Traditional Vs Smart Electricity Metering Systems: A Brief Overview

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Abstract
Electricity meters are devices for electricity consumption measurements, which have been used and are still in use today with modern technologies. In some places, traditional electricity meters are replaced with smart electricity meters for more accuracy, efficiency, features, privacy, security and visibility in electricity measurements. Literature review was used in this study to compare traditional analogue electricity meters with digital electricity meters. Therefore, the achievements and challenges of 12 countries around the world (2 countries on each continent except Antarctic), which adopted smart electricity metering solutions, were also explored. The paper considered consumers electricity meters and not power grid meters. It was shown that deploying smart metering solutions improve grid reliability, enhance revenue management, reduce electricity losses, address billing and credit control difficulties, promote energy efficiency, improve services to customers, postpone construction of new power generation plants, reduce power theft and reduce greenhouse gas emissions. However, smart electricity metering solutions are not adopted worldwide because of: ageing and outdated infrastructures, inadequate resources, lack of integrated communication platforms, cost of deployment, transition from legacy systems, management of the vast amounts of data, compatibility of elder equipment, lack of standards and interoperability and changes in regulatory protocols and policies.
Keywords: Traditional metering, Smart metering, Smart electricity meters, smart grid, Traditional electricity meters

I. Introduction

Customers receive electricity produced by generating units through the electrical grid (a system of generation, transmission, distribution and other services). Electricity meters are installed at customer premises for billing purposes and their function is to measure electricity consumption [1]. The discoveries of electrodynamics interaction between currents by Ampère (1820), relationship between voltage and current in conductors by Georg Ohm (1827) and laws of electromagnetic induction by Michael Faraday (1831), laid the foundations for the operations of generators, motors and transformers. Developments on the dynamo enabled large amounts of electrical energy to be produced, which was mainly used in lighting [2-3]. Before Watt-Hour meters, the sale of electricity to customers was on per lamp bulb basis. The incentives to develop electricity meters, which consistently and efficiently measure the cost of electricity to consumers, were driven mostly by competition. Consequently, competitors like Elihu Thomson, George Westinghouse, Olivier Shallenberger, Robert Lanphier, Thomas Duncan, and Thomas Edison invented their electricity meters, and some of their basic models are still in use with new functions and further improvements, today [2-3].

Basic working principles of electricity meters, Using Ohm's law [4]:

$P = V \times I$ (1)

Where P is the instantaneous power passing through a circuit element like the entire electric load of a house at any given moment; V is the voltage (or potential difference) across that element, and I is the current passing through that element. Therefore, the sum of each instantaneous power value over a period of time is the power used by the customer. It is expressed in Watt-hour [4]. From equation (1), the electricity bill becomes [5]:

$Electricity\ Bill = Electricity\ used\ (kW) * time\ (hours) * Cost\ of\ 1\ kWh$ (2)

In Australia: (a) Accumulation meters, are single rate or flat rate meters. They indicate how much electricity has been consumed, but cannot detect which time of the day electricity was used, (b) Interval meters record electricity used every 30 minutes. Hence, power retailers charge different rates at different times of the day electricity is used. This employs time of use (TOU), tariff, (c) Smart meters are digital meters, which use digital technology in energy metering. They are similar to interval meters, because they record electricity use in 30 minutes intervals, which enable TOU tariffs to be charged [6].

In the United Kingdom (UK): (a) Standard meters measure the number of units of electricity used every hour; (b) Dial meters contain six dials, which look like small clocks, and are more complicated than standard or digital meters, (c) Prepayment meters allow customers pay for the electricity before using it [7]. They are grouped by: (i) Type of display (analogue or digital electricity meter), (ii) Type of metering point (grid, secondary transmission, primary or location distribution), (iii) End applications (domestic, commercial or industrial), (iv) Technical (three phases, single phases, high tension (HT), low tension (LT) or accuracy class meters) [8].

II. Traditional Vs Smart Meter

Some countries and organizations are modernizing their utility grids by replacing their traditional electromechanical electricity meters with digital electricity meters, which measure and record electricity use every hour [9].

For traditional electricity meters [10]: (a) No data storage, (b) A meter reader physically comes to the customer's home or business to record the information and send it to the metering company, (c) If access cannot be gained to the meter, this may result in estimated bills, (d) Electricity use is tracked by either waiting for customer's monthly or quarterly bill or manually reading customer's household meter by oneself, (e) No outage detection, as distribution companies cannot react quickly to interruptions in the supply, (f) Connections and disconnections must be done manually. For smart electricity meters [10]: (a) Data storage, stores electricity consumed every half of an hour, (b) Data is automatically transmitted to the metering company, (c) Digital data of energy consumption and TOU are provided in near real time, (d) Automated outage detection enable distribution companies to restore power quicker than traditional electricity metering, (e) Connections and disconnections are faster, because they are managed remotely.

Traditional electricity meters only show the quantity of electricity consumed since someone (meter reader) last read the meter [11]. Using smart electricity metering, there is: (a) An increase in accuracy, features, visibility, privacy and security, (b) Fewer human errors and there will be no estimated bills [12].

Smart metering helps [13]: (a) Electric utilities eliminate manual monthly meter readings, (b) Avoid capital expenses of building new power plants, (c) Optimize income with existing resources, (d) Dynamic pricing, which raises or lowers the cost of electricity based on demand, (e) Power resources use more efficiently. Smart metering helps electricity consumers [13]: (a) Adjust their habits and lower electricity bills, (b) Reduce the number of blackouts and system-wide electricity failures, (c) Obtain greater and more detailed feedback on electricity usage. Smart metering helps the environment [13]: (a) Reduce the need for new power plants, which produce greenhouse gases (GHG) that substantially creates pollution resulting in health risks, and (b) Curb existing GHG emissions from existing power plants [13].

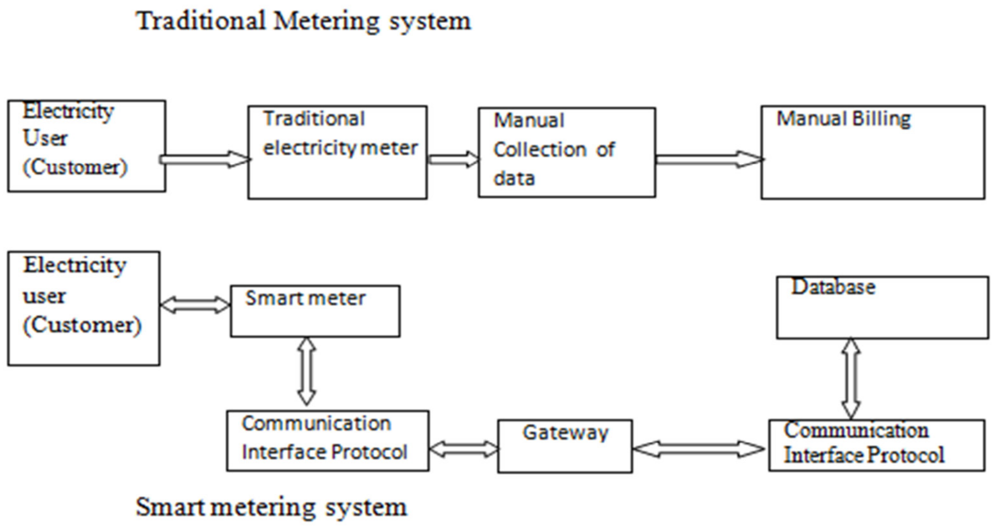

Figure 1 Traditional Vs Smart Electricity Metering Systems [14].

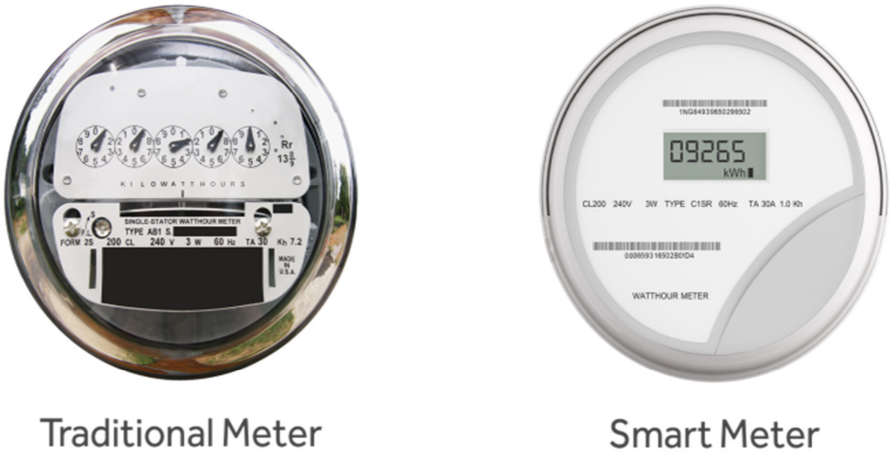

Figure 2 Traditional Vs Smart Electricity Meters [15]

Although smart meters have many advantages and benefits, they present some challenges and disadvantages as, smart meters have shorter life expectancy (5 to 7 years), compared to traditional meters (20 to 30 or 40 years) [16]. The disadvantages for utility grid companies include [13, 17]: (a) Costs in personnel training, equipment development and production to transition into new technologies and new sets of processes, (b) Managing negative public reactions and acquiring customer acceptance of the new meters, (c) Making long-term financial commitments to the new metering technology and the related software involved, (d) Managing, storing and analyzing the vast quantities of metering data collected, and (e) Ensuring the security and privacy of metering data. The disadvantages smart metering for consumers include [13, 17]: (a) It is difficult to ascertain if the new meter is accurate, and (b) There is additional fee for the installation of the new meter.

When customers use smart electricity metering systems, there are options in the installation of smart electricity monitoring systems [18-28], which help them to control their electricity usage rates. Whereas nobody would wake up in the morning and think, 'I want to use more energy (electricity) than my neighbor today', but inducing people to actually reduce their energy consumption is still very difficult [27]. For smart electrical energy monitoring systems to function as expected, it is preferable to: (a) Make electrical energy visible to consumers, (b) Utilize the full range of information delivery services available to consumers such as point of consumption and mobile devices to monitor energy consumption and (c) Push the boundaries of technology design through participatory studies [28, 29]. Furthermore, President Barack Obama said: 'Smart meters will allow you to actually monitor how much energy your family is using by the month, by the week, by the day, or even by the hour, so coupled with other technologies, this is going to help you manage your electricity use and budget at the same time" [30].

III. Smart Electricity Meters Worldwide

In Africa: (a) "South African municipalities have been considering deploying smart meters and smart metering systems as part of efforts to improve grid reliability, revenue management, reduce electricity losses, address billing and credit control issue, and promote energy efficiency while improving services to customers" [31], ESKOM (South African Electricity Public Utility), reported in 2017 that South Africa was losing R20 billion a year due to electricity theft and R15.2 billion a year due to municipal losses [32]. At first, there was a claim that smart metering systems need "operation and maintenance, investments in resources and capacity building" [31]. As smart meters are part of smart grid technology, the "implementation and development of a smart grid has benefits across three levels – societal; for the country as a whole, municipalities inclusive; and for individuals" [33]. b) Nigeria was having serious problems "of getting people to pay for their electricity bills quickly (slow payment of electricity), high line power loss rate (40%), serious electricity theft and the country was still relying on manual readings making it difficult to report faults and complaints. Ikeja Electric (Nigeria's largest electricity power distributor company) came out with a solution of embracing smart meters technology and thereafter, reported that there was line loss rate reduction, electricity theft reduction (fees for stolen electricity can be retrieved)" [34]. By now, Government and companies are working together for the deployment and roll out of smart metering systems [35, 36]. Australia and Oceania:"(a) According to the Electricity Authority, there are over 1,209,740 smart meters installed in residential homes, which is approximately 70% of all residential connections. This coupled with the smart meters installed for large and small commercial meters, means that New Zealand has a very good coverage of smart metering nationally" [37], (b) Ms Lyons, one Victorian consumer who has taken up the technology, said: "At first it was like any kind of new technology, you don't particularly want it...but it's really about what you do with it. For us it's had a good impact." A spokesperson for EnergyAustralia said consumer surveys had shown customers felt their ability to reduce bills increased when using a smart meter" [38]. In November 2015, Thailand was preparing for 2018 'Smart grid pilot launch. The Provincial Electricity Authority (PEA) of Thailand was set to rollout a smart grid pilot project in Pattaya by early 2018 in a bid to improve citywide energy efficiency. Under the project, PEA intended to install 120000 smart meters in homes, and construct a data centre for the processing of data" [39]. In 2017, "Thailand invested $58038320 toward smart grid rollout and PEA also viewed the deployment of smart meters as a key element in building energy management systems that allow users to monitor their energy usage in real time' [40]. In Singapore, Smart electricity meters have already been deployed for business consumers who are buying electricity from electricity retailers of their choice and "by the second half of 2018, the EMA (Company responsible for the reliable supply of electricity to consumers, as well as the operation of the power system in Singapore), will launch Full Retail Competition for the remaining electricity consumers, mostly households, who will also have the option of using smart electricity meters" [41]. "The EU aims to replace at least 80% of electricity meters with smart meters by 2020 wherever it is cost-effective to do so. This smart metering and smart grids rollout can reduce emissions in the EU by up to 9% and annual household energy consumption by similar amounts. To measure cost effectiveness, EU countries conducted cost-benefit analyses based on guidelines provided by the European Commission" [42]. In 2015, "France began its nationwide smart meter rollout with the country's planned path to 95% digital meters deployment by 2020 [43]". "The UK government has committed to deploying smart meters in every household by 2020, generating a £15 billion boon during the next 20 years for suppliers, customers and the country. The deployment is part of a wider energy efficiency policy called the "Green Deal" that provides financial help to citizens to install energy-saving and carbon-reducing measures in their homes" [44]. In North America, Jamaica Public Service (JPS) company, in 2016, "launched its project to deploy smart meters nationwide to ensure grid reliability and stability, and the utility company had plans to install 20000 smart meters at a cost of $ 5 million" [45]. In 2017, JPS decided a plan of "$2 billion investment in smart meters by 2018 in order to tackle electricity theft" [46-48]. In Greenland, there was a programme of "smart energy management for an entire country and then after replacing its entire energy meter fleet with smart meters and a radio based automated meter reading system, the company has achieved improved energy management and significant financial savings" [49-50]. In Brazil, "a country where power theft is as high as 20 per cent (2014) in some regions, utilities piloting the retrofit scheme are interested in the remote control and anti-tampering functions as well as remotely monitoring usage. UK systems company Cyan Holdings is using a purpose-designed retrofit module to give smart metering functionality to static electricity meters and the value of the smart meter market in Brazil is set to be US$432 million by 2020" [51]. In 2013, Guyana Power and Light (GPL) Inc. "moved to curb power theft with smart meters" [52].

V. Conclusion

Smart meters present attractive benefits and features matching the current era of technology modernization, "With upwards of 469 million smart meters at the end of 3Q 2017", China is still leading the smart meter industry market, "accounting for 68.7% of tracked global installations, a report from Navigant Research" [53-55]. Smart meters adoption and deployment are stepping up in some regions and their adoption especially in Africa is still facing some problems. The general difficulties facing smart grid adoptions, worldwide include [56]: ageing and outdated infrastructures, inadequate resources, lack of integrated communication platforms, cost of deployment, transition from legacy systems, management of the vast amounts of data, compatibility of elder equipment, lack of standards and interoperability and changes in regulatory protocols and policies.

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