Measures to Reduce Concerns Related to Smart Meter Data

Are detailed Consumer data needed for Smart Grid Operations?

Full paper

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Abstract

Intelligent information systems are necessary to improve power grid operations. The current trend reveals the deployment of smart meter at consumer sites as the energy provider's starting point to grid modernisation. Smart meters are considered as a core element in most of the smart grid projects. The smart metering system is designed to collect and transmit detailed consumption data. Detailed data from the smart meter could profile the consumer's lifestyle and this is among the reasons for consumer's resistance to smart meters. It is also not clear how the power grid will benefit from individual consumer's detailed power usage data. This article attempts to investigate this issue by analysing if detailed end-user data is required for the operation of other control systems in the grid. Further an analysis is conducted to identify which stakeholders will benefit from the detailed smart meter data. Based on the analysis remedial measures are proposed.

Keywords

Smart meter, Advanced Metering Infrastructure (AMI), energy consumer, smart meter data, feeder meter.

Introduction

Reliability, operational efficiency and services are deficient in the traditional grid's generation, transmission, and distribution systems. This has pressed the utility providers to search for new intelligent ways to supplement the grid and this has paved way for the concept of Smart Grid (SG). Installation of local power generation systems, smart meters, decentralised distribution automation systems and communication systems are part of the current smart gird projects (Fang et al. 2012; Farhangi 2010). The concepts and technologies used in SG are vast and it is essential to have a systematic analysis before integrating them into business practices else it could lead to operation and maintenance of ineffective systems or the need for expensive retrofits. Hence it is essential to carefully analyse the grid modernisation components before they are deployed.

Smart Metering Systems also referred to as Advanced Metering Infrastructure (AMI) has the capability to remotely control the end-user's load and automatically retrieve usage data(Wenpeng 2009). These had been the key factors that have fascinated the power industry to invest in these systems as it was expected to facilitate Demand Response (DR). DR is considered as one of the cheapest measure to reduce demand. Direct Load Control (DLC) and Time-of-Use (TOU) pricing are the two main programs under DR. The utility can use DLC to remotely shut down or cycle a customer's electrical equipment for a selected interval of time. Using TOU the utility can vary the usage unit price based on time period (FERC 2008; Newsham et al. 2010). Both these programs were intended to be applied on residential and commercial customers upon AMI deployment.

Many utilities hastened AMI-centered deployments and advertised them as the key to modernization of the grid. Even some utilities campaigned AMI systems as a sure means to help consumers save on power bills. But in reality they are facing significant opposition from consumer and also suffering from technological glitches. In many places, rollouts have been delayed and even stopped. Various reports even suggest that many utilities haven't analysed if the communication technologies used are capable of supporting the core functionalities attributed to the system(SSM Australia 2015).

AMI can be considered as a socio-technical system and it also has a 'green' element as it has lot of potential to contribute to environmental sustainability(Mattern et al. 2010). But if the current situation continues users will lose faith in the system and industry will not be able to use AMI even for its guaranteed benefits. It is always challenging to deal with such systems as it requires taking into consideration information about the end user and various other multiple perspectives. The current AMI system seems to lack the consumer perspective. It also does not take into consideration the limitation of the communication technologies used.

We use the design science approach to discuss the design and research problems in AMI. The design planning process based on Fuller's vison provides appropriate guidance in analysing the problem and in identifying the remedial measures(Brown et al. 1978). This contribution intends to identify design issues in the AMI system and thereby propose measures that will improve its adoption. The remainder of the paper is structured into four sections. In the following section, we elaborate on the electricity meter and how it evolved to become part of the smart grid. In section 3 we deeply analyse the problem. In section 4 we propose corrective measures and discuss how it is beneficial in various scenarios. The paper concludes with a discussion of the results and provides implications for research and practice.

Background

Evolution of electricity meters

The electricity meters evolved from a simple analog meters to a digital meter with storing and communicating capabilities. The smart meter consists of the metering module and a communication module with the network interface card (NIC). The meter is capable of storing data at a very fine interval like 1 min or even lower. The stored data can be communicated to the back-end / utility provider using the communication module. The automated digital meters evolved from Automated Meter Reading (AMR) Systems to AMI. (Amin 2008; Depuru et al. 2011; EEI 2011) There are also prepayment meter with a control box which will warn the consumer when the meter runs low on money. For these meters the payment is done in advance and there are no monthly bills. The AMR meters were capable of load profiling, tamper detection, outage detection (one way). As it evolved to AMI, the meters became even capable of TOU pricing, remote meter programing, integrated service switch, Home Area Network (HAN) interfacing and many more (EEI 2011).

The power grid has various control systems for generation, transmission and distribution and AMI was introduced as an element of the Distribution Management Systems (DMS). Though it is an element in the DMS, in various SG visions and models, AMI is highlighted as the IS that could influence all the sectors section of the power industry. Moreover it is considered as the core element that could make the consumer an active participant in energy management. Against this background many countries fostered the installation of AMI.

Most utilities opted for smart meters that could collect and transmits fine-grained data at the interval ranging from 15mins to 1hr. The notion was this real-time data would help in identifying and controlling demand. They expected that this information could be used in managing energy requirements. In case of excess demand, DR programs could be used as a curtailment measure. For the communication infrastructure some utilities chose to use the existing power lines and others chose to develop dedicated infrastructure for AMI system. Power Line Communication (PLC), RF mesh and GPRS are the most commonly used communication technologies(Yang et al. 2013).

Problem Analysis

Current context of smart meters

All the benefits of smart grids will require time to be fully realised, but many countries have decided to roll-out smart meter expecting that it will be the stepping stone to the progress. As the project deployment started, various issues started cropping up. There were technology glitches and consumer resistance to DR programs (Arnold 2011; Bari et al. 2014; Koutsopoulos et al. 2011). Apart from that health, safety and privacy issues also became prominent factors for negative sentiments to smart meters. There have been complaints that smart meters cause Electromagnetic hypersensitivity (EHS) related health problems(Baliatsas et al. 2012). There are fears that detailed data from smart meters could reveal occupancy, contents and people's lifestyle(Quinn 2009). There are worries that remote disconnection of power supply could be trigged by an accident or an attack (Berrio et al. 2012; Yang et al. 2013). Some of these issues are real and others are perceived, but both are detrimental to the adoption of AMI.

As a result of vocal opposition by consumer advocacy groups (Betz 2010; SSM Australia 2015; SSM UK 2015), government agencies are undertaking to make privacy policies and security measures more robust for AMI systems (Lockstep 2011; WP 29 2013). In this section the recent smart metering projects are analysed. There had been various initiatives around the world. Some projects have completed successfully on schedule where as some are facing various issues after roll out has started. There are other projects that are delayed to avoid facing the similar fate of the struggling projects. Considering the status of the smart meter roll out the projects can be classified into three categories:

- Successfully completed roll-out as planned
- Faced/ are facing significant issues during roll-out
- Continuing with discussions without starting roll-out

Projects that successfully completed AMI roll-out as planned

Sweden and Italy were among the few countries that were able to complete their smart meter roll-out in the time-frame they had scheduled.

In Sweden the smart meters with the AMR capability were introduced to mainly generate monthly bills. Prior to that, consumers paid their bills annually based on their previous year's consumption. A reconciliation bill was later issued for the difference between the actual consumption and previous year's data. Allowances were also provided to the network companies to cover the cost of deployment. There wasn't much opposition from the consumer to smart meter roll-out as it provided them with an opportunity to pay for their actual usage. The customer also didn't raise concerns over meter data. It is also reported that as the AMR technologies were used the infrastructure didn't support DR activities. PLC was mainly chosen for communication as the infrastructure already existed and there was no need for major investments(Balmert et al. 2012; Giordano et al. 2011).

In Italy reduction in fraud and theft were the basic motivation for smart metering deployment. Even in Italy, PLC was chosen for communication. The mandatory roll-out requirement was included in the Energy Law. To cover the costs for the roll-out, a separate metering charge has been levied. Since the smart meters were designed to reduce fraud, the whole set-up lacked customer benefits. Still the projects did not face any stiff resistance from consumers (Balmert et al. 2012; Giordano et al. 2011).

Projects that faced/ are facing significant issues during roll-out

Netherlands and Australia were among the two countries that faced significant issues during their roll-out.

Initially Netherland had an Energy Efficiency Bill in 2006 that required mandatory introduction of smart meters for all residential consumers. Resisting a smart meter installation was made punishable with a heavy fine or imprisonment for a maximum of 6 months. This led to campaigns against the smart meters. This forced the Dutch government to amend the bill to allow voluntary participation. After all the amendments the consumers were provided with the following choices : request for the deployed smart meter to be not read or operated by the utility ; have a smart meter to do the basic measurements but have no communication facilities and give consent to the utility to read more data than required for billing purpose. A privacy assessment was conducted and it also stated that the government had provided too little evidence for the necessity of remote disconnection to combat fraud. The report concluded that the characteristics of the proposed Dutch smart metering system were not proven to be necessary in a democratic society. Later in 2012, a two stage voluntary smart meter rollout was again initiated. Latest media reports announce that Netherlands are planning to go ahead with the large scale roll-out which will install 15 million smart gas and electricity meters by 2020(Balmert et al. 2012; Giordano et al. 2011).

Victoria was the first state in Australia that decided to have a state-wide rollout of smart meters, preceding National Smart Metering Program (NSMP). The Victorian Government mandated the implementation of smart meters for residential customers in 2006 and the rollout commenced in 2009. There was resistance from consumer to accept smart meters and thus Victorian Auditor-General's Office (VAGO) examined the advices and recommendations provided to Victorian government on the AMI roll out. VAGO concluded that technology risks and their implications were significantly underestimated (Victoria/Auditor-General 2009) . Energy price deregulation was introduced for all consumers to complement the smart meter roll-out and TOU was also part of the scheme(Benvenuti 2013). There was huge resistance to the TOU pricing scheme from consumer and their advocacy groups that the providers had to let the consumers stick to the flat rates even after the deployment of smart meters. Due to lot of resistance to the smart meter program there were speculations that the roll-out of smart meters could be suspended. The state government decided to continue with the roll-out as it became evident that it would be more expensive for them to support two different metering systems. More reforms were made to reduce the opposition. In 2014, Victoria managed to complete its smart meter roll-out to almost all its customers. The consumer was provided a rebate if the distributor failed to install a smart meter. Alternately, the distributors were permitted to recover the associated costs if the consumer refused to accept a smart meter(DED 2014).

Projects that are delaying roll-out and continuing with discussions

The UK government initially announced its plan in 2009 to have a complete smart meter roll-out by 2020. Issues faced by other installation around the world provided UK with an opportunity to do a better analysis. In 2010, the government's proposal was published for consultation regarding the cost-benefit analysis. The proposed roll-out required options to switch the meter to a prepayment scheme. It also required real-time data to be displayed to the consumer through an in-home-display (IHD); load management capability and remote disconnection feature. But in 2014, it was reported that the smart meter roll-out is being delayed because the communications system for the devices are not ready. They want a central communication model that will allow consumers to switch energy supplier without changing meters or communications equipment(Balmert et al. 2012; Faruqui et al. 2010).

Factors causing the problem

Smart meter roll-outs with simple purposes completed on schedule. With the projects facing issues and delays it can be noted that the meters are overloaded with functionalities beyond the original metering purposes. These functionalities also require communication channels that have the potential to support very high frequency two-way communication. This leads to complexities and risks.

The traditional purpose of a utility meter is to record the usage of the end-user. A smarter system should be more accurate and tamper proof. These functionalities do not create complexities. Complexities are created by functionalities that are currently designed to rely on detailed consumer data from consumer, and especially with the frequent transfer of this data to the utility.

Are detailed Consumer data needed for Smart Grid Operations?

This section will analyse if the smart grid control systems and stakeholder will benefit from detailed consumption data from consumer.

Influence on Control Systems

The control elements identified by Power Systems Engineering Research Center (PSERC) are used in this discussion(Govindarasu et al. 2012). The analysis will first consider the distribution controls followed by the transmission and generation controls. Table 1 examines if detailed consumer data is essential for the control element's operation

Control Element	**Identify need for detailed interval data**
Load Shedding	The load is shed at the feeder level. The smart meter data could help in determining the load. But there is no requirement for individual consumer data. An aggregation of data from all users under the feeder will be required. This data needs to be communicated to the back-end in real-time.
Demand Side Management	The data from the end-user could assist DMS system in identifying if more power will be needed from bulk generation units. It could also help in identifying if there is excessive feed-in from the consumer. This feature also does not benefit from individual consumer data. There may be multiple feeders under a substation and this functionality only requires aggregated data from all feeders.
High-voltage direct current (HVDC) transmission control	With the introduction of distributed energy resources (DER) and renewable energy resources (RES), firing angle calculations can be improved if the power quality in the grid is available. These operations cannot benefit from individual user's power quality. The data should be available at substations level.
volt-ampere reactive (var) compensation	This control mainly relies on local measurements and consumer's data will be of least use for its operation.
State estimation	This control mainly relies on local measurements and consumer's data will be of least use for its operation.
Security-Constrained Economic dispatch	Demand is one of the main inputs for this control and the aggregated demand data at substation level could assist in its operation.
Automatic Generation Control	Consumer's historical data if aggregated could be used to predict the consumption pattern; this could regulate generation at optimal level. Even for this operation, the system does not benefit directly from the end-user's data in real-time. It is sufficient to get the consumption data at substation or feeder level.
Governor Control	This control mainly relies on local measurements and consumer's data will be of least use for its operation.
Automatic Voltage Regulator	This control mainly relies on local measurements and consumer's data will be of least use for its operation.

Table 1 Analysing Control System's need for consumer's energy data

Various control operation in the grid will benefit from real-time knowledge of load or demand in the system. But that does not suggest that load data should be detailed consumption data from the end-user. For transmission and generation related control applications, the data that is required is the demand/load of the substation. For demand management at a substation it is sufficient to have information at a feeder level. If consumer data is used for this purpose; it has to be aggregated and transferred to the control points. This depends on the communication technology involved. For time-critical operations it is not efficient and realistic to make the generation and transmission systems wait for data from the consumer point to be processed and transmitted. At the same time, historical data on consumer load can be aggregated to make intelligent predictions and calculations, but it will not be essential if that data is already available at feeder level or substation level. Even for the distribution management system to prevent damage of cables and hardware and to make decision on load control there is no need for consumer level data. Detailed consumption data of individual consumer could be useful for making predictions on consumer behaviour patterns and power market operations and for most of those tools historical usage will be sufficient and the consumer will need to give consent to use their data

Influence on Stakeholder

There are various stakeholders involved in the smart metering system and few important stakeholders are: Customer Service & Field Operations; Revenue Cycle Services; Billing, Accounting& Revenue Protection; Load Distribution Operations; Utility Customers and Marketing & Load Forecasting (EEI 2011). Smart metering data is useful for many of these stakeholder operations, but apart from the utility customer no other stakeholders may requires the load profile data. Table 2 examines if detailed consumer data is essential for different stakeholder.

Stakeholder	**Identify need for detailed interval data**
Customer Service & Field Operations	AMI reduces their need to do onsite metering reading. Their job becomes easier as the consumer data will be sent to the utility provider. But there is no requirement for detailed consumption data, as it does not make any change to their operation.
Billing, Accounting, Revenue Protection	Billing and tamper detection becomes efficient with remote reading of consumption data. Current smart metering system sends detailed consumption data to utility and they apply TOU rates to this data. This is an inefficient practice. The smart meters are capable of accumulating the usage under different section for each demand period. It is sufficient to send this information at the time needed to calculate the bills. This reduces the need for transmitting detailed data from consumer and also reduces traffic in the communication lines. For revenue protection, real-time tamper alters are beneficial. Sending this data in real-time is beneficial for this stakeholder
Load Distribution Operations	The power quality and load details are required for these operations. The load details are mainly required at feeder level and hence it does not really need to rely on the consumer load data and if it does it has to undergo aggregation. The power quality details are also not required frequently. The threshold can be set in the consumer's smart meter to set alerts if it deviates from the settings. So for power quality and outage tracking it is sufficient for the meter to send alerts if there are issues.
Utility Customers	The consumers can benefit from real-time detailed data from the meter. With the help of feedback mechanism like In-House-Display (IHD), the consumer can view their usage in real-time. They can make wise choices to reduce wastage.
Marketing & Load Forecasting	They benefit from detailed consumer consumption data. AMI will reduce the costs for collecting this data for research purpose. But they will require consumer consent as it could invade the privacy of the consumer.

Table 2 Analysing Stakeholder's need for consumer's energy data

AMI system can help the utility to avoid errors from billing estimation and in early identification of theft. But for most of these operations, the real-time usage data is not necessary. As billing is done at a monthly or higher cycle, aggregated usage information is sufficient before the next billing date. Even for time-of-use (TOU) calculation, it is only necessary to have aggregated data for each tariff (peak, off-peak and shoulder) for that billing period. The electricity theft can be determined by using other parameters like setting alerts for meter tampering. So even for such operations there is no genuine need of real-time transmission of detailed smart meter data. Finally it comes down to the consumer and the power markets. Consumers could benefit from viewing usage in real-time. It could help them to make environmental friendly choices. Power markets also benefit from the detailed data for making lot of analysis and they could be allowed to use the data with the consent of the consumer.

Recommendations on System Modification

Factors affecting the current AMI System

The analysis conducted above sheds light on the issues in the current AMI design.

1. The consumer meter is overloaded with functions beyond its capability. It's better to assign only consumer billing and consumer specific functionalities to the end-user meter.
2. The system is designed to collect and transmit detailed consumer data even though there isn't sufficient justification for its need. It is better to limit the detailed data only to the consumer themselves. Other stakeholder can obtain it from the consumer upon consent.

Proposed Modification

The proposed measure is to have smart meter added at each level of the grid. These smart meters need to only serve specific functionalities at that level in the grid. i.e. there should be smart meter at power generation ,sub-station, feeder and the end-user level. Figure 1 shows a diagrammatic representation of the system.

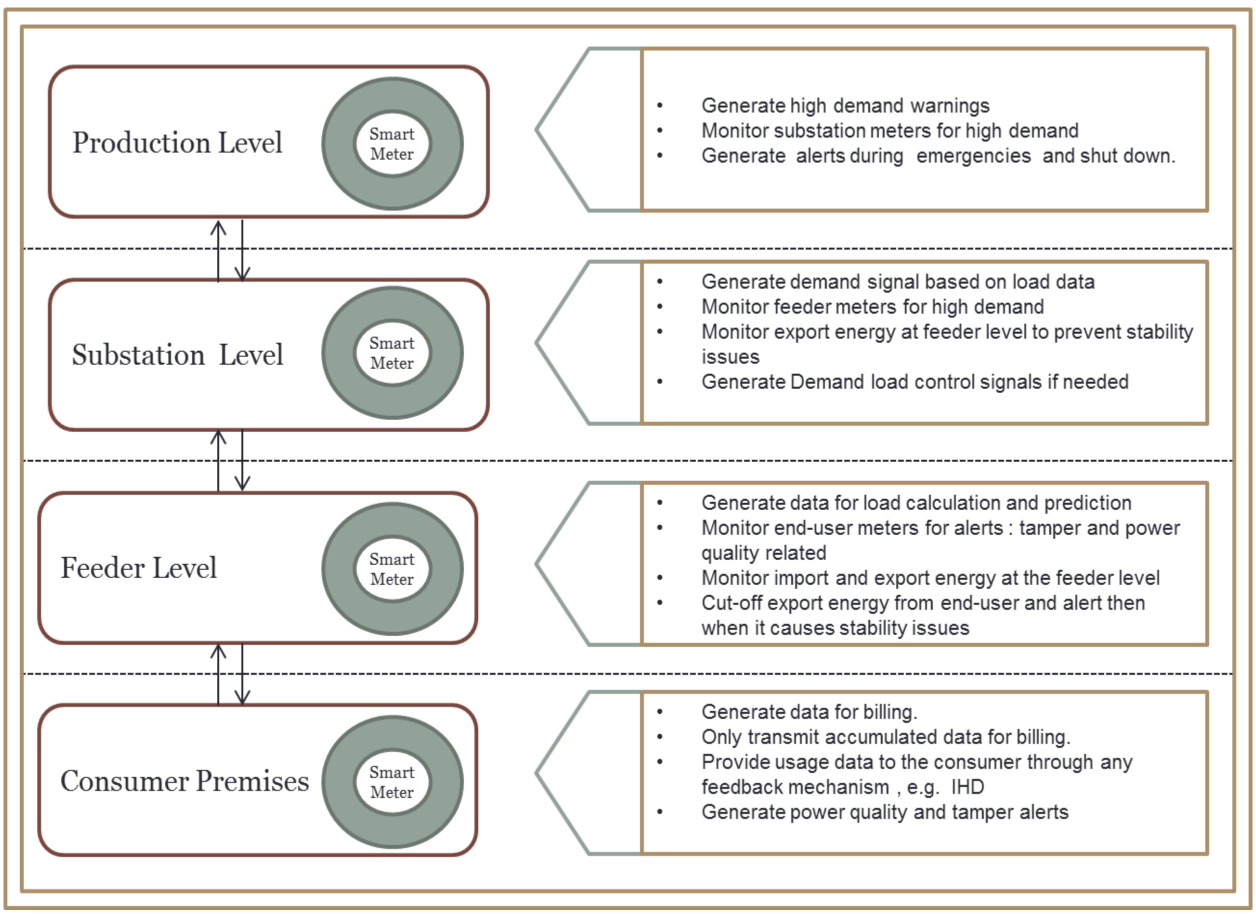

Figure 1 Schematic Diagram of the proposed smart metering system

Discussion on the proposed system

Feeder meters and sub-station meters are not new concepts (Baran et al. 1996). But in the smart grid they haven't been considered, instead all the data requirements are burdened on the end-user's meter. Feeder meters can play a significant role in intelligent operations for the grid. Feeder meters have been used in the past to identify power theft. An intelligent feeder meter can quickly provide the load requirement in the area without having to wait for consumers' data to be collected and aggregated. The substation meter should have sufficient information to generate demand signals. Even without a smart meter at the customer site, these signals can be communicated to the user. The meter at the bulk generation site will provide the real-time demand information for the production purpose. For making forecasts, the system only needs to rely upon substation for historical data; at most load data from the feeder level is required. This eliminates the need of end-user data for grid intelligence. This will reduce the unnecessary traffics in the system created by transmission of detailed consumer data. This minimises the need for aggregation tools. This also reduces privacy issues as there is no need to transmit detailed data from the end user. That data can be limited to consumer's viewing.

For new smart meter roll-outs, utility providers should start with meters at the production side and then work their way down the hierarchy. Even if meters with communication capabilities are not deployed at the end-user level, the rest three levels can provide sufficient information to forecast load.

System Evaluation

This section will discuss how this proposed setup could be used in different scenarios.

1. Places where majority of their societies abide by law and there is no shortage of power.

In such situations it is usually found that, the running cost of the infrastructure will be more than the savings achieved from smart meter usage. So it is sufficient to have smart meter up to the feeder level. This will reduce the infrastructure cost and still provide information for a smarter grid operation. To reduce the need for onsite billing reads, a secure online system or phone-in system can be introduced for the consumer to provide their usage data. The feeder meter data can be used to tally if there are discrepancies in data provided by the consumer in an area. Energy laws could also be introduces to ensure that people could incur fines for false information provided.

2. Citizens are provided with a choice to opt out of smart meter

In cases like Netherlands, the utility had to provide the option of opting out of smart meter due to stiff consumer resistance. In the current setup that will affect the accuracy of load forecast. Using the proposed measure, that will not be an issue as the feeder meters have the information required. As a feeder meter is not in the premises of a consumer nor does it have any detailed information of the user, consumers have no sufficient grounds to oppose a feeder meter. For the consumers who have opted- out, their interval meters can be manually read and TOU pricing can be applied. In such cases a manual read fee may also be charged from the consumer. But if they don't have an interval meter, it will not be possible to apply TOU rates and they may have to accept a higher flat-price.

3. Overcoming limitations is smart meter features

   Though smart meters are capable of identifying tamper and theft, there are also evidences of theft in AMI(McLaughlin et al. 2010). As the smart meter is in the consumer premises they find means to tamper it without being noticed. Feeder meter data will help to identify inconsistencies.

Discussion and Conclusion

The article initially identifies the problem situation in the current smart metering context. Then Design Science method is applied to analyse the problem and identify measures. The proposal is to reduce the function overload at the consumers' meter and then to introduce smart meters at other levels in the grid. This also provides an option to eliminate the need for detailed power data from the consumer.

There are certain limitations to this research. Due to the nature of the project, implementation and field testing was not a feasible. To retrofit a current project according to this proposal, there will be further infrastructure required for the feeder, substation and generation site meters. Yet it will be less compared to that of a consumer level roll-out. The information security requirements for the additional infrastructure have not been analysed in this article. Identifying the security needs of the system provides direction for future research in this area.

Smart metering systems have the potential to contribute to smart grids and improved energy management. Accuracy in meter read and elimination of human errors benefits the utility as well as the consumer. The infrastructure required for the system is vast and smart meters are expensive. The evaluation suggests that current smart metering systems can be improved and this will also reduce the consumer concern as the need of detailed end-user data is made minimal.

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