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A Review on Sensor Network in Smart Grid

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***Abstract**: The traditional power grid in many countries suffers from high maintenance cost and scalability issues along with the huge expense of building new power stations, and lack of efficiency system monitoring that could increase the overall performance by preventing potential failure. To address these problems, a new generation electric power system called smart grid has been proposed as an evolutionary system for power generation, transmission, and distribution. It utilizes renewable energy generation, smart meters and modern sensing and communication technology for the effective power system. Traditionally, grid management has been realized through wired system formed by communication cables, which involves a heavy cost in terms of installation and maintenance of flexibility, self-organization, and rapid deployment. A smart grid uses digital technology to improve reliability, security, and efficiency of the electric system.*

Keywords: Wireless Sensor Networks, Smart Grid, Renewable Energy, Application, Issues.

I. INTRODUCTION

A wireless sensor network consists of a spatially distributed autonomous sensor to cooperatively monitor physical or environmental conditions [1]. In the smart grid, wireless sensor network comprehensively senses (monitors) the specific objects, collects the useful data and controls devices, which makes WSN in smart grid, allowing two-way information exchange, monitoring, control and maintenance in real-time [2,3,4]. The traditional grid system is a centralized and unidirectional system as the power flows out to the consumer from a power generation and distribution station [5]. Smart grid is an intelligent power grid which allows sharing of information between customers and utilities. Our current electric power system is based on the smart power grid system for power generation, distribution, and consumption. Smart grid technology is based on the renewable energy resources such as solar energy, wind energy etc. smart grid provides better distribution system in which power will flow among the various stations such as central power stations, renewable energy centers, small distributed energy generation centers, electric vehicles, smart homes and smart buildings. WSN with the smart grid is depending on the two-way communication systems, customers will interact with the network, both while providing power consumption data and even in feeding back the produced energy into the grid. Smart grid technology is digital in nature rather than electromechanical so that it will provide real-time pricing and net metering. In the power grid, the daily operation will shifts from manual equipment checks to remote monitoring and predictive time- based maintenance by many specialized sensors [2, 3]. In smart grid technology, we use smart meters and the Advanced Metering Infrastructure (AMI), it will be easy to communicate with the consumers, monitor and control their power consumption. Consumers will need more advanced home automation tools which can be implemented by using advanced sensors technologies [6].

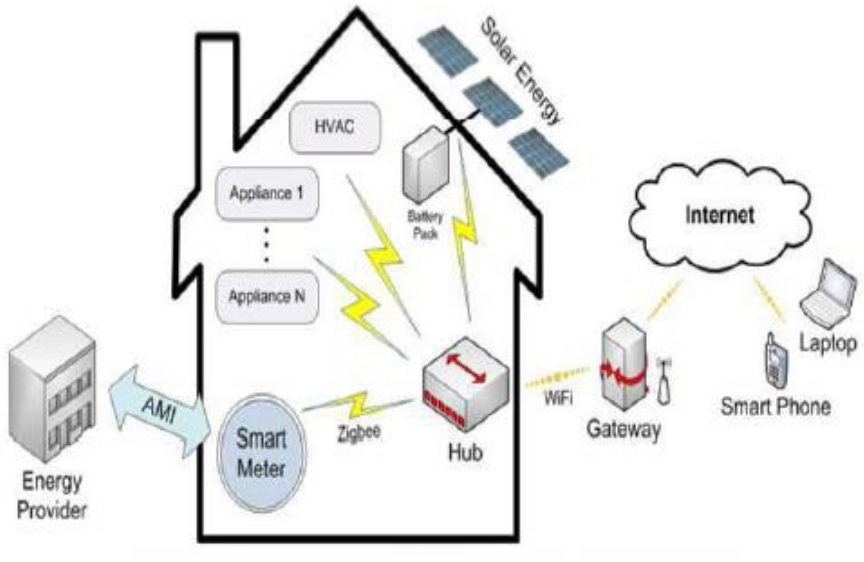

Fig.1. Home Automation Model

This model composes the Zigbee network which allows the hub to communicate with different components. HAN implements the two-way communication, hub receives the information from different components, and on another side, it will communicate with the outside world through the gateway by using Wi-Fi or Ethernet.

II. RELATED WORK

A. Wireless sensor network

WSN in smart grid allows the two-way information exchange, monitoring, control and maintenance in real time. It works on digital technology rather than electromechanical, which enables the real-time pricing and net metering. It gives the more collaborative and low-cost natural wireless sensor networks gives a more significant advantage in traditional communication technologies for the current power grid. WSN enhances the various aspects of today's electric power systems, including generation, delivery, consumption, and dispatch, making them a vital component of the next-generation electric power system, the smart grid [2]. The advantages of the WSN in the smart grid: low-cost infrastructure, rapid deployment and flexible connection to difficult areas, aggregate intelligence via parallel processing [7] [8].

B. SMART GRID

One of the main developments and important technologies in the power system is the Smart Grid [9]. The smart grid has an intelligent power system, which includes sensing, inspection, communication, IT, energy and new material technology and so on. The basic and key technology in the smart grid is the advanced micro-sensor networks and communication technology [1, 2]. For the construction of the smart grid, intelligent and automation requirements are proposed for the traditional substation. As the important part of the smart grid, the electrical substation consists of many smart devices supported by the intelligent MIS integrated with the technology of wireless sensor network [3,10]. Smart Grid also unlocks the enormous potential of the current power grid such as: the push of the renewable energy source, improve the safety and stability of the power supply with the participation of consumers [11]. Smart grid is the emerging new power grid that uses information and communication technology to gather and act on information, to provide automatic control to improve the efficiency, reliability, and sustainability of the existing power grid [12-17].

C. WSN communication via Zigbee

Zigbee has a short-range, low-data-rate, energy- efficient wireless technology; it works based on the IEEE 802.15.4 standard. Zigbee has 16 channels in 2.4 GHZ ISM band worldwide, 13 channels in 915 MHZ band in North America and one channel in 868 MHZ band in Europe. Its allowing data rates are 250 kbps, 40 kbps, and 20 kbps. Its range is 30 meter indoors. It has to support 16-bit and 64-bit addressing modes, and 64000 nodes (devices).

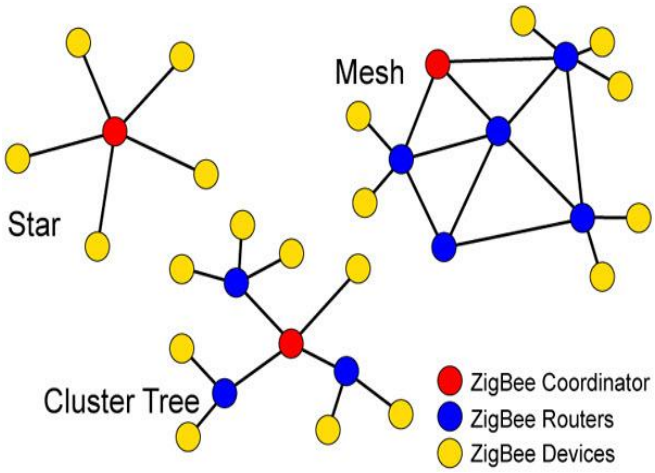

Fig.2. Zigbee Network Topology

Zigbee has two types of devices which are full function device (FFD) and reduced function device (RFD). FFDs are communicated with their peers while RFDs are simple than FFDs and they have edge nodes in a star topology. In Zigbee, sensor nodes organized either in a star topology, mesh topology, or a cluster-tree topology. WSNs are organized in a star topology. Zigbee has a personal area network (HUB) coordinator. Hub coordinate is operated in beacon-enabled mode or beaconless mode [18-19].

III. EVOLUTION OF SMART GRID

DATA Smart grid is an intelligent technology, in which electricity distributors focused on three key areas: household devices are used for an automated meter reading of electrical usage, remote sensing devices are used for monitoring and control of the electrical network and management of distributed power energy sources such as solar at home. There are several other grid enhancements which are also addressed including smart (real-time) pricing, in-home energy saving devices, and support for hybrid electrical vehicles [20].

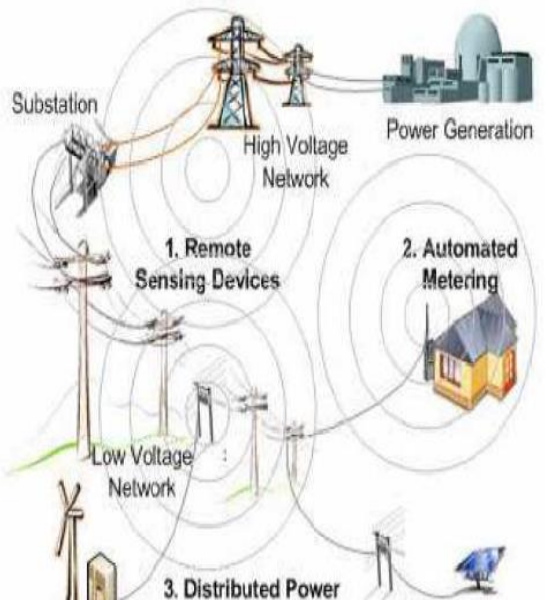

Fig.3. Smart Grid System

These are the key elements of the smart grid, automation metering, remote sensing devices, and distributed power. These elements create increased demands of adhoc communication between various devices.

A. Remote Sensing: Monitoring and control

Remote sensing of the network is taking in energy distribution grid using supervisory control and data access (SCADA) solution. These systems used to monitor and control other utilities such as gas and water. In electrical grid these systems are used in high voltage (132 kV) networks, includes high voltage switches, transformers, and transmission lines. But now the electrical grid is transformed in smart grid, so these control and monitoring points are also increases. The smart grid has three essential components remote sensing, monitoring, and control. They provide better manage network growth, improve utilization of the grid, and reduce time to repair network switching elements.

B. Automation Metering

Automation metering is also called smart metering which read customer's electrical usage, manages load control, monitors for electrical faults, and supports appliance level reporting. All these functions require two-way communication channels.

C. Distribution power

Distributed power such as photovoltaic, wind and solar are induced by the industries to meet the future needs. The injection of power through these sources not only requires the automation metering but also requires fine-grained monitoring and control. It provides secure and reliable communication to urban and remote locations. Grids are also providing the support to electrical vehicles, granular support is necessary to manage both distributed (home) and monolithic (power station) distribution of power for vehicle refueling (recharge).

IV. APPLICATION

A. To WSN in the power generation

In the power generation, power generation devices and environment are sensed by the sensors. Generators are key equipment in the power plants, thus it is very important to ensure the safety and stability of them [21]. There are various sensors such as balance sensors, smoke sensors, and magnetic field strength sensors etc. which monitor the states of generators. The data receives from sensors are used to know the detailed state of generator and environment, and then will do the fault diagnosis, early warning, optimal scheduling etc.

B. WSN in power transmission

The transmission lines are used for transmitting the power resources to substations, user-side etc., which is necessary to protect and monitor the transmission line. Due to the accident occurred such as the coal mining, construction, and other external damage, the transmission line faces a significant threat to the safe operation of the grid [2, 22]. Moreover, there are large numbers of power towers in more broad scope, and relying on the daily inspection of the transmission line patrol officers, it is difficult to achieve timely and accurate discovery of fault occurs [23,24].

C. WSN in the power substation

The substation has a critical role in power systems, smart substation combines the power grid management with the communication management. In smart substation, there are types of sensing devices which sense the objects and monitor the devices such as SF6, temperature, humidity etc. in figure 4 and 5.and it transmit the parameters and data to the intelligent systems, which has ensured the secure delivery and effective management of the data and information to users, and enhancing the availability, reliability, safety, risk management in smart Grid.

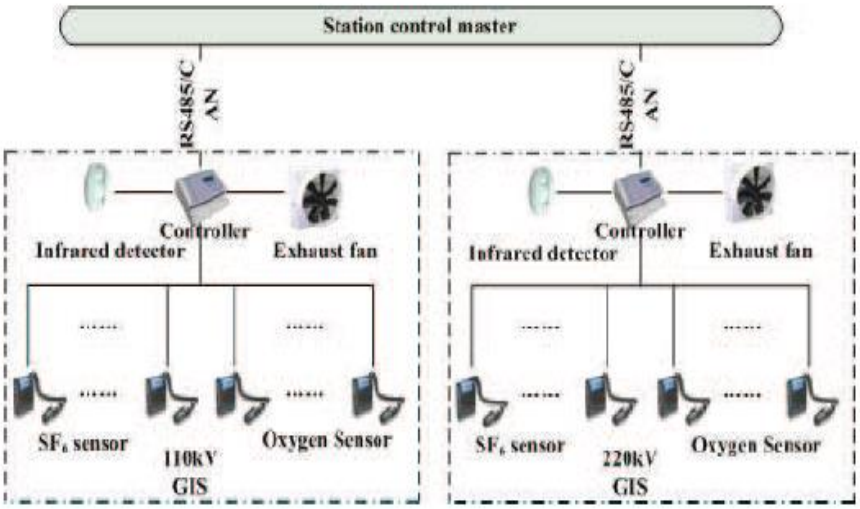

Fig.4. SF6 in substation

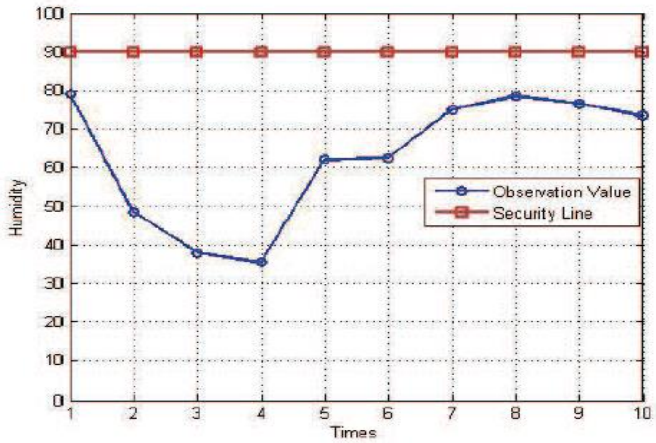

Fig.5.The humidity in smart substation

D. WSN in power distribution

For the power distribution, most of the companies adopt the scheduling acquisition and supervisory control (SCADA) system to manage the distribution system. For power distribution, they start the support system that is based on IEC 61968/61970/61850. For collecting the information timely and accurately, we deployed many sensors to detect or sense the objects in the distribution system, such as current and voltage sensing, fiber optic temperature sensing, power grid interface detection.

E. WSN in the power consumption

WSNs are widely used in many applications such as the smart home, electric vehicles, advanced metering infrastructure, and power grid emergency management etc. To achieve the convenient management, smart grid adopts the three-dimensional visualization display for the full range of detection. Data visualization provides the graphical representation of data in a format that allows a qualitative understanding of the information provided in figure 6 [25, 26].

Fig.6 The 3D inspection of transmission line

V. COMPARISION OF WSN WITH TRADITIONAL WIRELESS NETWORKS

In WSN the architecture, addressing methods, the communication modes, and routing structure are different from the traditional network. WSN have more sensing nodes, no supplementary of energy, and energy has constrained in a WSN nodes. In order to improve the network lifetime, routing protocols are involved for to reduce energy consumption and load balancing. The characteristics of the routing protocols for wireless sensor networks are:

Restricted Energy: As we know that in wireless sensor network there are numerous nodes with weak mobility and irregularity in energy supply, so energy consumption is one of the challenges of the WSN

Local Topology Data: In WSN the big challenge is to save energy and ensuring some efficient routing mechanism because the energy is limited.

High Topology Changes: In WSN there are number of nodes, it is difficult to move but its network topology is non-stationary, requested its high routing protocol to adapt to the topology changes.

Particular Application: WSN have a wide variety of application, there is no routing mechanism suitable for all application, and different applications adopt different systems.

Large Data Redundancy: WSN have random distribution of nodes, so there is a huge chance that multiple nodes collect the same data.

Due to a large number of sensor nodes and high density, sensor node energy, computing power, and storage capacity have limited. Hence, a new concept has introduced in smart grid WSNs by SDN controller (open flow), in which the entire system is controlled by "controller" part of the SDN. SDN is software- defined networking has allowed a network administrator to manage network services through low-level networking functionality.

I. ISSUES

Due to the complexity of the infrastructure and environment, WSN in smart grid is vulnerable and fragile. More is the complexity of the system more is the chances of failure. If the planning and designing are not proper than the system will give worst reliability performance than expected and in WSNs there are some issues which are to be resolved.

A. Recourse

Sensors in the smart grid have supported by the batteries, these batteries provide only limited energy. Moreover, usually, sensors have the inherent imperfections, such as small storage and low computation, which makes it impossible to deal with large or complex information or processes [2]. These limited recourses have required the protocols, such as transmission protocol, security protocol etc., has lightweight and also require reducing the data transmission in smart grid to save energy.

B. Reliability

The reliability refers to the stability and veracity of the signal transmitted in the network [27]. Sensors have usually deployed in harsh environments, and complex system of smart grid may undergo to operational failure, without proper planning and design it will provide worst reliability performance than expected. Due to the difference in environment and function, sensor networks in the smart grid have a different quality of service (QoS), reliability and delay [28]. Radio frequency interference, corrosive environment, high humidity, vibration, dust particles have seriously affected the transmission of information through the sensor nodes.

C. Security

The security has the most important requirement for the smart grid. Because sensors have deployed for sensing or monitoring the important parameters of the power grid, and collect useful information for various application systems. However, there are many attacks such as eavesdrop, replay, Sybil, tamper, jamming attacks and so on [29]. These attacks affect the smart grid, happens on the sensor nodes, wireless networking and communication protocols. So it is essential to establish some lightweight secure protocols to defense those attacks. The below figure give the security architecture of WSN for smart grid and improves the WSNs security.

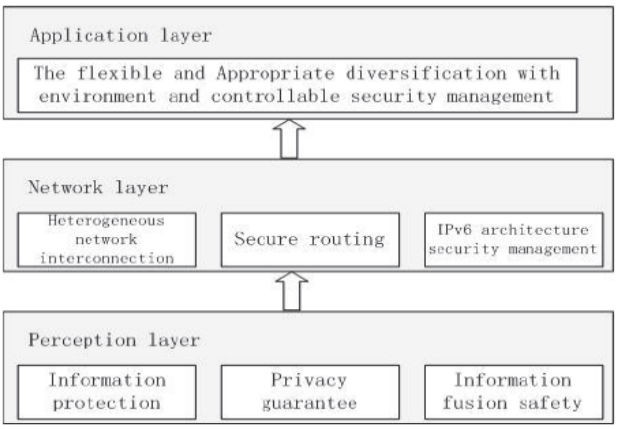

Fig.7.The security of WSN in different layers in smart grid

CONCLUSION

By using the tradition grid in power generation, transmission and distribution, it suffers efficiency degradation, so we move toward the smart grids based on wireless sensor networks which are highly efficient. It provides high data rate, low power consumption. By consuming low power it works for a long time without any backup source. For the power generation, we use renewable energy resources so that it will reduce the global warming problem. In WSN we use Zigbee protocol as compare to the Bluetooth and Wi-Fi. Zigbee provides high transmission data rate with low power consumption. Zigbee is also cheaper than other WSN protocols, it is based on the IEEE 802.15.4 standard which provides the low power consumption. Star topology based wireless sensor network is used to working in harsh environment, which provides more accurate results. The IEEE 802.15.4 standard provides low power, low data rate based wireless sensor network.

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