respective metering system. With the use of 'multiple TCP socket', a true disciplined 'multi-master application' can be achieved and overall data limitation through traditional methods can be realised.

7. Conclusions

Smart metering at both the residential and large facility scale should be robust and commissioned correctly. Utilities and urban developers need to engage with communities and consumers to better understand how smart meters and data feedback can best achieve societal goals [13]. This will then ensure accurate and live consumption information is easily accessible to the consumers and utilities where appropriate to enable the most efficient consumption, generation and storage of electricity, water and gas.

These goals can be achieved by choosing meters with standardised high-level communication inputs and outputs, which provide connectivity for additional sub-metered services such as water and gas and ultimately connectivity to a reporting system to the consumer. While the connectivity ultimately should be TCP/IP, for internal university campuses, utilising Modbus and open-source master gateway devices has proven to be a cost-effective structure. Where large-scale multi-tenanted residential or commercial tenancies involved, direct TCP/IP connectivity to the meter provides for future proofing within the Australian market due review of all aspects of the energy landscape and particularly how metering can be leveraged by both consumers and in particular networks and generators.

Energy management systems provide both residential and large energy consumers with the ability to capture, monitor and control their energy consumption and therefore their expenditure whether this is by reducing consumption directly through energy efficiency upgrades or behaviour change to optimise consumption against price signals from the utilities. Accuracy of data is a key element in order to represent the measured outcome for analysis.

Energy management systems combined with structured metering also enable consumers with renewable energy generation such as photovoltaic (PV) panels to monitor their own generation, consumption, import and export. As battery storage becomes integrated with renewable energy generation, consumers will have the ability to consume cheaper renewable energy than can be bought from the grid and sell energy back to the grid at the most economically viable times. While uncertainty surrounds the grid and its impact on rising electricity prices, smart metering, intelligent control systems and utilities offering consumers more amenity and the ability for consumers to participate in the wholesale market will ensure the smart grid can contribute to future carbon neutral [14] urban environments.

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