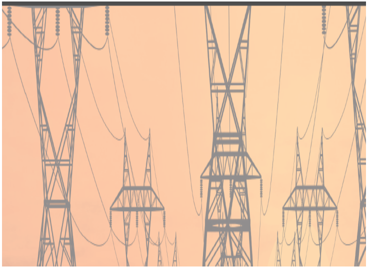
A PRESENTATION ON: SMART GRID



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Introduction to M2M

- M2M stands for machine-to-machine communications. It is about networking the machines and devices that pervade our everyday lives.
- M2M communications aims to connect an array of equipment from mainframes to everyday products (e.g., home appliances, vehicles, buildings) to each other.
- M2M allows thing can communicate without the intervention of human beings.
- M2M has many applications. One of the major applications is that of Smart Grid.

Introduction to Smart Grid

- Historically, the electrical grid has been a broadcast grid, where a few central power stations 'broadcast' electricity to the consumers via a large network of cables and transformers.
- This grid system is a centralized and **unidirectional** system and the power flows out to consumers from a power station.

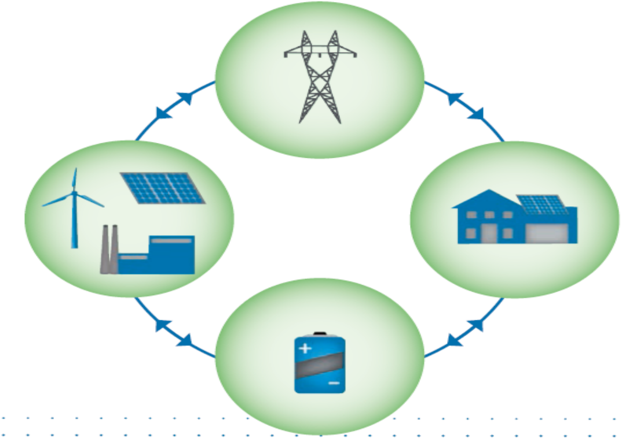
Introduction to Smart Grid

- The next generation power grid is evolving toward a “smart grid” concept with power generation and distribution that is not limited to large power stations but also other alternative sources.
- Smart grid can be defined as an **intelligent electric grid** that shares information between utilities and customers.
- A smart grid integrates the actions of all users connected to it and makes use of communications technologies to save energy, reduce cost and increase reliability and transparency.

Introduction to Smart Grid

- The smart grid will be characterized by a **two-way flow electricity and information**, creating an automated, widely distributed energy delivery network.
- It will allow delivery of real-time information that will help balance power supply and demand.
- To be successful, the smart grid initiative will require collaboration, integration, and interoperability among an array of technologies and disciplines.

Introduction to Smart Grid



Advantages

1. Smart grids enable consumers to manage energy usage down to individual networked appliances. Consumers can pro-actively manage their energy use.
2. Consumers will be able to take advantage of variable pricing by purchasing electricity when it is cheapest, generate their own electricity and sell it back to the grid.

Advantages

3 Utilities will be able to monitor the health of the grid, detect power outages instantly, and remotely sense damage to grid assets while locating and isolating the failure as repair crews are dispatched.

4 Smart grids allow utility companies to better understand power demand in near real time, so they can improve delivery and dynamically incorporate energy from different sources.

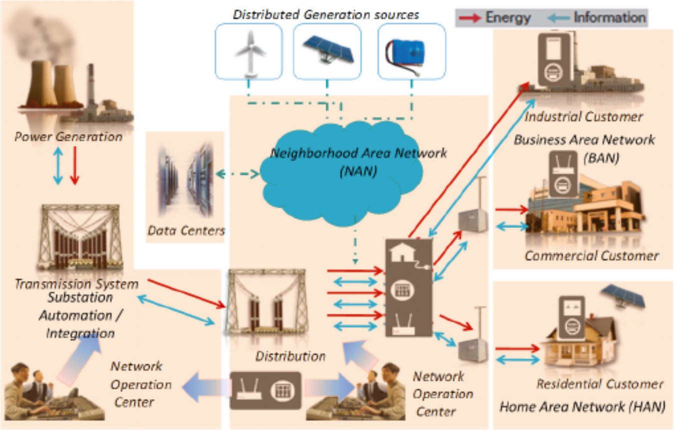
5 They support greater use of more sustainable and clean energy sources, such as wind and solar generation.

Architecture

- A Smart Grid system is based on a hierarchical architecture that performs data collection and control of electricity delivery and wherein each layer is comprised of several subsystems.
- The major layers of smart grid system comprises of:

1) SCADA system
2) Sensors and Meters
3) Communication Infrastructure and
4) Security Support.

Architecture



SCADA

- One basic subsystem of smart grid systems is the Supervisory Control And Data Acquisition (SCADA) solution - which is at the core of the monitoring and control of a substation. It is also called the **brains of the Smart Grid**.
- Sensors and other connected equipment on a smart grid provide a stream of data back to a central control room where SCADA system analyzes information and decisions are automatically made and executed.
- SCADA functions include regulating voltage levels, optimizing efficiency, routing and generation, self-healing etc.

Sensors and Meters Deployment

- Sensors and Meters in Smart Grids are part of the Advanced Metering Infrastructure (AMI) that have enabled replacement of old fashioned mechanical devices with "smart devices".
- Sensors and smart meters gather data for remote reporting.
- The installation of sensors and smart meters will trigger adoption of "energy aware" devices that can be communicated with.
- Sensors and smart meters keep track of the energy consumed from the electricity network.

Communication Infrastructure: Wireless Network

- It is very critical for Smart Grid to find the best communications infrastructure to handle the data delivery.
- Different communications technologies supported by two main communications media, i.e., wired and wireless, can be used for data transmission between smart meters and electric utilities.

Communication Infrastructure: Wireless Network

- In some instances, wireless communications have some advantages over wired technologies, such as **low-cost infrastructure** and **ease of connection** to difficult or unreachable areas.
- However, the nature of the transmission path may cause the signal to attenuate.
- On the other hand, wired solutions do not have interference problems and their functions are not dependent on batteries, as wireless solutions often do.

Communication Infrastructure: Wireless Network

- Basically, two types of communication infrastructure are needed for information flow in a smart grid system.

  (A) The first flow is from sensor and electrical appliances to smart meters.

  (B) The second is between smart meters and the utility's data centers.

- The first data flow can be accomplished through powerline communication or wireless communications, such as ZigBee, 6LowPAN, Z-wave, and others.

- For the second information flow, cellular technologies or the Internet may be used.

Smart Grid Communications Requirement

1 **Security**

- Secure information storage and transportation are extremely vital for power utilities, especially for billing purposes and grid control.
- To avoid cyber attacks, efficient security mechanisms should be developed and standardization efforts regarding the security of the power grid should be made.

Smart Grid Communications Requirement

2 **System Reliability and Robustness**

- Providing system reliability has become one of the most prioritized requirements for power utilities, this is because the system must always be functioning because of the nature of the data being served.
- Robustness means that it must withstand faults and other unforeseen circumstances and recover from failure.

Smart Grid Communications Requirement

3 **Scalability**

- Many smart meters, smart sensor nodes, smart data collectors, and renewable energy resources are joining the communications network.
- Hence, smart grid should handle the scalability with the integration of advanced web services, reliable protocols having advanced functionalities, such as self-configuration, security aspects.

Challenges to Implement Wireless Network in Smart Grids

A. Harsh environmental conditions

- In electric-power system environments, the topology and wireless connectivity of the network may vary due to link failures.
- Furthermore, sensors may also be subject to RF interference, highly caustic or corrosive environments, high humidity levels, vibrations, dirt and dust, or other conditions that challenge performance.
- These harsh environmental conditions may cause a portion of sensor nodes to malfunction or render the information they gather obsolete.

Challenges to Implement Wireless Network in Smart Grids

B. Reliability and Latency requirements

- The wide variety of applications envisaged for smart grid will have different quality-of-service (QoS) requirements and specifications in terms of reliability, latency, network throughput, etc.

- In addition, since sensor data are typically time sensitive, e.g., accidents in the electric power systems, it is important to receive the data at the controller node in a timely manner.

C. Packet errors and variable link capacity

- The bandwidth of each wireless link depends on the interference level perceived at the receiver, and high bit error rates are observed in communication.
- In addition, wireless links exhibit widely varying characteristics over time and space due to obstructions and noisy environment in electric power systems.

Challenges to Implement Wireless Network in Smart Grids

D. Resource constraints

- The design and implementation of Wireless Networks to connect sensors and meters are constrained by three types of resources:

  a) Energy; b) Memory; and c) Processing.

- For this reason, communication protocols mainly tailored to provide high energy efficiency.

Potential Technologies: ZigBee/IEEE 802.15.4

- ZigBee (IEEE 802.15.4) is a wireless communications technology that is relatively low in power usage, data rate, complexity, and cost of deployment.
- It is an ideal technology for smart lightning, energy monitoring, home automation, and automatic meter reading, etc.
- ZigBee has been realized as the most suitable communication standards for smart grid residential network domain by the U.S. National Institute for Standards and Technology (NIST).

Potential Technologies: ZigBee

Advantages

- ZigBee has 16 channels in the 2.4 GHz band, each with 5 MHz of bandwidth.
- 0 dBm (1mW) is the maximum output power of the radios with a transmission range between 1 and 100 m with a 250 Kbps data rate and OQPSK modulation.
- It is ideal for smart grid implementations because of its simplicity, mobility, robustness, low bandwidth requirements, low cost of deployment.
- It operates within an unlicensed spectrum and is a standardized protocol based on the IEEE 802.15.4 standard.

Potential Technologies: ZigBee

Disadvantages

- There are some constraints on ZigBee for practical implementations, such as low processing capabilities, small memory size and small delay requirements.
- It is subject to interference with other appliances which share the same transmission medium i.e. ISM frequency band ranging from IEEE 802.11 wireless local area networks (WLANs), WiFi, Bluetooth and Microwave.
- Hence, these concerns about the robustness of ZigBee under noise conditions increase the possibility of corrupting the entire communications channel due to the interference of 802.11/b/g in the vicinity of ZigBee.

Potential Technologies: Wireless Mesh

- Mesh network is a flexible network consisting of a group of nodes, where new nodes can join the group and each node can act as an independent router.
- The self-healing characteristic of the network enables the communication signals to find another route via the active nodes, if any node should drop out of the network.
- Every smart device is equipped with a radio module and each of them routes the metering data through nearby meters.

Potential Technologies: Wireless Mesh

Advantages

- Mesh networking is a cost effective solution with dynamic self-organization, self-healing, self-configuration, high scalability services.

- It extends the network coverage range allowing meters to act as signal repeaters noting that adding more repeaters to the network can extend the coverage and capacity of the network.

Potential Technologies: Wireless Mesh

Disadvantages

- Network capacity, fading and interference can be counted as the major challenges of wireless mesh networking systems.
- Choosing a sufficient number of smart nodes, taking into account node cost, are very critical for mesh networks.
- There can be loop problems causing a reduction of the available bandwidth.

Potential Technologies: Cellular Communication

- Existing cellular networks can be a good option for communicating between smart meters and the utility and between far nodes.
- The existing communications infrastructure avoids utilities from spending operational costs and additional time for building a dedicated communications infrastructure. environment.
- 2G, 2.5G, 3G, and LTE are the cellular communication technologies available to utilities for smart metering deployments.

Potential Technologies: Cellular Communication

Advantages

- Cellular networks already exist. Therefore, utilities do not have to incur extra cost for building the communications infrastructure required for a smart grid.
- Cellular communication coverage is extremely good. A huge amount of data will be generated and the cellular networks will provide sufficient bandwidth for such applications.
- Anonymity, authentication, signaling protection and user data protection security services are the security strengths of this approach.

Potential Technologies: Cellular Communication

Disadvantages

- Some power grid mission-critical applications need continuous availability of communications.
- However, the services of cellular networks are shared by customer market and this may result in network congestion or decrease in network performance in emergency situations.
- Hence, these considerations can drive utilities to build their own private communications network.

Potential Technologies: Powerline Communication

- Powerline communication (PLC) is a technique that uses the existing powerlines to transmit high-speed (2–3 Mb/s) data signals from one device to the other.
- PLC has been the first choice for communication with the electricity meter due to the direct connection.

Potential Technologies: Powerline Communication

Advantages

- PLC can be considered as a promising technology for smart grid applications due to the fact that the existing infrastructure decreases the installation cost of the communications infrastructure.
- The standardization efforts on PLC networks, the cost-effective, ubiquitous nature, and widely available infrastructure of PLC, can be the reasons for its strength and popularity.

Potential Technologies: Powerline Communication

Disadvantages

- The powerline transmission medium is a harsh and noisy environment that makes the channel difficult to be modeled.
- The low-bandwidth characteristic (20 kb/s for neighborhood area networks) restricts the PLC technology for applications that need higher bandwidth.

Summary of Potential Technologies

Technology	Spectrum	Data Rate	Coverage Range	Applications	Limitations
GSM	900-1800 MHz	Up to 14.4 Kpbs	1-10 km	AMI, Demand Response, HAN	Low date rates
GPRS	900-1800 MHz	Up to 170 kbps	1-10 km	AMI, Demand Response, HAN	Low data rates
3G	1.92-1.98 GHz 2.11-2.17 GHz (licensed)	384 Kbps-2Mbps	1-10 km	AMI, Demand Response, HAN	Costly spectrum fees
WiMAX	2.5 GHz, 3.5 GHz, 5.8 GHz	Up to 75 Mbps	10-50 km (LOS) 1-5 km (NLOS)	AMI, Demand Response	Not widespread
PLC	1-30 MHz	2-3 Mbps	1-3 km	AMI, Fraud Detection	Harsh, noisy channel environment
ZigBee	2.4 GHz-868-915 MHz	250 Kbps	30-50 m	AMI, HAN	Low data rate, short range

Smart Grid Standards

- There are many applications, techniques and technological solutions for smart grid system that have been developed or are still in the development phase.
- However, the key challenge is that the overall smart grid system is lacking widely accepted standards and this situation prevents the integration of advanced applications, smart meters, smart devices, and renewable energy sources.

A. Enabling Interoperability

A key feature of smart grids is the interconnection of a potentially large number of disparate energy distribution networks, power generating sources and energy consumers. The components of each of these entities will need a way of communicating that will be independent of the physical medium used and also independent of manufacturers and the type of devices.

A stable communication architecture of the future smart grid is yet to be defined. As a result, multiple communication technologies and standards could coexist in different parts of the system.

Current Issues in Research

For example, short-range wireless such as Bluetooth or UWB could be used for the interface between meter and end customer devices, IEEE 802.15.4 (ZigBee) and IEEE 802.11 (Wi-Fi) could be used for smart meter interfaces in the home and local area network, and cellular wireless (e.g. GPRS, UMTS, or 4G technologies like 802.16m and LTE) could be used for the interface between meters and the central system.

It can be envisaged that in a complex system such as this, heterogeneous communication technologies are required to meet the diverse needs of the system. Therefore, a current research issue for smart grid is making interfaces, messages and workflows interoperable.

B. Developing Security Framework

Analyzing and implementing smart grid security is a challenging task, especially when considering the scale of the potential damages that could be caused by cyber attacks.

Each case imposes different security challenges such as protection against single point failures or protection against multiple points of attack.

This threat becomes significant considering the potential openness of the system and its interconnections with different networks such as NANs and the Internet.

Current Issues in Research

Power stations and SCADA (supervisory control and data acquisition) systems have always been targeted by hackers.

The move from closed control systems to open IP networks opens up a new range of vulnerabilities. For example, data integrity and authentication may be compromised through network attacks such as man-in- the-middle spoofing, impersonation, or Denial of Service (DoS) attacks.

Similarly, data security may be compromised by sabotage/insider attacks such as viruses and Trojan horses.

A secure framework needs to be developed to address all the above issues.