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Evolution and Efficiencies of Energy Metering Technologies in Ghana

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Abstract

This paper examined the efficiencies of the evolved energy metering technologies used by the Electricity Company of Ghana (ECG) vis-à-vis their metering challenge. We used literature survey and field interactions with ECG experts and electricity consumers in Ghana in order to firmly conclude. This paper determined that the types of Post-paid and Prepaid metering technologies employed so far never addressed ECG?s metering challenge. The Prepaid metering technology, being the latest, was found to be more porous to energy theft and fraud or illegal connections than even the traditional postpaid technology. The economic conditions of energy consumers, their corrupted instincts, the ?customer factor?/tamper possibility of meters, the technical know-how of the flaws in installed metering technology and sometimes instigations from technical experts propelled consumers to take advantage of the technological porosity to manipulate the metering system to their advantage. Advanced Metering Technology (AMT) whose billing system runs parallel with mobile phone billing system, without the ?customer factor?, was recommended to address ECG?s metering challenges.

Index terms— electricity company of ghana, energy meters, illegal connections, electromechanical induction meters, advanced metering technology.

1 Introduction

echnological advancements in the 21 st century offer us unprecedented opportunities to solve our present problems and those of the generations to come. Technology in Ghana's Energy Sector has seen a lot of evolutions in the recent past especially in the area of metering and tariff estimation. The prime aim of these technological advancements and evolutions at a specific time in a given environment is to provide the best solutions to our problems. A given technology might best solve a problem in one environment and fail in another due to the prevailing factors governing the selection, the technical know-how of those placed in charge of the technology and how the implementation or installation of the technology is carried out.

The proven obstacles to efficient power generation, transmission and distribution are losses but can be minimized if properly managed [1]. Losses are any input energy that goes unbilled or unmetered [2]. But it is known that a larger percentage of the losses are non-technical, which emanate from the consumers' end [3]. Among the common factors responsible for non-technical losses are: energy pilferages and thefts, defective meters generating errors in meter readings, wrongful estimation of meter readings, un-metered or flat rated consumers, customers tampering with their meters, free power usage (for legally connected consumers), illegal connections, etc. [4]. These Nontechnical losses (NTL) account for over 70% of the total losses representing several hundreds of kilo Volts Amperes.

Critical considerations of all the NTLs sum up to metering losses. The reason is that Power Suppliers cannot remotely and effectively monitor the happenings at the consumers' end and take the necessary action efficiently. Consequently, the Electricity Company of Ghana (ECG) has deployed a number of metering technologies to address this problem. These included: Electromechanical Induction Meters (EIM) or Standard Meters,

Prepayment Card Electric Meters, Solid State Electric Meters or Electronic Meters and presently, Pole Prepaid Card Meters. This paper examined the different metering technologies adopted by ECG, why they excelled or failed and recommend better alternatives.

Electricity distribution is a sector where technological evolution is gradual, at least in the network assets. However, there is a field, in which progress in the last few years has been rapid, at a speed typical of the telecommunications sector. The present goal is towards Remote metering, reading, and monitoring of electricity consumption referred to as advanced metering infrastructure (AMI) [5]. Drasticreductions in prices of metering and telecommunication equipment is making their adoptioneconomically feasible, starting with large consumers and gradually applying AMI to medium andsmall ones. II.

the Big Problem

The most predominant objectives of energy meters are to increase operational efficiency; to enhance durability of energy grids; and to reduce operational cost [7]. As confirmed, every energy meter should be able to at least help in the elimination of fraud and theft (possibility of tampering with meter), reductions in meter reading costs, reduction in prepayment metering costs and reductions in peak demand (thus, reductions in energy usage during peak demand), automatic adjustments of rate with respect to subsidies per energy usage -lower costs, better security of supply and efficient billing [8]. Also, lack of consumer information in conventional metering may be a barrier to reducing energy consumption (reducing energy wastage). This is because energy-use related information could be used to help consumers make decisions relating to energy use and the choice of appliances to minimize energy wastages. The predominant electromechanical metering system lack this feedback functionality and hence deprives consumers the desired awareness about energy efficiency and a better understanding of the energy consumption experience, budgeting and planning benefits.

The greatest challenge of energy distribution by ECG has ever been free power usages; and this constitutes over 70% of their total losses [6]. Factually, several factors encourage this challenge, but in all cases the solution seems imbued in the installed metering technology. With the recent metering technologies (prepaid card metering technologies) in the urban centres, energy consumers are conscious of the fact that the energy meter could be by-passed. No wonder ECG was unable to bill over 100,000 customers connected to the national grid in 2013 [9]. Again, 9,537 illegal electricity connections (by-passing the prepayment meters) were detected, constituting GH¢ 18.23 million (US$9.115 million) loss of revenue to the nation [6]. The big problem is as a result of the Tamper-Possibility of installed energy metering system without any efficient monitoring mechanisms, thus the existence of ”consumer and or Energy Provider factor” in the tariff estimation chain. If the possibility of manipulating the system exists, then the poor consumer will definitely be tempted to also take advantage after all, as many people are doing it. ECG therefore needs metering system with the effectiveness to detect and discourage theft and other ways of enormous unmetered consumption. This is because deploying the right metering technology significantly contributes to sustainable development and efficient performance of the power sector in developing countries, for the reason that it provides powerful tools to reduce total losses and increase collection rates. After all, the rural folks are even capable of paying their electricity bills without any external interventions [10].

Considering the behavioral trends, the economic discrepancies/hardships and geographical distributions of ECG’s consumers, the most efficient and desired metering technology of greatest want in Ghana should have the following catalogued qualities: a) ”Watchdog” effect on Consumers Consumers being aware that ECG continuously and actively monitors Electrical power consumption at their convenience can quickly detect any abnormal consumption due to tampering or by-passing of a meter and take fast corrective action to ensure consumer discipline. This has been shown to be extremely effective with all categories of large and medium consumers having a history of stealing electricity. They stop stealing once they become aware that the utility has the means to detect and record it. Recent experience in such countries as the Dominican Republic and Honduras shows that consumers stop stealing if they face the risk of social condemnation [11]. These Instances of theft by large consumers usually involve collusion between these consumers and meter readers. Most consumers acquired the needed expertise of by-pass meters, ”jeossing” or minimizing the monthly readings of meters, etc. from field service personnel.

Corruption is also likely to occur in operations of service disconnection related to unpaid bills and other free power consumers. Installing the right metering technology eliminates those field operations (meter reading and service disconnection, tampering with the accuracies of meters, flat rating operations) and makes information on consumption transparently available to the consumers and managers of ECG. This will greatly enhance governance and reduce corruption. c) Implementation of pre-paid consumption Pre-paid consumption is generally a very good commercial choice for low-income consumers. There are dozens of cases of very poor countries in Africa, Asia, and Latin America with a booming mobile phone industry, often by-passing land lines. According to the International Telecommunication Union, by the end-2007, about 60 percent of mobile subscriptions in the whole world were prepaid. The Prepayment system stimulates users’ consciousness regarding power consumption [10]. Although prepaid tariffs tend to be more expensive (per minute) than postpaid tariffs, the prepaid mobile subscriptions in Ghana exceed 60 percent [10]. It is the most practical payment option available to low-income users who might not have regular income.

With this quality, it is expected that Credit bought by the consumer is loaded in his/her account in a commercial management system (CMS) with the aid of mobile phones or similar devices. The customer should be able to access his remaining credit, receive alert messages from ECG when the credit is about to expire, buy

new credit, received disconnection message, etc. Remote disconnection and reconnection should be possible even for low-voltage consumers in cases of credit expiration and non-renewal in the same way pre-paid mobile phones work.

This approach of pre-paid consumption must show significant improvement over the classic pre-paid card meters widely used in South Africa and other countries. The principal ones must include: significantly lower hardware costs, and permanent monitoring of consumption, which is not possible with the classic card meter [11].

2 III.

3 Types of Metering Technologies

Adopted so far

The present power sector arrays three agents-Volta River Authority (VRA)-in-charge of power Generation, Ghana Grid Company (GridCo) -responsible for bulk power transmissions and lastly, ECG distribute or sell power to consumers. ECG distribute/sell power to three core consumers viz: industrial, commercial and residential customers. Though VRA and GRIDCo deploy meters in their operations, this paper however deals with the case of ECG because of their higher non-technical losses or "metering losses". ECG has always relied on the services of different energy metering technologies to bill their stated customers. Meters are devices installed in the Customers' premises to measure and record the amount of electricity supplied (consumed) over a period of time. Presently, there are two (2) kinds of meters installed in customers' premises: the post -paid and pre -paid meters or Smart Cash (as usually called in Ghana).

ECG predominantly use Ferraris meters; some of them have maximum demand indication whilst others do not have. Digital meters have been introduced recently in both transmission (by GRID Co) and distribution networks (by ECG). Meters with Time-ofused functionalities are not in use but there has been introduction of prepaid meters by ECG. In the distribution network, residential and commercial customers are billed by the energy (kilo-Watt-hour or kWh) consumed. There are however some customers without meters who are billed on "estimated energy consumed" (Flat Rate). The flat rated consumers pay fixed amounts every month irrespective of the amount of electrical energy (kWh) consumed.

4 a) Post-Paid metering technology

The aged-electromechanical induction watthour meters and the recent digital or electronic meters are the main post-paid meters prevalent in Ghana.

5 i. Electromechanical Induction Meters (EIM)

These meters operate by counting the revolutions of a non-magnetic, but electrically conductive, metal discs which are made to rotate at a speed proportional to the power passing through the meters. The number of revolutions is thus proportional to the energy (kWh) consumed. The disc is acted upon by two sets of coils, which in effect form two phase induction motor. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees, due to the coil's inductive nature, and calibrated using a lag coil. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product Global Journal of Researches in Engineering ( ) of the instantaneous current, voltage and phase angle (power factor) between them. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc. The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power or rate of energy usage. The revolutions in order to render measurement of the total energy used. This type of meter is used on a singlephase AC supply. Multi-phase (2 or 3-Phase) configurations will require additional voltage and current coils. Figure 2a presents a typical EIM used in Ghana.

ii. Electronic Meters These energy meters 'operation is similar to the electromechanical induction type, in that the energy used is digitally displayed on an LCD or LED screen, and some (not used in Ghana) can also transmit readings to remote places. These meters, sometimes called Solid State Electric Meters (SSEM), have digital signal processing "engine" that codes/processes digital signals received from analogue to digital converters into information that can be analysed. In addition to measuring energy used, some electronic meters can also record other parameters of the load and supply such as instantaneous and maximum rate of usage demands, voltages, power factor and reactive power used, etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours. They calculate and show the exact value of the electricity consumed rather than its amount. The rate of the unit consumed varies according to the time of the day and the day of the week.

As illustrated in Figure 2(b), these electricity meters must be manually read every month by representatives of ECG for the bills to be estimated hence the name Post-Paid Meters. Generally, prepayment electricity meters in Ghana measure energy in the same manner as a conventional EIM. The main difference with a prepayment meter lies in the intended manner in which the meter is to be operated and used for the sale of electricity. The prepayment electric meters accept tokens or prepaid cards to get electricity supply. The customer has to pay the charges for the power supply in advance. One can also top-up the amount for extending the period of

electric supply or when the balance over the supply is automatically cut off by a relay in the electric meter. Thus, electricity consumption is integrally measured but the measurement is actually started and stopped in conjunction with the activation and deactivation of the load circuit by the prepayment control system. To activate the load circuit, the consumer must prepay for electricity usage or purchase a quantity of electricity that may include statutory or fixed charges. The payment information may be loaded on the meter through a specific peripheral control device like the magnetic card reader used by ECG. Once activated, the load circuit will run and remain activated until the monetary or equivalent energy information loaded into the prepayment control system has run out, subject to any other conditions established by the contractor.

The consumer can buy electricity through various vending options as token with a code printed on Global Journal of Researches in Engineering ( ) disc drives a register mechanism which counts it. The meter is credited with the amount of credit bought and supply is switched on automatically at the load side. As the consumer's balance reaches the emergency limit or "grace period" corresponding to a set value by ECG, the meter signals for recharge. If the "grace period" expires then the meter automatically disconnects the supply at load side.

As shown in Figure 3 (a), the commonest type of prepaid meters installed in Ghana is the traditional EIMs with the system to engage and disengage supply to the load side. Virtually, this meter has nothing to aid monitoring power theft, fraud or illegalities facing ECG.

6 i. Pole Prepaid Meters

The prepaid meters replaced some postpaid meters in Ghana in the year 2005 up to date. According to ECG, the prepaid meters will ensure efficiency in the usage of electricity and also reduce the cumbersome work of ECG personnel in the processes of billing. Thus, the prepaid meters are indeed convenient to ECG and the personnel because there is no need for distribution of electricity bills to various houses or residence. In fact, ECG until not many years ago, were sending their personnel to residential and non-residential premises to read credit meters and also deliver bills. They then switched partly to Pre-paid meters installed in both residential and non-residential premises.

In spite of the fact that they have not finished changing all the traditional EIMs to Pre-Paid ones, it is speculated that they will introduce 'Smart Pre-Paid Meters' in 2014. Surprisingly, they are replacing existing pre-paid card meters or the smart cash meters to 'Pole prepaid card meters' which leaves customers to various risks. This is because consumers 'lives and properties are posed with danger with the "pole metering system", especially when consumers leave their secured house to poles on the street to reload credit to the pre-paid meter. Now the big question still holds "do these pole meters address our metering challenges?"

7 Critical Issues

Several metering technologies have evolved but the question is "how these technologies efficiently addressed the stipulated metering challenges in Ghana's energy sector". Do we just adopt the technology because it is successfully used elsewhere or we need to do retrospection to discover what we actually need? The inception of the pre-paid meters has rather increase illegal connections in the energy sector instead of curbing the menace. Also, countless consumers on the post-paid metering system are either unmetered at all or improperly billed [10]. The tamper possibilities and the hassles in billing render the postpaid meters unsuitable. The prepaid meters are convenient to ECG and their personnel because they have jettisoned the hassles in the distribution of electricity bills to various customers. Perusing this freely expressed merit of the installed prepaid meters with a typical Ghanaian eye, not with an assumed eye of perfection of most Ghanaians, one can say the postpaid meters are arguably more efficient. The old system of post payment saw to the problem of various illegal connections and free power usages with the meter wiring. Over 70% of ECG's debt has been attributed to illegal connections and free power usages [9]. If the post-paid system where there were monthly or routine visits by ECG personnel to various compounds to distribute electricity bills saw various illegal connections or free power usages, audience can guess what is happening with the present non-tamper evident pre-paid metering system. In 2013, 9,537 illegal electricity Global of Researches in Engineering ( ) connections (by-passing the prepayment meters) were detected, constituting a GH¢ 18.23 million (US$9.115 million) loss [6]. All these illegalities were found with customers on the prepaid meters.

So the question to answer is that "are we dealing with an enjoyable era of convenience? Or we are V.

8 Proposed Technology

Several authors have racked brains for the best electricity metering technology but the ideal solution has not been found. Quite a lot of countries have and are still benefitting from the "outdated" electromechanical metering technology. However, this technology is aproxy of free power usages and complementary source of illegalities in Ghana's energy sector. The "customer factor" in our electricity billing is the main albatross around the neck of ECG's metering system. Figure 4 shows the causes of metering losses, and mitigating these causes imply addressing the non-technical losses in the energy sector. With the cemented facts about the deployed metering technologies so far, customized Advanced Metering Technology (AMT) commonly known as a 'smart metering Technology (SMT)' is recommended for ECG. The Economic conditions of energy consumers, their corrupted instincts, the "customer factor"/tamper possibility of meters, the technical know-how of the flaws in the installed

metering technology and sometimes instigations from technical experts propel consumers to take advantage of the technological porosity to manipulate the metering system to their advantage. AMT whose billing system runs parallel with mobile phone billing system is a remedy.

AMT is a reasoning instrument with enhanced intelligence. When it is applied to the measurement of a specific resource, such as electricity, and networked with similar mechanisms within a domestic context, its value and potential become clear [12].

AMT employs two-way communication, which allows a household meter to communicate with the suppliers' information systems, and vice versa, and allows remote control mechanisms but only from the suppliers' end. Interval reading functionality is one of the most important components of AMT systems as it allows the autonomous retrieval, storage and communication of consumption data according to time-of-use. An advanced metering system (AMS) is an electronic metering device at the point of consumption, along with the communicative potential for metered data to be transmitted and processed for meaningful action or feedback. This creates an environment where information must be either sent by unconventional means outside the premises, or communicated directly to the occupants, via a feedback channel. The later allows users (or occupants of the building) to understand and manage the associated resources with minimal or no external support.

9 VI.

10 Conclusion

Technology has come far to solve our problems when rightly applied. Thus, a particular technology might be a success at one place and a failure at a different place. Several energy metering technologies have evolved in Ghana but none seemed to address the metering challenges of ECG. The latest technologies are rather more problematic than the traditional ones. The Economic conditions of energy consumers, their corrupted instincts, the "customer factor"/tamper possibility of meters, the technical know-how of the flaws in the installed metering technology and sometimes instigations from technical experts propel consumers to take advantage of the technological porosity to manipulate the metering system to their advantage. AMT whose billing system runs parallel with mobile phone billing system, without the "customer factor", is recommended to address ECG's metering challenges.

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