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Smart Grid with Internet of Things

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Outline of Presentation

- Introduction to Smart Grid
- Importance and feature of SG (Smart Grid)
- Architecture of SG
- Communication network
- IoT role in SG
- Challenges of SG implementation

Introduction

Internet of Things is now the talk of every city. It witnessed a tremendous growth in every sector. From connected medical devices, connected cars, roads to smart grids for energy management.

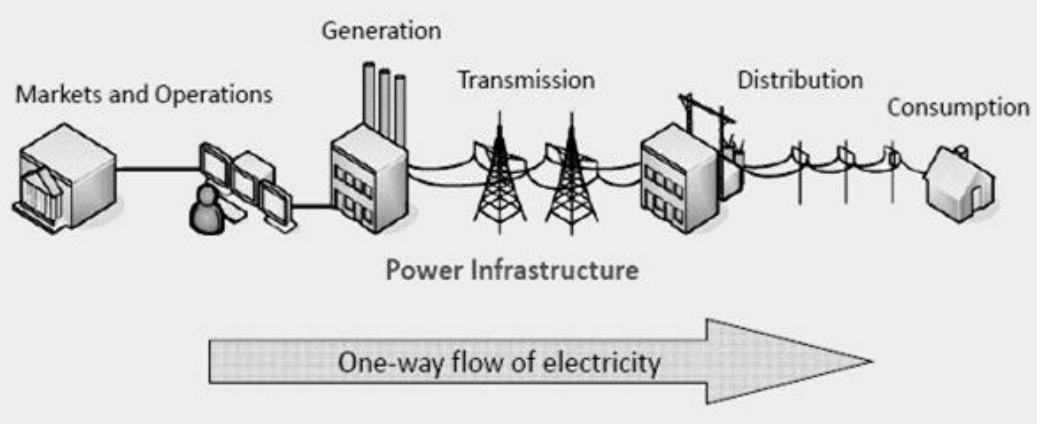
When we talk about energy management, smart grid is the first thing to appear. Internet of Things can play a significant role in developing smart grids which eventually leads to energy saving. IoT enabled smart grids are more about the energy efficiency and the management of energy consumption at the lowest cost.

What is Smart Grid

A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

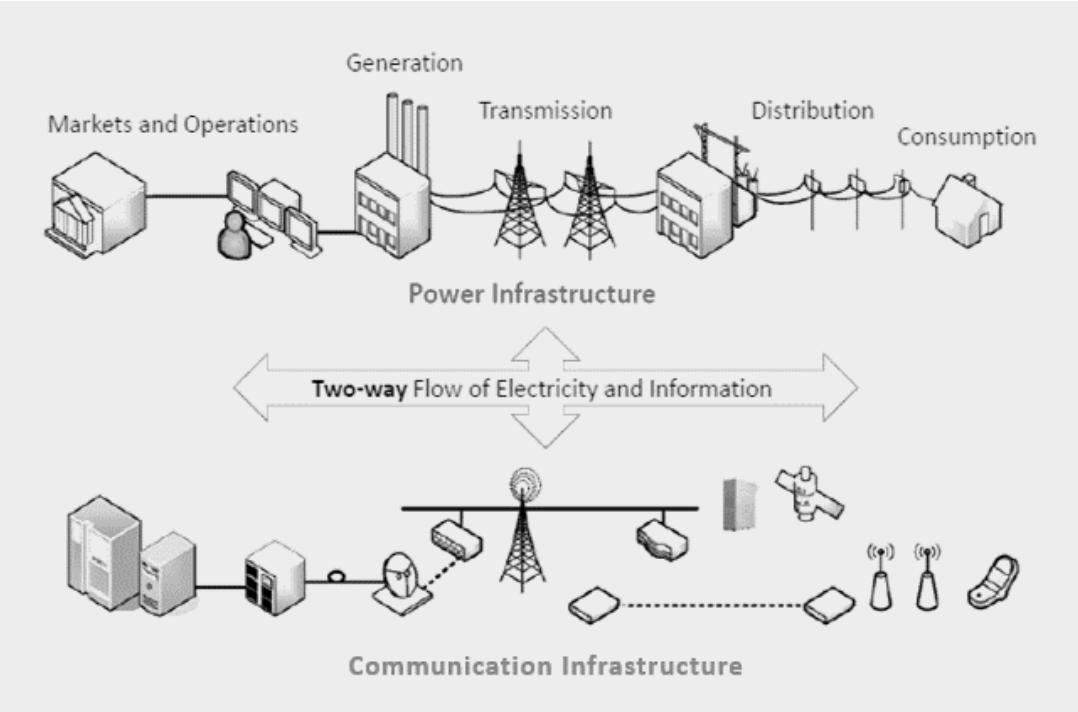
- Source: European Technology Platform Smart Grids

Traditional Power Grid



vs

Smart Grid



Why Smart Grid

Blackouts

Ageing Infrastructure

New Types of Load. Ex. Electrical Vehicle

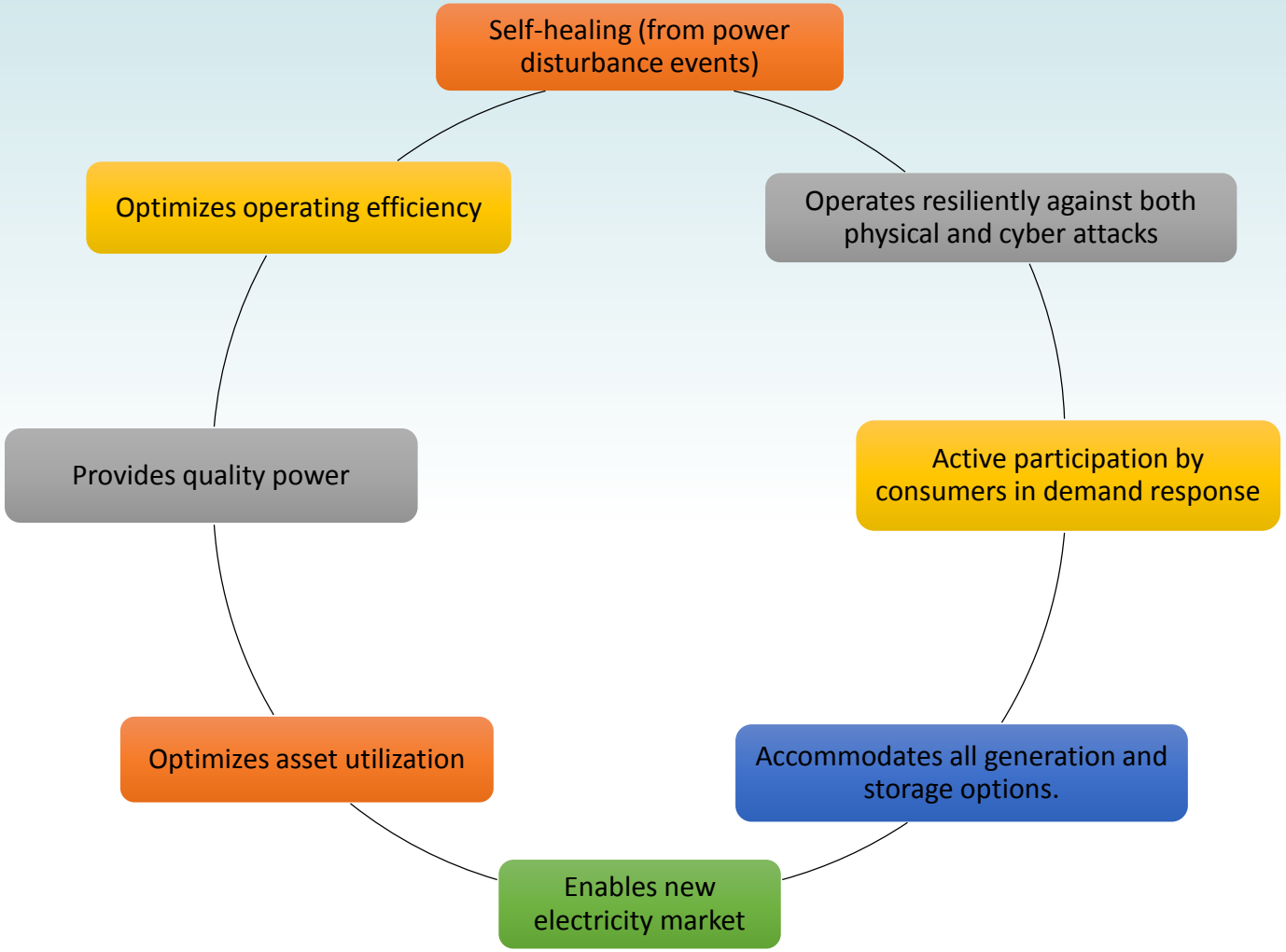
Lower Carbon Emission Necessity

Integration of Large Number of Renewable Generation Sources

Smart Grid Components

- **Smart Meter**
- **Phasor Measurement**
- **Information Transfer**
- **Distributed Generation**

Feature of Smart Grid



Smart Grid Architecture

- Conceptual model
- Electrical network
- Communication network

Conceptual Model

*Smart Grid is a large "**System of Systems**".* According to Smart Grid Interoperability Standards Roadmap proposed by NIST the American National Institute of Standards and Technology, the conceptual architecture for smart grid is composed of seven big domains

- Bulk Generation
- Transmission
- Distribution
- Customers
- Operations
- Markets
- Service Providers

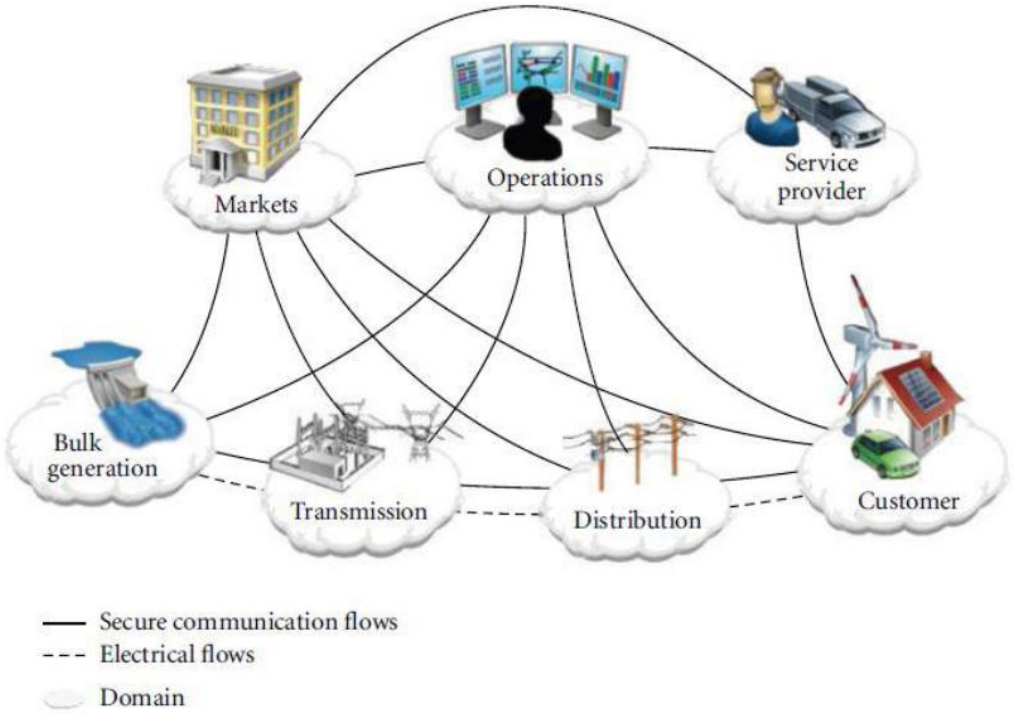
Conceptual Model

All these functional domains have different inter and intra domain communications

- *Consumer domain is the user of electricity domain such as domestic, industrial, commercial or utilities.*
- *Market domain refers to power market operators.*
- *Operation domain deal with power supply management.*
- *Service provider points service utilities companies providing customers with electrical power.*
- *Bulk Generation, Transmission and Distribution refers to generation, storage, transmission and distribution of power to customers.*

One of the key elements of smart grid's successful operation is the interconnection of these seven domains.

NIST Framework for SG



Source: National Institute of Standards and Technology framework and roadmap for smart grid interoperability

Electrical Network

Production Domain

composed of a mixture of nuclear, solar, coal, wind or hydro power plant

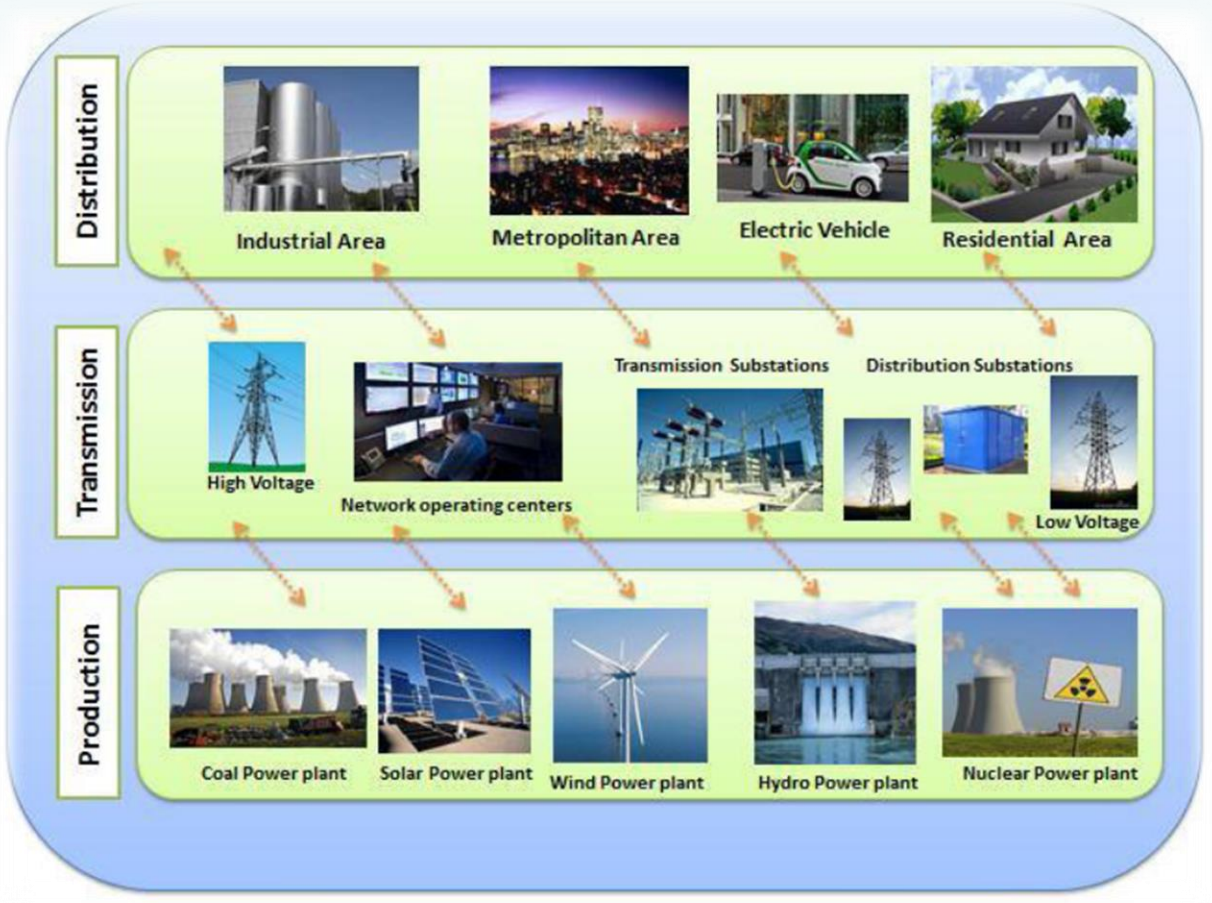
Transmission Domain

managed by huge number of network operating centers and substations, a large number of power lines deliver the electricity to distribution domain

Distribution Domain

sum of complex networks topologies delivers electrical power to residential areas, rural farms, metropolitan areas, and industrial areas for consumption

Smart Grid Electrical Network Architecture



Communication Network

Communication networks for smart grid systems use a big range of communication technologies from wired, wireless and hybrid networks technologies.

- *Home Area Network (HAN)*
- *Neighborhood Area Network (NAN)*
- *Field Area Network (FAN)*
- *Wide Area Network (WAN)*

Communication Network

HAN

- Customer domain network
- Covers in-home smart devices and appliances
- IED send data readings over HAN to AMI applications threw home smart meter or residential gateway
- Important component of HAN is the home energy management system (HEMS) that allows consumers to see real time power consumption of household
- BAN and IAN networks refer to HAN parallel networks when implemented respectively in business/buildings or industrial areas
- Wireless technology -ZigBee, 6LowPan

NAN

- Distribution domain network
- Mesh of smart meters
- NAN connects the AMI applications access point to smart meters in customer domain and various gateways in the distribution domain
- Main purpose of this network is data collection from smart meter for monitoring and control.
- Wireless-ZigBee, 6LowPan,WiMAX, LTE, 3G and 4G. Wired -PLC and Ethernet

FAN

- Distribution domain network.
- FAN include power line monitors, breaker controllers,voltage regulators, capacitor bank controllers, recloser controllers, transformers, data collectors, etc. These are used to response automatically when detecting any abnormalities and failure.
- Enables mobile workers to access field devices using their laptops, tablets or hand-held equipment.
- Wireless - WiMAX, LTE, 3G and 4G and wired - PLC and Ethernet could be used for FAN

WAN

- Affords communications systems between smart grid & core utility system.
- It is composed by two types of networks backhaul and core network.
- Core network offers the connectivity between substations and utility systems
- Backhaul network connect the NAN network to the core network.
- Variety of technologies such as WiMAX, 4G, and PLC could be used in WAN networks. Also virtual technologies like MPLS could be used for the core network.

Wireless Sensor Networks (WSNs)

Wireless sensor networks (WSNs) play a very important role in IoT as well as in the smart grid.

The wireless sensor networks are one of the most important technologies in 21st century. In a few years, sensors will be everywhere, in our houses, in the animals, even in the human body. Smart Grid network contains a large number of sensors that communicate wirelessly (specially in HAN and NAN) one to each other in order to exchange information.

IEEE 802.15.4 based protocol ZigBee and the IETF IPv6 over Low Power WPAN (6LoWPAN) are the two most commonly used protocol in HAN and NAN network. These are specifically designed for transmitting short-range and low speed data over wireless personal area networks (WPAN).

ZigBee

- ZigBee is the most popular, low-cost, low-power wireless mesh networking standard on the market right now.
- It is typically implemented for personal or home-area networks, or in a wireless mesh for networks that operate over longer ranges.
- A benefit of ZigBee is that nodes can stay in sleep mode most of the time, drastically extending battery life .
- It cannot easily communicate with other protocols, additional mechanism is required to communicate

6LoWPAN

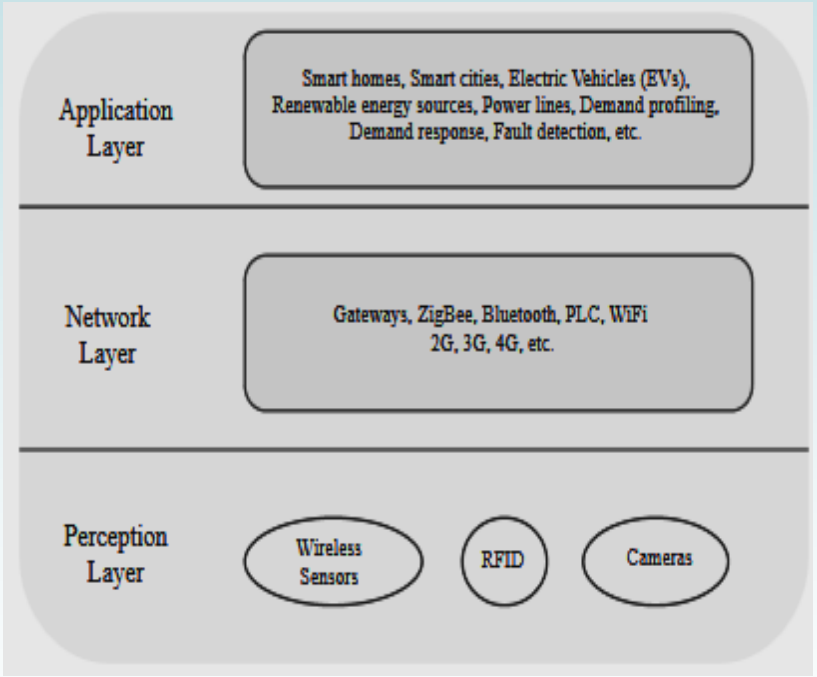
- 6LoWPAN allows for the smallest devices with limited processing ability to transmit information wirelessly using an internet protocol. It’s the newest competitor to ZigBee.
- Concept was created because engineers felt like the smallest devices were being left out from the Internet of Things. 6LoWPAN can communicate with 802.15.4 devices as well as other types of devices on an IP network link like WiFi.

IoT Role in Smart Grid

Deploying multi-level implementations

Due to the multi-layered architecture of the smart grid, the addressing mechanism should happen at multiple levels, such as the object layer level, communication layer level, and application layer level.

IPv6 can be used in multilayered smart grid infrastructure on multiple scales in homes, buildings, and smart cities through global , public or private IP address spaces depending on the scale of deployment.



Architecture of IoT in Application of SG

IoT Role in Smart Grid

Home energy management

IoT can play vital role to manage consumers' energy consumption profiles according to real time electricity price.

IoT components collect energy requirements of different home appliances and send them to smart meters.

The control unit in smart grid schedules energy consumption of homes' appliances by balancing user's and utility companies' preferences.

IoT enabled home storage devices intelligently interacts with the grid to understand the peak demand period and, if required, disconnects the home circuit from the grid to supply power on its own.

If required smart storage devices can add power supply to main grid. This two way electric flow convert consumer into prosumer.

Prosumer=Producer+ Consumer

IoT Role in Smart Grid

Integration of renewable energy

Renewable energy generators are being combined into today's power grid because of environmental reasons, climate change, and its low cost.

IoT technology uses wireless sensors to collect real-time weather information to help in predicting the energy availability in the near future.

IoT Role in Smart Grid

Electrical Vehicles Tracking

Electric Vehicles (EVs) are used as energy storage devices while they are idle.

IoT enabled perception devices collects information about electric vehicles'

- identity
- battery state
- location, etc,

to improve the efficiency of charging and discharging scheduling thus reduce emissions, shave peak load, and increase percentage of renewable power generation.

IoT Role in Smart Grid

Online Monitoring	Self-Healing
IoT is deployed for continuous online monitoring of *power plant* *transmission line* *distribution line* *energy consumption* *energy storage, etc.*	Deployment of IoT can also improve quality of smart grid's self-healing feature. Sensors can detect unpredictable conditions or breakdowns and response rapidly. Smart grid may switch from grid to islanded mode and operate in it until system is stable or breakdown is fixed.

CHALLENGES

One of the biggest challenges of implementing millions of new devices for the Smart Grid is that each of these devices could become a potential target for hackers, being in this sense security a vital point to be solved with full safeguards against intrusion by a third party.

Ukraine attack is a wake-up call, this attack was relatively short-lived. The next one might not be.

Around 3:30p.m. December 23 ,2015

Ukraine experienced the first confirmed cyber-takedown of a power system. Prykarpattya Oblenergo, a power distributor says 27 of its substations went dead. Immediately, 103 cities were "completely blacked out," and another 186 cities were left partially in the dark. Meanwhile, Ukrainian customers were unable to report about the blackout. The call centers at Prykarpattya Oblenergo and another energy provider, Kyivoblenergo, were blocked. Hackers launched a telephone denial-of-service attack against customer call centers
Within a few hours, electricity was flowing again. But the control centers were not fully operational even after two months later.

CHALLANGES

To deploy IoT enable local smart grid, numerous sensors have to be installed and the amount of transferred data will be significant. Big data management and storage is a big challenge.

Efficient interoperability between different communication networks is also a main concern of smart grid deployment.

Conclusion

Development of smart grid is unavoidable.

IoT can be a valuable solution to support it.

To make IoT in smart grids implementation possible, some economical, policy and technical challenges must be solved.

It will take long time to convert traditional electric grid to smart grid.

Currently mass installation of smart meter make it possible to control some home appliances by two way communication between in-house smart meter and control center.

Smart meter can give customers an opportunity to know real time pricing.

Real-time pricing provides a market signal to customers to reduce their use during peak demand. This approach will allow customers to take advantages of lower tariff and optimized energy cost at off-peak time and reduce blackout and carbon emissions.

Lower blackout and carbon emissions will make smart grid to lead green technology.

Despite many challenges, it's clear that we will need a move toward deployment of smart grid for greener, smarter energy.

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Thank You