Opportunities and Challenges for Smart Grid Communications

Lincoln Kamau, Philip Kibet and Maina Muriithi

***Abstract*—**The current power grid is in the verge of being improved. Recent technological advances have made possible the creation of a new and improved grid known as the smart grid. Smart grid allows for better interaction between all parties involved in power generation, transmission, distribution and consumption. This will bring about cost savings, more efficient usage of power, less harm to the environment and reduce power outages. Effective communication is crucial in bringing this about. Opportunities and challenges in smart grid communications are discussed here.

***Keywords*—**communications, power line carrier, power distribution, smart grid

I. Introduction

THE current electrical power grid in current use has many shortcomings. It uses a broadcast approach where power is generated from a few central points and distributed to many users. This has little feedback from the consumers and thus planning is difficult. Integration of renewable energy sources is also a challenge. Manual meter reading involves greater operational costs as power utilities send people to collect data. The current system has low monitoring capabilities, resulting in frequent blackouts because problems are not detected and solved quickly.

Another problem is that peak demand for electricity has been growing steadily without a corresponding growth in the power system. This growth has been due to population growth, bigger houses, bigger TVs, more air conditioners, more computers and other consumer electronics. Spending on research and development in power generation and transmission has been relatively low.

In the current system, the challenge of planning for dynamically changing loads has lead to the use of peaker plants. These are generators which are turned on when demand for power is high. They use fossil fuels. These can be depleted and cause CO_2 emissions, which are unfriendly to the environment. Furthermore, peaker plants are difficult to site, peakers and expensive to operate. They are generation assets that typically sit idle for most of the year without generating revenue in spite of their cost. Better planning of power distribution would help reduce the reliance on peaker plants.

These challenges have led to the development of a new and improved grid known as the smart grid. A smart grid is an intelligent electricity network that integrates the actions of all users connected to it and makes use of advanced information, control, and communication technologies to save energy, reduce cost and increase reliability and transparency [1]. Much research is going into smart grid. In USA, there is the American Recovery and Investment Act which includes $11 billion in investment to “jump start the transformation to a bigger, better, smart grid” [2].

With smart grid, there is better monitoring of what is going on in the system. Problems can be detected faster and hence avoided. Planning can be done more efficiently, in some cases even real time. Table I gives a brief comparison between the traditional power system and smart grid.

Smart grid utilizes new technologies which allow for higher data capacity, greater processing speed and better accuracy. This allows for more innovations such as home energy management systems (HEMS) which help users to spend energy better. Smart metering further allows users to know their energy usage and make adjustments where appropriate.

One key element of smart grid is communication. Without effective communication, the benefits of smart grid would not be realized.

Smart grid implementation is not without its own challenges. There are several barriers, some technological others political and social, which need to be addressed. In this paper, the focus will be on the communication needs.

The rest of the paper is organized as follows. Section II considers the benefits of using smart grid. In Section III, there is a discussion of the communication requirements for smart grid. Next, Section IV outlines the main communication options available for smart grid. In Section V communication challenges are given. Section VI gives recommendations and future work. Finally, Section VII concludes the paper.

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TABLE I
Comparison between existing grid and smart grid [8]

Existing Grid	**Smart Grid**
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

II. Benefits of Smart Grid

a) *Distributed generation:* By making use of improved communication, smart grid allows for integration of power generated from different sources. This is an improvement on the traditional approach which is a mainly a broadcast grid. Transmission losses are reduced by choosing the nearest supply option. This reduces the distance from generation to consumption making it more efficient, economic and environmentally friendly power.

b) *Faster response:* There is better monitoring of the power grid. Power usage is measured and recorded using Advanced Metering Infrastructure (AMI). AMI measures and records at a minimum, in hourly intervals and provides usage data to both consumers and energy companies at least once daily. The condition of the system is also monitored. Samples of voltage and current are taken and used to obtain the Phasor Measurement Units (PMU). PMUs offer wide-area situational awareness and they work to ease congestion and bottlenecks and mitigate – or even prevent – blackouts. Smart grid is capable of giving more samples (30 samples per second) than the earlier Supervisory Control and Data Acquisition (SCADA) technology (1 sample every 2 or 4 seconds). When problems occur, the utility is better equipped to identify their source and apply appropriate solutions.

c) *Better customer participation:* Customer can participate more actively in the power grid and receive more feedback. Customers can better monitor their power consumption. They can also resell the power they generate through solar or wind. Running devices can be managed better (e.g. to reduce peak load). Smart grid also makes it possible to implement Demand Response (DR). DR is a mechanism for achieving energy efficiency through managing customer consumption of electricity in response to supply conditions [6]. Futhermore, customers can make use of third party applications which help in managing power consumption. Home Energy Management Systems (HEMS)

d) *Potential Innovations:* Smart grid adoption will potentially lead to innovation of many new applications. Plug-in hybrid electrical vehicles (PHEV) require a reliable power grid which will handle the large load when connected. Applications for energy management among customers are also expected to increase.

e) *Long term savings:* Though implementing smart grid involves high initial costs, in the long run, power will be distributed more efficiently and thus lead to savings. For example, through planning, energy can be obtained from the nearest source thus saving on the losses which would occur through long distance transmission. Providing power at lower cost allows for network expansion as more users can be connected to the grid.

III. Communications Requirements

Communication is crucial for the development of smart grid. For smart grid communication to be effective, there are requirements that need to be met [10]:

a) *Reliability:* It is important for the communication backbone to be reliable (i.e. have a low probability of error) for successful and timely message exchanges.

b) *Security:* Physical and cyber security from intruders is crucial. Smart grid data traffic such as billing, signal prices and control messages is very important traffic that needs to be encrypted and prevented from malicious changes and unauthorized access.

c) *Time synchronization:* Some of the devices on power grid need to be synchronized in time.

d) *Multicast support:* This is helpful when a message is to be communicated to several peers at the same time. Instead of multiple individually addressed messages, a single multicast message is sent to a switch that forwards it to all outgoing ports. This reduces the network traffic.

IV. Communications Options

Several options are available for the communication needs of smart grid. The choice of system to choose depends on the environment, amount of data and the Quality of Service (QoS) needed. Different sections of the grid will have communication protocols that are different from those of others

a) *Power line carrier:* Power line communications (PLCs) uses existing electrical wires to transport data. A modulated carrier signal is impressed on the wiring system.

It has two main advantages. First, it has extensive coverage since it can be used anywhere as long as power is connected. Second, it has a low installation cost because it uses existing wires.

Its main disadvantage is its susceptibility to noise. The power line is a noisy environment which leads to an increased bit error rate. Cables are often unshielded and thus become both a source and a victim of electromagnetic interference (EMI) [3].

The lack of twisting and shielding in PLC introduces security concerns. The Electro Magnetic Interference (EMI) produced can be easily received via radio receivers [5].

b) *Optical Fibre:* Optical fibre can be used in smart grid communication by laying it along the power line. It provides extremely high data rates. It supports long distance data communication with fewer repeaters compared to traditional wired networks. Its main setback is the cost which becomes significant owing to the large scope involved in smart grid. The high cost can however be offset by offering data services such as internet.

c) *Wireless communication*: Various wireless protocols can be used for smart grid. Some have shorter ranges than others and are thus applied in different sections of the grid.

Zigbee is a wireless communication technology that is relatively low in power usage, data rate, complexity and cost of deployment. It is ideal for applications such as home automation and automatic meter reading [7].

Wi-Fi has a high data rate and has been increasingly used on laptops. It can be used for convenient and low cost data exchange. This could include sending data to the smart meter.

Public cell phone carriers can be used to connect household smart meters directly with the utility's systems. This could save on installation costs, but since it is not specialized in machine-to-machine communication, some requirements may not be met.

WiMAX uses licensed wireless spectrum, which is arguably both more secure and reliable. It yet to be deployed at scale, which means some risks when applied to utilities [3].

Advantages of wireless communication include: rapid installation because there are no cables or wires to be laid; cost savings since cabling cost is eliminated and when an existing network is used, such as cellular, the cost is less.

Disadvantages include: Limited coverage, high power consumption (e.g. Wi-Fi) and low security since transmission can be captured by nearby devices.

V. Communication Challenges

Challenges in implementing smart grid include:

a) *Interoperability:* Several communication options available for the transfer of the required information: fibre optics, copper-wire line, power line communications, and a variety of wireless technologies. One standard cannot meet the needs of smart grid in an optimally. There is currently ongoing debate surrounding what will emerge as the communications standard of choice [2]. There is need for communication standardization for smart grids in order to ensure interoperability between different system components rather than defining these components (meters, devices or protocols).

b) *Scalability:* It is important to have a scalable implementation of smart grid in order to make room for expanding the network (e.g. when new customers are connected).

c) *Distinct characteristics of smart grid traffic:* The traffic for smart grid is different from that of most applications such as internet and mobile calls. The requirements for the Quality of service will vary depending on the type of service required. A good design ensures that each section uses technology having appropriate data rates and acceptable bit error rates.

d) *Cyber security and privacy:* Large amounts of data from the user are required to optimize power distribution. On one hand, with more information available, smarter decisions can be made by a management system. On the other hand, more information could lead to privacy leaks [8]. Through analyzing how a user spends their power, their day to day activities can be known (e.g. when they have breakfast or when they watch TV). Fig. 1 illustrates how a user's consumption can be used to extract information about how they live. If such information would fall into the wrong hands the effects could be devastating. Robbers could use such information to plan their attacks as well as to identify equipment that they would like to steal.

The question of how much control utility companies have over users' equipment is worth considering. Some energy management approaches require greater control for them to be more optimal. This should not invade the privacy of the user unduly.

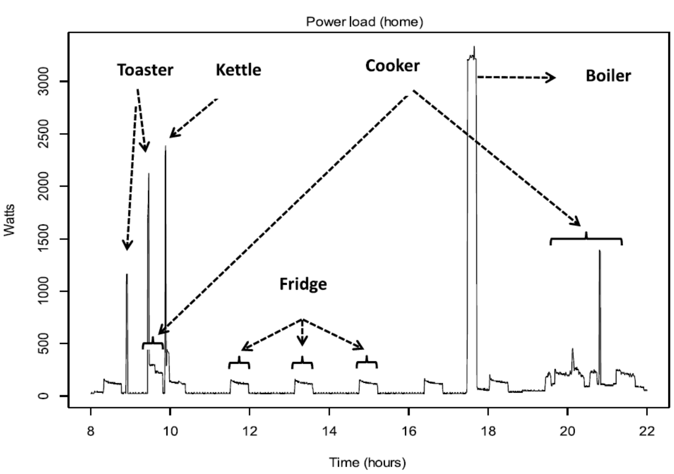

Fig. 1: Household demand profile showing the activity of the user [9]

e) Cost: Cost is an important factor especially due to the large geographical scope covered by smart grid. The solution to the challenges given here need to be solved without making the cost prohibitive.

The losses which occur due to blackouts need to be considered when doing a cost benefit analysis. Smart grid is expected to reduce the power outages and thus have other long term benefits among the users involved.

f) *Customer concerns:* Recent technological advances have made customers more willing to participate in decision making. Customers however do not want technology to interfere with their lifestyles, such as by demanding frequent settings modification. Interfaces need to be simple and accessible. Customers choose settings based on comfort, price and environment, and then the rest happens automatically. This approach to setting has been described as "set-it-and-forget-it" technology.

Customers also need to be educated about the benefits of smart grid. When new innovations are introduced, instructions of usage need to be simple to understand.

VI. Recommendations and Future work

Smart grid is a growing area with much research to be done. Interoperability needs to be looked into since it is crucial in ensuring that current communication schemes can work effectively with one another and allow for the introduction of new technologies.

Customer concerns need to be looked into. Adoption should be done in a systematically and a review on how effective it is should be done so that improvements can be made in future deployments. Civic education is also crucial in dispelling the myths that could hinder adoption.

Work on privacy and cyber security needs to be done. This should be both technical and legal – minimizing the possibility of hacking and enforcing laws where technical solutions cannot work. The schemes developed should bear work with the limited resources available within the grid.

Simulation would be an important tool in testing the different schemes and topography to be used in smart grid implementations. This would help in identifying problems faster and with less risk involved. The use of software in planning could also help in assessing the viability of new innovations.

VII. Conclusion

Smart grid is expected to be highly beneficial both to consumers and utility companies. Like any new technology, the initial planning and deployment is crucial in determining its success. Communication is crucial in bringing about system efficiency. By prudently choosing the most effective communication technology, the cost can be greatly reduced and reliability can be enhanced. The challenges arising need to be addressed: both the technical challenges and the social ones. Though regions have different needs, smart grid when appropriately deployed is expected to be universally beneficial.

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