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# Exploration of the Advanced Metering Infrastructure and its Application in Smart Grids

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**Abstract:** *In this exploration emphasis is on the Smart Grid (SG), the role of the Advanced Metering Infrastructure (AMI) in SG and security concerns in the AMI. This work is primarily on AMI, which is responsible for gathering all the data and information from loads and consumers, as the benchmarks for SG. AMI is also concerned with therealization of control signals and instructions to effect necessary regulatorytasks, Security in line with threats to the AMI. In this assessmentfocus is on SG and some of its structures, establish the link between SG and AMI, explain three main subsystems of AMI and discuss related security issues.*

**Keywords:** *Smart Grid; Advanced Metering Infrastructure; smart metering*

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## I. Introduction

Some of the challenges that are facing the power industry include, though not limited to; introduction of Distributed Energy Resources (DER), enhancement of delivered power quality, environmental apprehensions over traditional and consolidated methods of power generation, privacy of consumer's data or information together with security of the system against external cyber or physical attacks and the need for better control arrangements for complex systems, (Momoh,2009).Europe and North America have both modernized their energy generation and distribution systems and switched to Smart Grid (SG) as a solution to such challenges(Ramyar, Fung, Mohammadi,& Raahemifar, 2014).

It is said that electrical grids were invented in the late 1800s. However, early 1960s are regarded as the terrific times of the of power grids in first world countries (http://edisontechcenter.org/). It is believed that at this time, there were increasing rates of network distributions and their respective load delivery, reliability and quality of delivered power were acceptable and consolidated power generation in fossil, hydro and nuclear plants thundered, technically and economically (http://edisontechcenter.org/).There was increased demand of electricity in the last parts of the 20$^{th}$ century and this is believed to be due to introduction of new consumers, such as entertainment systems and dependence on electricity as the main source of heating, cooling and ventilation.

With emerging challenges, several South African municipalities are on the verge of embracing the deployment of the smart meters and smart metering systems, all focused on improved grid reliability, revenue management, reduce electricity losses, address billing and credit control issues, and promote energy efficiency, at the same time ensuring that the customers are getting improved services(SAMSET, 2015). This is in line with global trends of smart metering and local electricity industry regulations. At this point a crucial question is posed to find out whether South African municipal electricity distributors are well stationed for smart metering technology investments. It is noted that the operation and maintenance of a smart metering solution is a comparatively new business worldwide and needsquite immense capital if form of human and monetary resources(Patel and Modi, 2015). Such an investment will necessitate the municipalities to formulate sound business cases.

In this study, concerns related to utilization of Advanced Metering Infrastructure (AMI) in Smart Grids are investigated.

## II. The Concept On Smart Grid And Smart Metering

The concept "smart grid" is loosely understood as the integration of all supply, grid, and demand fundamentals connected to a digital upgrade of power grid with a reliable, resilient, secure, and manageable standards-based open information infrastructure which can provide two way communications to offer numerous benefits for both the power suppliers and consumers (Koliou, 2014). The primary goal of a SG is to deliver the optimal amount of information and load control for customers, distributors and grid operations in order to reduce system demands and costs while increasing energy efficiency.

The SG concept is reasonablyconnectedto the production of energy through the use ofrenewable energy sources(RES) as the SG supports social benefits like reduced emissions, lower energy costs, and greater flexibility to accommodate new renewable distributed energy sources. In this case the outcomes can be attained by bringing together several different technologies including Information and Communication Technology (ICT) needed to make energy demand and production more manageable(Carlo*et al*., 2010).

A smart meter can be defined as an innovative meter that measures energy consumption to detail than a traditional meter. It is also anticipated that smart meters to come will be able to relay information back to the local utility for management purposes in form of monitoring and billing(Alahakoon and Yu, 2016). As well, the smart meter could be structured in that it is capable of relaying information with a number of appliances and devices within residences.Smart Meters are essential constituents of the Smart Grid and the AMI technology. In addition to the total electrical consumption metering, Smart Meters compute and monitor statistical consumption data in various time intervals. They SMs relaythe computed statistics to the companies and consumers in various ways (Majumdar and Pal, 2016).

## III. Smart Grid Technologies

***Advanced Metering Infrastructure (AMI)***

The AMI is a not a solitary technological application but a fully arranged infrastructure that encompasses Smart Meters on the side of the consumer, information flow networks between consumers and utilities and data collection and management systems (Ramyar, 2014). In order to attain an intelligent grid,a string of sub-systems has to be realized. The proper functionality of the individual sub-systems is vital in the general SG performance, as each layer's outcome serves as the feed for the subsequent layer.

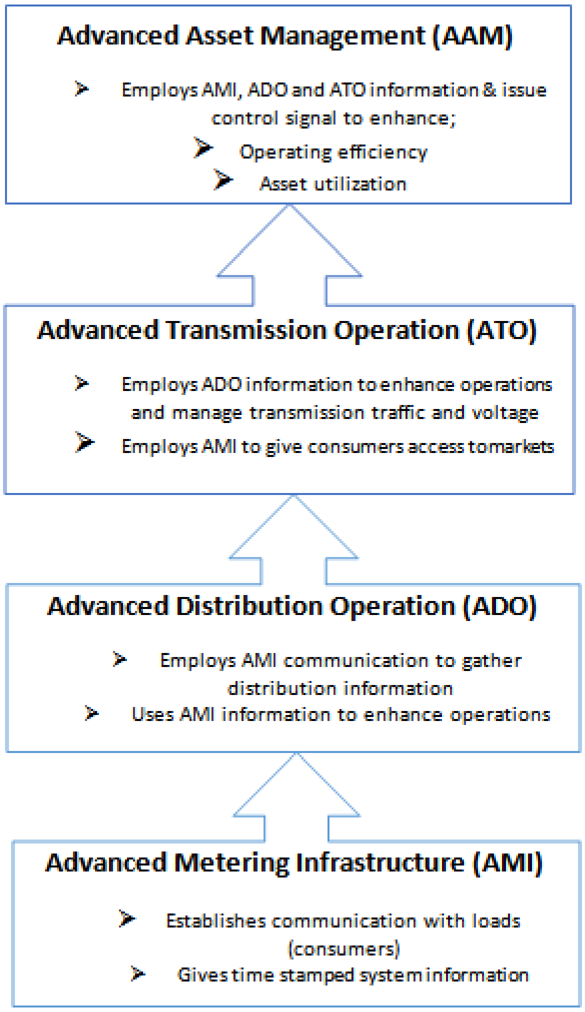


**Fig. 1.** Smart Grid sub-system sequence overview

From Figure 1 the association and summary of each of the sub-systems in the developing of the grid is portrayed (NETL Modern Grid Strategy, 2008).

***Concepts***

As earlier stated AMI cannot be given a single definition just like SG.It is known that AMI is not a lone technology; it is a configured infrastructure which integrates several technologies in order to accomplish the desired objectives. The infrastructure includes smart meters at the consumer end, communication networks at different layers of the infrastructure pyramid to link two ends, Meter Data Management Systems (MDMS) (Farhangi, 2010) and also the capabilities of linking the gathered information into software submission platforms and interfaces at utility head end (Ramyar, 2014). In this case, the end user (customer) is furnished with an advanced solid state electronic meter which gathers time-dependant information. These meters are capable of transmittinggathered information via the readily available securenetworks. The AMI host system receives the secure metered data.The data are then transmitted to a MDMS which is concerned with data storage, examines and gives the information in a more appreciated style or form that is easily understandable to the utility service provider. The AMI permitsa two-waycommunication; consequently, price signals from the utility provider to the meter controlling devices are as well conceivable(Ahmad, 2016).

**Sub-Systems Of Ami**

It also has to be comprehended that AMI is not only for electricity distribution; gas and water networks supply are its products. It may outwardly seem that the infrastructure for metering the various forms of energy consumption are similar, however, there are differences that exist between them (Albino, Berardi, & Dangelico, 2015). Electric meters are essentially fed from the same electric supply which they that they are manage or monitor whereas flow meters are characteristically powered by stored energy, that is, batteries; consequently, involve utilization limitations. The limitations are largely apparent in communication, as there is a huge requirement of power to enable transmission and reception of signals.The meters as well contain embedded controllers in order to manage the metering sensor, a display unit, and a communication unit, this is characteristically a wireless transceiver.

***Smart Devices***

As earlier stated, Smart Meters are essential constituents ofthe SGand the AMI technologies. The Smart Meters calculate and monitor statistical consumption data for various time intermissions on addition to thetotal electrical consumption metering (Dincer& and Acar, 2015).The Smart Meters gives the statistics computed to the companies andconsumers in a number of forms. Such an interplay ensures a wide range of services provision, for example, electricity billing, consumer awareness about consumption, critical events etc. (Uribe, Hernández, Vega &Angulo, 2016). The capability of the Smart Meter to provide a two-way communication ensures that on time data transmission, such as spot price signals are availed to the stakeholders.Smart meters essentially have three different classifications which are; electrical, fluid and thermal. Smart Meters also several functionalities such as remote load operations for Demand Response (DR) purposes, energy prepayment and energy quality monitoring, detection of meter data tampering, load changes in a case of non-payment as well as some other functionalities that are not limited to communication with other smart devices in the network and notifications of potential loss of load and recovery(Uribe*et al*., 2016).

***Demand Response (Communication)***

The demand response is one crucial ability that the Smart Meters encompass. The DR device is a set of actions that can be taken from the utility and/or the consumer side in predefined cases of high pricing or Grid congestion (Wang, Chen, Kang, Xia, & Luo, 2017).

The Smart meters should be capable of transmitting the obtained data to the examiningunit and, as well receiveoperational instructions from the operation unit.Consequently,standard two-way information flow is essential as part of AMI (Pau, Collotta, Ruano & Qin, 2017).Taking into account the numbers for users and the smart meters, at the respective end points, anextremelydependableinformation or communication flow grid is required fortransferring the high big data. The establishment and collection ofa suitable communication network is a painstaking procedure that needs careful consideration of the essential factors such as (Paradiso, *Communications of the ACM*); huge amount of data transfer, restricting dataaccess, confidentiality of sensitive data, showing status of grid,cost effectiveness, authenticity of data along with precision incommunication with target device, ability to host modernfeatures over and above AMI and future expansion.

The DR mechanisms are an efficient solution for serving the load increase over time as opposed to the construction of new power plants. Also, their activation within 5 minutes is very much possible, whereas a power plant can take up to 30 minutes to reach its full power potential (Jeff& Dilip, 2007).

***Network Topologies***

There exists different network topologies for information transmission in SG. A widely employed architecture is gather information from various groups of meters in local data concentrators and then transmit them using a backhaul channel to central command, where the servers, data storing and processing services, managementand billing applications are located(*NETL Modern Grid Strategy*, 2008). Given the fact that various forms of architecture and networks are available for realization of AMI, there is therefore, differentmeans and communication technologies to effect this purpose;Optical fibre, cellular,Peer-to-Peer, Power Line Carrier (PLC),WiMax, Bluetooth Broadband over power lines (BPL), GPRS, Zigbee and a few others. At AMI level, communications are between devices in a home while at upper layer, they occur between Home Area Networks (HAN) and the utility provider. These two, in short, could be called in-home and utility networks (Liu, Liu,Wang,Zomaya,& Hu,2015).

It is also known that, the HANs are meant to link smart meters, smart devices in the premises of the homes, energy loading, storage and generation i.e. solar, wind, etc., electric vehicles, also IHD and controllers together (Beaudin& Zareipour, 2015; Ramyar, 2014). Owing to the fact that the information conveyance is prompt rather than incessant or continuous, The HANs requirebandwidth that ranges from 10 to 100 kbps for the individual devices, conditionalon the activity to be performed. There should be a way in which the network, could be extended or expanded in case there is an increase in the rate to numbers of data flow to the designated area. The computeddependability and assumed delays are too dependent on the respect that the loads and usage are non-essential. In the presence of the requirements mentioned, the needs and also considering the short distances that exist between nodes, enable low power broadcast, wireless technologies are the most employed remedies for HANs. These technologies include, *ZigBee, HomePlug* and 2.4 GHz *WiFi*, 802.11 wireless networking protocol(McCary&Xiao,2015).The Zigbee is largely dependent on the wireless IEEE 802.15.4 standard with similar technology as that of the Bluetooth. For the *HomePlug*,it relays information over the existing electrical wiring at thehome premises. Currently, there is no standalone application for the in home information flow on the market; nonetheless, *Zigbee* and somewhat the *HomePlug* and *ZWave* are the prevailingclarifications. Some of the merits of*Zigbee*are; providing wireless information flow, relatively low power consumption, suppleness and economic effectiveness. On the other side, the primary disadvantageof the *Zigbee* is the low bandwidth (Lucia, Kögel, Zometa, Quevedo & Findeisen, 2016). However, the commercial structures, a wired technology, *BACnet* is the mostly used information flow protocol.

***Data Management System***

Figuring out an appropriate data management (MDS) system is one of the most essential decisions a utility will make for its Smart Grid project.At the utility provider end, a system has to be available to store and examine the data aimed at billing the users. It has to be in position to accommodate DR, consumption profile and real time reactions to any variations and disasters in the grid. Modules of such multi modular structure include, but no limited to (MDMS, 2013);

- Outage Management System (OMS)
- Mobile Workforce Management (MWM)
- Meter Data Management System (MDMS)
- Enterprise Resource Planning (ERP), power quality management and load forecasting systems
- Consumer Information System (CIS), billing systems,and the utility website
- Geographic Information System (GIS)
- SmartData for Transformer Load Management

The MDMS serves as the connective tissue thatbrings together all of the disparate data collection points, interfaces, and systems together in order to create usable and accurate data that can be employed for revenue and system planning purposes.

MDMS is taken as the pivotal module of the management system that contains the analytical outfitsnecessary for information flow to other modules combined withit. Its other mandates are; to perform Validation, Editing and Estimation (VEE) on the AMI data in order to guarantee accurate and complete flow of information from customer to the management modules irrespective of any unprecedented interruptions at lower layers (Report to NIST, 2009).

The data collected at the interval of 15 minutes for the existing AMIs, that information is really huge commonly referred to as “Big Data” Consequently exploration of such data necessitates highly specialised software (Jain, 2013).

## IV. Smart Grid Security Issues

A lot of energy and resources have been directed toward integrating new technologies into the current Power Grid, geared at transmuting it into a more supple, easily accessible and efficient Smart Grid. The number of smart meters was about 38 million in the USA in 2012, representing the 23% of the total installed meters and a 14% increase from 2010 (Federal Energy Regulatory Commission, 2012). However, in South Africa, smart meter roll out started in 2013 and later resisted by some residents in the townships, brings the rollout to a halt in 2015. The emerging demand for Smart Grid technologies was foreseen by the ESKOM which rushed hurriedly to serve the new need. The focus on the deployment rush resulted in the emergence of security concerns.

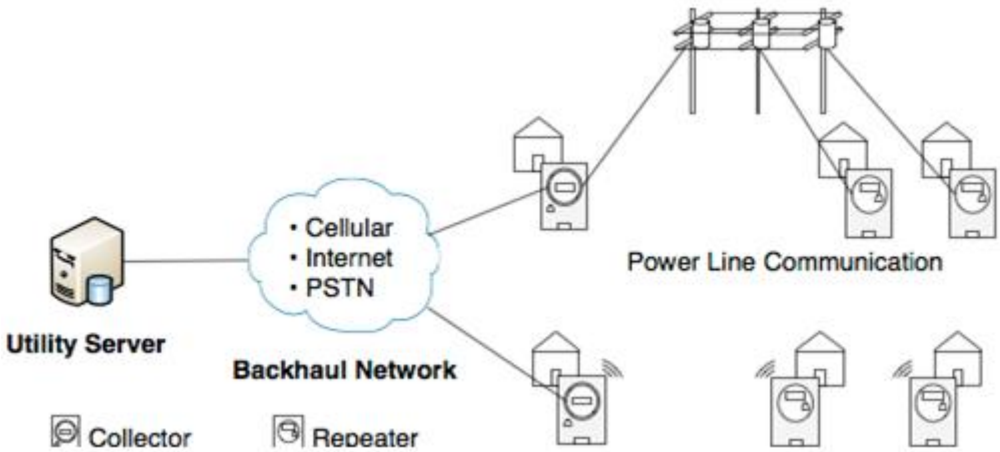


**Fig.2:** Advanced Metering Infrastructure Security, (SIIS Lab, 2010)

Figure 2, represents the AMI which is hypothesized to be the next generation electric metering platform for smart grids. AMI connects digital *smart meters* with electric utilities to provide advanced billing schemes, remote meter reading, outage supervision, and a number of other relevant electronic (automated) services. As the smart meters presently aresubstituting the analog meters,a number of households around the world, more significantly in the US, it is thus important that the stakeholders understand efficacy of the security appliances present in meters, networks, and utilities.

**SECURITY IN AMI**

***Consumer Threats***

One of the primary concerns about consumer threats is the violation of their privacy. Highly sensitive consumer information like; name, physical address, and social security number, could possibly be conveyed via Smart Meters and could end up being attractive to potential attackers or any other form of criminal elements. Smart Meters also handle consumers' history, information portraying their presence, individual preferences, social activities, consumption habits, as well as health issues (Aloul, 2012). Data of that form can be exploited for a number of activities, with the advertising case to seem the most innocent among others.

***Utilities and Government Threats***

Industrial Control Systems are “eye-catching” targets to cyber-attacksowing to their critical functionality and explicitcommunication capabilities (Smart Grid Interoperability Panel Cyber SecurityWorking Group, 2010).A potential attacker, gaining access to such systems, can interfere with the power production process for various reasons such as; financial, reputation, revenge and blackmail. Such technical violationsof data availability apply also to terrorist activities or evenwarfare which might aim to cause chaos in a country througha blackout (Martin& Rice, 2011)

## V. Conclusion

Conventionally, the analog meters employed for metering purposes presented little security and were easy to manipulate. Electricity theft in the analog meters may be done by direct connection to distribution lines, grounding the neutral wire, attaching a magnet to the housing, stopping the coil from rotating by blocking it, damaging the rotating coil by hitting it or reversing input and output connections (Ramyar et al., 2014) . However, the application of smart meters can control by minimising the issues mentioned. Smart meters are in position of recording zero readings and alerting the concerned utility companies. In the case of grounding neutral wire, the smart meter assumes that the circuit is not closed and does not perform a reading. The problem of tampering with the meter's rotating coil is a problem of the past. In comparison with conventional systems, AMI makes tampering with meters more difficult by using data loggers. The loggers are capable of recording power outages to the meter or any inversion of power flow.

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