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A Survey on Smart Grid Communication Analysis and its Challenges

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***Abstract*— Implementation of smart grid applications has most challenging task of employing proper communication system. There may be lack of expertise in communication technology, and have insufficient understanding of strengths and weaknesses of different communication options. And there is no formal decision process to choose the best communication option for specific usage. Due to these reasons, the current communication implementation process is more time consuming and has less efficiency. This paper studies the specification of different communication types, and provides the advantages and disadvantages of each communication type. There are different communication options for different smart grid applications. Finally we discuss about the communication challenges in smart grid and to decide which communication is best suited for different smart grid application.**

Keywords*— Smart grid, Supervisory control and data acquisition, Communication, Advanced metering infrastructure.

I. INTRODUCTION

Smart grid [1] is a next generation electrical grid which provides power to consumers using two way secure communication. Smart grid has given many opportunities for electric power industry with advanced technologies. Many companies are starting to invest in smart grid applications with real-time data. The Advanced Metering Infrastructure (AMI) and Supervisory Control and Data Acquisition (SCADA) are most widely used application. The architecture of smart grid communication is shown in Fig. 1.

Employing the communications into the systems is a difficult task to implement smart grid application. Communications are very important to the application as supplying power to the consumer. Bad quality of communication line leads to entire smart grid failure.

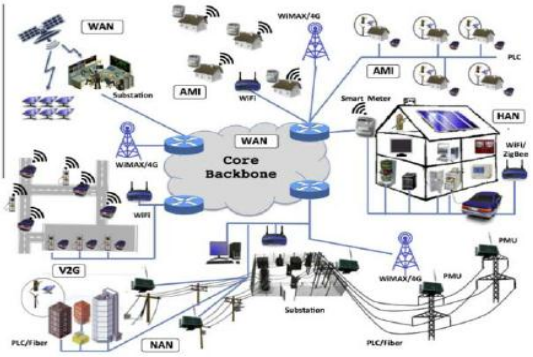

Fig. 1. Architecture of Smart grid communication

Many personnel are struggling to choose an optimal communication for smart grid due to lack of knowledge in communication technology. They need to consider multiple factors during the selection procedure, such as communication speed, reliability, availability, etc. Now a day, there is a lack of formal process for choosing appropriate communication technologies for specific applications. This paper aims to provide the details of different communication for different smart grid applications for choosing communication technologies when smart grid is implemented. This paper provides a information to provide communication options to communicate between the different applications. In Section II, the two main smart grid application technologies, AMI and SCADA, are discussed. In Section III different smart grid communication options are discussed. Section IV discusses communication options with interfacing smart grid applications, followed by the conclusion.

II. SMART GRID TECHNOLOGIES

This section introduces the two main smart grid applications: Advanced Metering Infrastructure and Supervisory Control and Data Acquisition.

A. Advanced Metering Infrastructure (AMI)

Advanced Metering Infrastructure (AMI) technology allows the utilities that automatically reads the electrical meters on a specified period of time and gives the bill to the consumers. The meters can read automatically and even hourly instead of using manpower. AMI also allows the utilities to keep track of outage power distribution system performance, and read through historical information to monitor the system [2].

With hourly reads, the device can now offer time of use rates which allows the device to use various rates to bill at different times in the day. This will help out the transmission of the electrical power flow because it encourages consumers to use electricity when the electrical demand is not in such high demand due to cheaper electricity rates. The basic functional representation of AMI is shown in Fig. 2.

More complicated communication systems are required for AMI systems. The AMI system that got several parts in itself that are helpful while considering about different communication technologies. One communication path is within the system itself. The other portion of communication system is to obtain information that can be accessed remotely. The device has to consider how the information from each meter is transmitted to different stations. To achieve such communication path power line carriers are used.

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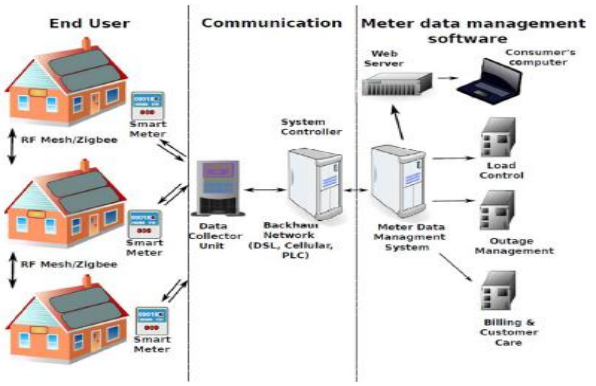

Fig. 2. Functional representation of AMI

The automatic meter reading (AMR) is the important part of AMI technology. The AMR systems will not only read KWh to bill, but also reads maximum demand with time period, voltage levels, and the number of power outage on each meter per day. The information about a specific location can be quickly accessed every minute of the day. AMR can also report other segments to the utility. For example, with the AMR, utilities can now tell if someone is tries to steal power.

In addition to the meter-reading segment, AMI provides the information about other factors such as collecting money from consumers that have past due balances. By using remote switches, AMI can disconnect the power without going to the locations of such consumers.

Another important factor is that AMI provides the information of the power usage to the consumers and this will help the consumers how much power has been consumed.

B. Supervisory Control and Data Acquisition (SCADA)

The main job of SCADA systems is to monitor and control utilities in real time [8]. Reliability is the main factor when considering a SCADA system, for larger utilities, since they have a larger service area and more employees to perform operations [4]. The data are transmitted between Master Terminal Unit (MTU) and Remote Terminal Units (RTU) or Programmable Logic Controllers (PLC). In this system, the RTU collects data, and then MTU send the data to the operator terminals. The communication paths include the path from the field interface device to the RTU, and from RTU to MTU, etc. These communications paths are achieved using wired or wireless.

III. OPTIONS FOR SMART GRID COMMUNICATION

This section discusses different communication options, their strengths and weaknesses, and determining the communication types that is the most effective.

A. Dial-up Communications

Telephone Company's offers dial-up connection. It allows the customer to have access to the Internet by using the telephone landlines or twisted pair wires to call in to IP addresses. It is the slowest but cheapest communication type that is available in currently in market. In the past, it is mainly used in remote areas where high speed Internet is not available. Currently, with the option of satellite Internet now available, dial-up communication is almost extinct.

In dial-up communication the reliability is considered to be good when using existing infrastructure. The reliability is only going to be poor when telephone lines fail within the telecommunication system. If landlines are damaged during storm or bad whether then the communication service will fail.

The bandwidth of dial-up communication is very low, ranging from 10 kilobits per second (Kbit/s) to 56 Kbit/s.

The biggest advantage of dial-up communication is its cost. Dial-up has a very low cost when compared to other connections. In conclusion, in dial-up communication, the utility will obtain a cheap price for Internet, but speeds and reliability is going to be very poor [5].

B. Digital Subscriber Line /Broadband Communications

Digital Subscriber Line (DSL) is a type of broadband communication which transmits a data signal over a higher frequency than dial-up communication. It provides faster speed than dial-up connection and very good reliability. This technology is used for communication for transmitting data in AMR and SCADA.

Asymmetric Digital Subscriber Line (ADSL) and Symmetrical Digital Subscriber Line (SDSL) are used to transmit the data at a very high speed [6]. In this ADSL is the most widely used DSL communication which gives faster download speed than upload speed, while SDSL allows the download speed and upload speed to be approximately equal. The download data speeds are around 3 Mbit/s up to 12 Mbit/s [7].

Broadband doesn't require any special device to be equipped it requires one time installation fees. The price for this communication depends on different data speeds [8].

The main advantage of this system is it doesn't fail often. And it provides more faster and more reliable than dial-up connection.

C. Fiber Optic Communications

Fiber optic communication is the most expensive communication and it is also the fastest communication available.

An optical light has the capability to travel 126,000 miles per second. In the fiber optic networks, there are two types of cables that are used in the communication, single-mode fiber and multi-mode fiber. The single-mode fiber can carry an huge amount of information in one direction, but it does not provide a return path. The multi-mode fiber, can transmit and receive signals from multiple direction.

The main disadvantage of fiber optic is its high cost. The installation of fiber optic cables is expensive, when it needs to be communicated for long distances, the cost is very high, and it is not reasonable to purchase this technology based on a Benefit to Cost Analysis (BCA). When fiber optic communication fails then the replacement of the cable cost is very high. Another disadvantage is that it requires very skilled person to install and maintain the communication.

In spite of the disadvantage, the main advantages of fiber optic cables it has very high bandwidth and it can transmit huge amount of data. The data transmission speed is approximately 100 Mbps. On the other hand, fiber optic cable has a less interference to noise and a very less prone to failure.

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Currently, fiber optic communication is used as communication medium between smart grid applications devices. In remote places where IP connectivity is not available then collecting real time data of smart grid is very difficult. Fiber optic cables are used to retrieve real time data from smart grids.

D. Power Line Carrier (PLC)

PLC has been broadly used with the idea of AMI. PLC uses the distribution of power lines to transmit the data. PLC is used to carry both data and Electric power with a very high frequency. There are two types of PLC, Narrow Band (NB), and Broad Band (BB). NB can offer a high data speed ranging from 2 kbps to 500 kbps, and BB offers access to the Internet over the power line.

The main smart grid application for PLC is AMI. One of the main advantages of PLC is that it does not require a communication infrastructure, power lines themselves can carry huge amount of data. The only cost is sending and receiving the information through the power line. This can save the installation cost, but the drawback is that if the power system has excessive amount of noise, the data can be lost.

Another communication type which is called Broadband over the Power Line (BPL) uses PLC technology to provide customers with access to high data speed and the Internet.

One major problem is that the high frequency signal will reduce after going through transformers in the distribution system. To solve such problem, the BPL signals have to be amplified around every mile of the line they travel.

Since BPL service is provided by the utility itself, no extra cost except the signal injection equipment is needed.

E. Wireless Communications

All the communication options discussed requires a common feature that is communication cable but if there is any damage in communication cable then the whole transmission is broken for many hours. This type of communication is not best suited for smart grid transmission. So another way of communication is by wireless. There are many ways of communication in wireless.

1) Satellite communications: Satellite communication is mainly used for AMI and SCADA applications, and it is designed to provide Internet connectivity over long distances. This communication is best suited for rural areas where the only option is ground communication using dial-up.

Although the cost of satellite communication can be very high, but the advantage is that it provides very high speed Internet to rural areas. The Internet connection can be available anywhere it is desired. The disadvantage is its daily/monthly download limit. And it gives the most latency delay among all the systems.

2) Radio system communications: Radio system Communication does not provide direct access to the Internet. Radio system transmits data from one location to another using different frequency.

Radio system communication can transfer data at higher throughputs it is considered to operate in the range of 900 MHz to 2.4 GHz.

One of the biggest drawbacks of radio system is its initial investment cost. Latency is also very low. Wireless interference within multiple applications that use the same frequency is another big problem.

The maintenance cost is low once after the installation is done. There is no monthly charge either. If the utility can install the antennas or modules on their own towers, the cost can be lower.

3) Microwave communications: Microwave communication uses antennas for transmitting of data for a longer distance and it has been used for a very long time.

Designing and implementing microwave communication systems is very challenging for utility engineers. Like the radio communication system, the biggest disadvantage for microwave communication is the initial investment cost. When it comes to the advantages of microwave communication, such system can offer high channel capacity, which enables transmission of huge amount of data.

4) Cellular data communications: The other major wireless technology is the cellular communication offered by cellular companies. Cellular data communication can be used for both AMR and SCADA.

The cellular data communication has a very good cellular coverage area. The maximum data speed of cellular communication is higher compared to other systems, which offers larger bandwidths.

Cellular communication has many drawbacks as well. It is limited by the coverage area. The data transmission speed is dependent on the location. Although the speed can be slow as a result of mobile voice traffic. But the reliability of transmission is good when compared to other communications.

IV. COMMUNICATION OPTIONS WITH SMART GRID APPLICATIONS

Based on the following factors the smart grid data transmission can be decided.

First, the location where the communication is going to be implemented is determined. Then the communication analysis is carried out based on the available options in that particular site. Finally, the decision is made.

A. Location

The first factor to be considered is the location where the implementation of the communication takes place. Different options might be available for different locations. For instance, if there is a DSL or broadband connection is available at the substation then there is no use for the implementation for the wireless. Unless a wireless communication such as cellular can be implemented at a cheaper price for better reliability.

Once the available communications types are known for an area, the actually area needs to be studied and evaluated. That means if the area is very hilly with locations in valleys and mountains, or if the area is more flat land where long distances can be achieved with no obstacle.

If the area is hilly, any wireless communication options except the satellite and cellular types might not be possible to implement. In this case, the cost of implementation is high. If the area is a flat area, almost any communication types would be feasible to implement.

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In summary, this step determines which options are available for a certain area. The next step would be analysis for these available types.

B. Communication Analysis

This step is most important for deciding which communication type is best suited for particular location. In this analysis, the engineers will analyze the attributes of each communication type including reliability, advantages, disadvantages, cost, etc.

For AMI applications, the best way is to invest in third party companies. The advantage of this is the low price and can have high reliability and more speed. Therefore, budget can be saved for the AMI project. There are different communication paths needs to be obtained in the AMI application. The most important part is the communication path that needs to be defined is the path from the equipment to the central server. This communication path needs to have Internet activity or an active IP address. Another communication path is the path from the substation to the meters and then from all the equipment that helps send and retrieve information. The other communication path is the one between different equipment inside the substation. However, the utility does not have options to choose from for this part. The communication type is determined on the vendors design.

SCADA applications require highly reliable communication. When performing the communication analysis of any wireless communication types, the signal strength of the location should be the primary aspect to be studied. Cellular might not be a suitable solution depending on the coverage area where the SCADA equipment is located as with the area networks, such as DSL, the reliability of the service will need to be studied as well. The weakest link within these networks is the Internet modems. Although reliability requirement is strict for SCADA communication, the bandwidth does not have to be large, as SCADA data are transmitted in low data packet sizes. This allows the use of radio systems to transfer SCADA data.

C. The Final Decision

To decide which communication path is best suited for smart grid application, all the communication paths should be studied. Most smart grid applications require three different communication paths. The first path is from the substation to headquarter. The Internet access is required for this communication. As discussed in this paper most of the technologies can offer Internet access, including DSL, satellite, and cellular communications. The second path is between different application equipment. The final communication path is from the field devices back to the substation. Radio frequency communication and Power line communications are available for this particular path. For large populated areas the radio frequency option is a better solution, and in areas with obstructions to signal propagation PLC is a better choice.

An example decision process for implementing communication to an AMI system is presented to help understand how to make the decisions is as follows.

So, the first step is to determine location of the AMI applications. The technology used in path from the field equipment back to the substation can be determined based on the location's information. The radio frequency solution should be used if the location's type of area is flat area. The power line communication should be used if the location's type of area is rural area, hilly area. This step determines the type of meters to be purchased from the AMI vendor.

The next step is to decide the technology to transfer the information from substations to headquarter. Dial-up, cellular, DSL, satellite, and Wi-Max [9] options are considered, as they all provide Internet IP connectivity. For rural areas dial-up can be used but the speed is less. DSL has high data speed and the reliability is good, but it has limited range. Satellite has a wide availability range including the rural areas, but the service can be expensive. Cellular has high reliability within its service area, but it has limited coverage area. Wi-Max provides high reliability and high data speed, but it requires line-of-sight clearance. Utility personnel have to make decisions based on the options available for the particular site communication analysis.

The utility personnel should determine how the service can be provided to the substation if the communication option is not located near the substation. This is done either by, using the technology of fiber optic cables or by investing in a radio communication system.

V. CONCLUSION

The implementation of smart grid is very difficult with increase in adoption of smart grid applications to find the best communications options among them. The companies will spend huge amount of money by hiring personnel to install and maintain these applications due to lack of knowledge in communication technologies. So the best way is to understand the advantages, disadvantages and characteristics of all the communication technologies.

This paper explains the existing communication systems in terms of availability in different locations, strengths, weaknesses, and other attributes. An implementation decision process is proposed. The availability analysis, communication analysis, is described. An example decision process is also presented to help understand the procedure. When implementing the communication system for smart grid applications the utility personnel can gain the knowledge from this paper.

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