Smart City’s Energy Management- IoT Integrated Smart Grids and Communication Technologies

Sarika Y. Mane

Abstract - The concept of a smart city is based on consistent power supply. Traditional power grids are being transformed into Smart Grids (SGs) to solve the problems of unidirectional information flow, energy wastage, growing energy demand, reliability and security. IoT integrated Smart Grids can result in efficient power transmission and energy management. SGs require connectivity, automation and the tracking of such devices. This is achieved with the help of Internet of Things (IoT). IoT help SG systems to support various network functions throughout the generation, transmission, distribution and consumption of energy. In the paper we have discussed about the Smart City, Smart Energy, Traditional Power Grids, Smart Grids, IoT Integrated Smart Grids and IoT and Non-IoT Communication Technologies for SGs. We have also discussed the India’s Smart Grid Scenario. The main objectives of this paper are to study the Smart Grids along different communication technologies and put it in simplest way for the new learners.

Key Words: Internet of Things (IoT), Smart Grids (SGs)

1. INTRODUCTION

1.1 Smart City

Smart Cities Mission is an urban renewal and retrofitting program by the Government of India with the mission to develop 100 cities across the country making them citizen friendly and sustainable. A smart city is a sustainable and efficient urban centre that provides a high quality of life to its inhabitants through optimal management of its resources.

Energy management is one of the most demanding issues within such urban centers. Therefore, significant attention and effort need to be dedicated to this problem.

1.2 Smart Energy

Smart Energy [1] is one of the most important research areas of IoT because it is essential to reduce overall power consumption [4]. Smart Energy includes a variety of operational and energy measures, including Smart Energy applications, smart leak 260 monitoring, renewable energy resources, etc. Using Smart Energy (i.e., deployment of a smart grid) implies a fundamental re-engineering of the electricity services [5] Smart Grid is one of the most important solutions for Smart Energy.

1.3 Traditional Power Grids

A traditional power grid consists of a large number of loosely interconnected synchronous Alternate Current (AC) grids. As shown in Figure 1, it performs three main functions: generation, transmission and distribution of electrical energy [6], in which electric power flows only in one direction, i.e., from a service provider to the consumers. In power generation, a number of large power plants generate electrical energy, mostly from burning carbon and uranium based fuels. Secondly in power transmission, the electricity is transmitted from power plants to remote load centers through high voltage transmission lines. Thirdly in power distribution, the electrical distribution systems distribute electrical energy to the end consumers at reduced voltage.

Figure 1: Traditional Power Grid Architecture [6]

2. SMART GRIDS

Traditional power grids are being transformed into Smart Grids to solve the problems of unidirectional information flow, energy wastage, growing energy demand, reliability and security. As shown in [2] Figure 2, SG offers bi-directional energy flow between service providers and consumers. The SG is comprised of four main subsystems such as power generation, transmission, distribution and utilization. Three types of networks, a wide area network (WAN), a neighborhood area network (NAN) and the home area network (HAN) are used in SGs. The power flows through the subsystems while information flows through networks. SGs employ various devices for the monitoring, analysis and control of the grid, deployed at power plants, distribution centers and in consumers’ premises in a very large number. Hence, SGs require connectivity, automation and the tracking of such devices. This is achieved with the
help of Internet of Things (IoT). IoT helps SG systems to support various network functions throughout the generation, transmission, distribution and consumption of energy by incorporating IoT devices (such as sensors, actuators and smart meters), as well as by providing the connectivity, automation and tracking for such devices.

![Smart Grid Architecture](image1)

**Figure 2: Smart Grid Architecture presenting power systems, power flow and information flow [2]**

### 2.1 IoT Integrated Smart Grids

IoT technology plays a significant role in SG construction. IoT technology provides interactive real-time network connection to the users and devices through various communication technologies. IoT realizes real-time, two-way and high-speed data sharing across various applications, enhancing the overall efficiency of a SG [7]. The application of the IoT in SGs can be classified into three types. Firstly, IoT is applied for deploying various IoT smart devices for the monitoring of equipment states. Secondly, IoT is applied for information collection from equipment with the help of its connected IoT smart devices through various communication technologies. Thirdly, IoT is applied for controlling the SG through application interfaces. IoT sensing devices are generally comprised of wireless sensors, RFIDs, M2M (machine-to-machine) devices, cameras, infrared sensors, laser scanners, GPSs and various data collection devices. The information sensing in an SG can be highly supported and improved by IoT technology. The IoT technology also plays an essential role in the infrastructure deployment of data sensing and transmission for the SG, assisting in network construction, operation, safety management, maintenance, security monitoring, information collection, measurement, user interaction etc. Prototype plays an important role in the deployment of system in order to test various functions and verify the operation before the actual commercial implementation. Figure 3, describes the one of the three layered architecture [2] of an IoT aided SG system. It comprised of a perception layer, a network layer and an application layer. The perception layer consists of two sub-layers, a communication extension sub-layer and perception Control sub-layer. Some other prototypes such as energy efficient prototype, web enabled architecture etc. also have been developed for IoT integrated SG systems.

![Three Layered Architecture](image2)

**Figure 3: Three Layered Architecture of IoT integrated SG [2]**

### 3. INDIA’S SMART GRID SCENARIO

[3] “Energy conservation is critical to resolving India's power crisis. Millions of people have no access to power, with 40% households (about 400 million) going without power. Initiatives like Smart City and Digital India depend on power supply. The concept of a smart city is based on consistent power supply.

Transmission losses in India stand at 40–48% compared to world standard of 8%. If losses can be controlled, power shortage could be managed. According to the World Resources Institute, power transmission losses in India are highest in the world. For a cleaner and safer environment, measures would have to be in place to drastically reduce electricity losses and conserve energy.

Smart grid is very essential to meet the constantly increasing energy needs and the target of supplying 24/7 power for all by 2022. The country is making several efforts and is active in bringing the best of its solutions out of which smart grid is one solution that is expected to meet the energy demand. It is indeed the need of the hour as it transforms the electricity grid into more reliable grid which also helps in controlling and monitoring the electricity flow. Smart tripping of feeders and voltage fluctuations, finally sees some progress, in the Smart Grid project that was approved in October 2015. The
city will soon see an end to diesel generators and chronic power woes. The numbers of Smart Grid projects have been introduced and are currently underway such as KEPCO in Kerala, BESCOM in Bangalore, etc. Such project plays vital role to meet growing electricity demands of the country, curb power losses and enhance accessibility to quality power."

4. IOT AND NON-IOT COMMUNICATION TECHNOLOGIES FOR SG

Figure 4 shows the Classification of Communication Technologies for the Smart Grid. There are many [2] IoT and non-IoT communication technologies available for SGs and the users have to select among them, suitable to their needs. There is a lack of proper guidelines for the selection of communication technologies for SG. In this section, we have listed various IoT communication technologies together with non-IoT communication technologies, including their characteristics, advantages and disadvantages and application areas. Table 1, provides a summary of communication technologies. This table will be helpful to take better decision for the selection of most suitable communication technology.

The IoT and non-IoT communication technologies used in the SG for data transmission between smart meters and electric utilities. These are categorized into two types, wireless and wired technologies. Wireless technologies have some advantages over wired technologies in some cases, such as their ease of connection to otherwise unreachable or difficult areas, as well as their low cost infrastructure. An SG requires information flows. The first data flow can be achieved through power line communications or wireless communications, such as by using 6LowPAN, ZigBee and Z-wave [8]. The second data flow can be achieved by using cellular communications or via the Internet. However, there are various key limiting factors that should be considered in the deployment process of smart metering, such as operational costs, deployment time, availability of technology, and the operating environment (such as rural, urban, indoor, outdoor). Hence, the choice of technology that suits one environment may not be applicable for another.

The main motivation of the [2] Table 1 is to provide some guidelines for the selection of communication technologies of SG based on the requirements. We came to know that most of the communication technologies are designed by focusing HAN.

Furthermore, it is important to note that there is no overall the best technology, but certain ones are more suitable to particular SG applications than others. In general, wired technologies such as DSL, PLC and optical fiber are expensive for wide area deployments, especially in rural areas. However, they can maximize both communication capacity and security. Wireless technologies, on the other hand, can reduce installation costs but they have bandwidth and security limitations.

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**Figure 4:** Classification of Communication Technologies for the Smart Grid
Table 1: IoT and Non IoT communication technologies for the Smart Grid [2]

<table>
<thead>
<tr>
<th>Technology</th>
<th>Protocol</th>
<th>Advantages</th>
<th>Disadvantage</th>
<th>Applicability SG</th>
<th>Application Areas</th>
<th>Data rate</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>IoT Wireless Technologies</td>
<td>Z-Wave</td>
<td>No interference with other wireless technologies; reliable; low latency; scalable</td>
<td>Not suitable for NAN and WAN; only one propriety company for making chips; short range</td>
<td>HAN</td>
<td>Home automation</td>
<td>100 Kbps</td>
<td>30 m</td>
</tr>
<tr>
<td></td>
<td>6LoWPAN</td>
<td>Robust; low-power; support large mesh network topology; can be applied across various communication platforms</td>
<td>Require extensive training and knowledge; short range; low data rate</td>
<td>HAN</td>
<td>Smart metering; home automation</td>
<td>250 Kbps</td>
<td>10-100 m</td>
</tr>
<tr>
<td></td>
<td>LoRaWAN</td>
<td>Low-power; long range; no interference with different data rates; enhance gateways capacity by creating virtual channels; low-cost secure bi-directional communication</td>
<td>-</td>
<td>NAN; WAN</td>
<td>Management of operation and equipment; online monitoring of power transmission lines and tower</td>
<td>0.3-50 Kbps</td>
<td>2-5km (urban environment); 15km (suburban environment)</td>
</tr>
<tr>
<td></td>
<td>ZigBee</td>
<td>16 channels each with 5 MHz of bandwidth in 2.4 GHz spectrum; low power usage; low complexity; low deployment cost</td>
<td>Low data rates; limited energy of battery; low processing capabilities; short range</td>
<td>HAN</td>
<td>Energy monitoring; smart lightning; home automation; automatic meter reading</td>
<td>250 Kbps</td>
<td>10-100 m</td>
</tr>
<tr>
<td>Non-IoT Wireless Technologies</td>
<td>Bluetooth</td>
<td>Low power consumption</td>
<td></td>
<td>HAN</td>
<td>Home automation</td>
<td>721 Kbps</td>
<td>1-100 m</td>
</tr>
<tr>
<td>Cellular communications</td>
<td>Wide area coverage; improved QoS</td>
<td>Network congestion due to high density; critical for emergency applications; non-guaranteed service in unfavorable conditions (e.g., wind storms)</td>
<td></td>
<td>HAN; NAN; WAN</td>
<td>Monitoring and management of DERs; SCADA</td>
<td>60-240 Kbps</td>
<td>10-50 km</td>
</tr>
<tr>
<td>Wireless mesh</td>
<td>Low cost; self healing; self organization;</td>
<td>Prone to interference and fading; network coverage problem in</td>
<td>HAN; NAN</td>
<td>Monitoring and controlling of DERs;</td>
<td>Depends upon</td>
<td>Depends upon</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology</th>
<th>Scalability</th>
<th>Data Rate</th>
<th>Advantages</th>
<th>Challenges</th>
<th>Protocol/Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>WiMAX</td>
<td>high</td>
<td>high</td>
<td>Long range; high data rate</td>
<td>Trade-off between performance and distance; costly RF hardware; low frequencies are already licensed and require leasing; high frequencies do not penetrate obstacles</td>
<td>HAN; Real time pricing; automatic meter reading; outage detection and restoration; 75 Mbps (LOS); 1-5 km (NLOS)</td>
</tr>
<tr>
<td>Mobile broadband wireless access</td>
<td>low latency</td>
<td>high</td>
<td>Low latency; high mobility; high bandwidth</td>
<td>Communication infrastructure not readily available; high cost; moderate data rate</td>
<td>HAN; WAN; Broadband communication for electric vehicles; SCADA system; wireless backhaul for SG monitoring; 20 Mbps; Vehicular standard (up to 240km/h)</td>
</tr>
<tr>
<td>Digital microwave technology</td>
<td>long distance coverage; high data rate; high bandwidth</td>
<td>Prone to multipath interference and precipitation</td>
<td>HAN; NAN; Transfer trip between DER and distributed substation</td>
<td>155 Mbps; 60 km</td>
<td></td>
</tr>
<tr>
<td>Non-IoT Wired Technologies</td>
<td>cost effective; low installation cost; wide availability; utility's own ownership and control; dedicated network</td>
<td>Noisy and harsh medium; sensitive to disturbances; signal quality gets affected by the type and number of devices, wiring distance between nodes and network topology; cost of ownership; complexity of management</td>
<td>HAN; NAN; Low voltage distribution; automatic meter reading</td>
<td>2-3 Mbps; 1-3 km</td>
<td></td>
</tr>
<tr>
<td>Digital subscriber lines (DSL)</td>
<td>high speed; low latency; low installation cost; high data rate; high capacity; long range; wide availability</td>
<td>Quality is distance dependent; high installation cost in low density (rural) areas; unreliable</td>
<td>HAN; NAN; Smart metering</td>
<td>1-100 Mbps; 5-28 km</td>
<td></td>
</tr>
<tr>
<td>Optical communications</td>
<td>long distance communication; ultra-high bandwidth; robustness against radio and electromagnetic interference; high reliability</td>
<td>High deployment cost of fiber installation; high cost of terminal equipment; difficult to upgrade; not suitable for metering applications</td>
<td>HAN; NAN; Physical network infrastructure</td>
<td>Up to 100 Tbps; 10-60 km</td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSION

We discussed about the Smart City’s Smart Energy requirements. Smart Grids along with IoT integration plays vital role. India is adopting the Smart Grid Technology. In IoT Integrated Smart Grids, IoT and Non-IoT Communication Technologies are used. With proper selection of communication technology, IoT integrated Smart grids increase quality of power supplies and increase energy efficiency with proper energy management. They have demand response capacity to strike a balance between power consumption and supply. Smart grids can integrate new energy sources like solar and wind with traditional sources. For the new learners comparison table of communication technologies is added for easy understanding and ready reference.

FUTURE SCOPE

IoT integrated Smart Grid can highly benefits from the IoT vision. There are lots of challenges in actual implementation of IoT integrated Smart Grid technology. To meet these challenges lots of research work is needed in the field of WSNs scalability, security issues and challenges.

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BIOGRAPHIE

Sarika Y. Mane received the M.E in Instrumentation and Control from University of Mumbai, India in 2011. She is an Assistant Professor in Electronics Engineering Department of K. J. Somaiya Institute of Engineering & Information Technology, University Mumbai. Her area of interest is Embedded Systems, Internet of Things and Robotics. She is member of Robotics Cell and e-Yantra Team of the Institute. She has few research publications to her credit in National/International Journals.