Internet of Things Integration in Smart Grid

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***Abstract*— Electricity as the primary source of power for gadgets, computers, machinery, and other electronic goods is used at the home-to-industrial level. Most of the world's Electric Grids operate on fossil fuels which are getting thinner and expected to run out soon, the best solution that is possible to do is Smart Grid. The Smart Grid realized extensive use of information sensing, transmission and processing. Today, IoT technology become a essential role in construction of power grid. This paper reviews the Integration of IoT in Smart Grids. IoT-integrated Smart Grid systems are already deployed, but the full capabilities of instant knowledge and sustainable large-scale data processing have not been exploited optimally. Two of the architectures of IoT integrated Smart Grids is four-layered architecture and Web Enabled Smart Grid. To process and manage the Big Data in Smart Grid, Supervisory Control and Data Acquisition (SCADA) system can be used and furthermore enhanced with cloud computing. The smart grid is the future of electric grid that solves the problems of information flows, rising energy consumption, energy waste, reliability and security in the conventional power grid.**

Keywords- Internet of Things, Smart Grid, Electric grid.

I. INTRODUCTION

To live in the era of rapidly evolving technology today is not possible without the existence of electrical energy. Electricity as the main source of power for gadgets, computers, machinery, and other electronic goods is used at the home-to-industrial level. For example at home, shops, offices, factories, hospitals, schools, on the streets, or in other public places. In Indonesia, electricity demand is fulfilled by PLN. PLN is a State-Owned Enterprise (SOE) company so that the use of electricity is still largely subsidized by the government. PLN service that often extinguishes rotating electricity and sometimes without notice causing losses of many parties. The industrial world as the largest electricity user will certainly feel the most significant impact if there is a power outage. Losses suffered certainly not small. According to kompas.com (1/10/2009) due to rotating power blackouts, the business world in Jakarta loses Rp 100 billion per day [1]. Power outages in one city could cost hundreds of billions, not to mention hundreds of other cities. So, if calculated, losses experienced by the world of industry Indonesia reached Trillion figures every time a power outage happened.

Most of the world's power plants operate on fossil fuels. The fossil fuel reserves are getting thinner and expected to run out soon. At the World Economic Forum 2010, it was revealed that coal-fired power plants in the US accounted for 40% of the country's carbon emissions [2]. The availability of sufficient electrical energy is something that must be maintained for the sake of human survival. So the best solution that is possible to do is the Smart Grid. Smart Grid has been the answer since last three years [2]. Smart Grid is a concept of electrical energy governance that can accommodate the role of a small electric power plant that combines renewable energy optimally [3]. The Smart grid infrastructure is a dynamic interactive concept that includes a variety of power generation systems and electricity distribution. [4]. smart grid is a power grid that is more reliable, more efficient, and more "smart" than existing conventional electricity networks.

One of the technologies that will be the backbone of smart grid implementation is the technology of information and communication, specifically the Internet of Things (IoT). IoT is a network consisting of various sensors and devices that perform information processing consisting of an infrared sensor, laser scanner, global positioning system (GPS), radio frequency identification (RFID), and internet.

The power grid/electricity system plays a major role in the conversion of energy from energy sources to all activities that are useful to support economic development. Sustainable development depends on the future power grid that supports it. A well-functioning smart grid will be able to contribute to (1) reducing carbon emissions from energy sources, (2) increasing efficiency in the process of energy conversion and end use, and (3) environmentally friendly transportation [5].

II. SMART GRID

Smart Grid is a modern electrical grid concept that has been planning, developing and researching since 2007. Several countries in America and Europe have been very intensive to realize the technology. In the USA the smart grid implementation is coordinated by the Department of Energy (DOE) together with EPRI (Electric Power Research Institute) with its project called "Intelligent Grid", this project develops the communication process between the power grid with a computer to improve the reliability of the power system and service to consumer [6]. Also, DOE

978-1-5386-7548-9/18/$31.00 ©2018 IEEE

also affiliates with the industrial sector through the Grid wise program. The focus of this program is to define the communication design and smart grid standards, simulation and analysis tools, smart technology, test infrastructure, and demo plant, legal umbrella, and market framework.

Meanwhile, Smart Grid European Technology Platform (ETP) has a vision that power system network in Europe must be flexible in meeting consumer needs, easy access, reliable and economical. To realize that vision the main requirements include: (a) creating a technical solution that can be applied cost-effectively to accept the integration of all sources of electrical energy. (b) harmonizing regulations and facilitating cross-commercial structures in Europe in the service of electrical energy. (c) issuing technical regulations and standards. (d) develop an IT-based system. (e) ensuring the successful integration of the old system design with the new system [6].

Indonesia is currently continuously developing Smart Grid because Indonesia is projected to require energy around 457-Terawatt Hour (TWh) in 2025. Therefore, to meet the needs, it is necessary to apply the Smart Grid network system. This system does not increase the electrical energy generated from the plant but regulates electrical distribution according to customer needs through electrical sensors and software [7].

Until now, there is no mutual agreement on the definition of the smart grid. Each country and research institute of the world defines smart grid differently, but generally has the same framework, According to the National Institute of Standards and Technology (NIST) smart grid can be defined as a network of electric power systems that use two-way information technology, secure cyber communication technology and intelligence of computing integrated in the entire spectrum of electrical energy systems ranging from generators to consumers [8]. While the smart grid according to the Department of Energy (DOE) USA is a power system based on sensing technology, communications, digital control, information technology (IT) and other field equipment that serves to coordinate the existing processes in the power grid making it more effective and dynamic in its management [9]. At International Electrotechnical Commission (IEC) in 2010 Smart Grid is defined as a smart electricity network capable of integrating the actions or activities of all users, from generation to consumer in order to be efficient, sustainable, economical and safe electricity supply [10].

The feasibility and reliability of the power supply are a vital parameter in energy distribution, especially for cross-application or operator. The information available in each generator, transmission and distribution area is usually only for each local power grid, and the system data has not been based on real-time data. This is a challenge in the future so that the electricity network can be more qualified with a high level of reliability and safe from interference. The inefficiency of existing systems is one of the things that encourage the presence of smart grid paradigm. The general comparison between the traditional grid and smart grid can be seen in table 1 [11]:

TABLE I. COMPARISON OF THE CONVENTIONAL GRID AND SMART GRID

Characteristics	Conventional Grid	Smart Grid
Technology	Electromechanical	Digital
Distribution	One-Way Distribution	Two-Way Distribution
Power Generation	Centralized	Distributed
Sensors	Few Sensors	Sensors Throughout
Monitoring	Manual	Self/automatic
Restoration	Manual	Self-Healing
Control	Limited	Ubiquitous
Customer Choices	Few	Many

III. INTERNET OF THINGS

The Internet of Things concept was proposed by members of the community developing Radio Frequency Identification (RFID) in 1999. At present, IoT is very relevant to world conditions due to the growth of ubiquitous communications, cellular devices, data analysis, and cloud computing [12]. Internet of Things (IoT) is when billions of objects can communicate with each other and share information, all devices are connected through public or private Internet Protocol (IP) networks. these interconnected devices have massive data that is collected frequently, analyzed and used for various purposes such as: providing intelligence for planning, management and decision making. [13,14]. Internet of things common definition is: Internet of things (IoT) is a network of interconnected devices. The internet is not just a computer network, but has evolved into a network of various types of devices, smartphones, household appliances, toys, cameras, medical devices, vehicles, and industrial systems. Humans, animals, plants, and buildings, all connected, communicated and shared information through standardized protocols to achieve intelligent organization, security, control, positioning, real-time online monitoring, and online updating. [13,14].

The Implementation of the Internet of Things enables wider communication through the Internet to various objects around us. Technology Enabler that allows the implementation of the Internet of Things for communication between objects includes: sensor networks, GSM, GPRS, 2G / 3G / 4G, WI-FI, GPS, RFID, microcontrollers, microprocessors, and so on.

The Internet of Things is a combination of different hardware & software technologies. The Internet of Things integrates information technology, which refers to hardware and software used to obtain, store, and process data and communication technology that includes electronic systems that are used for communication between one object or several objects at once. The combination of heterogeneous communication technologies needs to be adjusted to meet IoT application requirements such as reliability, speed, security and energy efficiency.

There are various potential applications from IoT to almost all areas of the life of companies, individuals and society as a whole. implementing IoT includes "smart" environments in domains such as Lifestyle, Retail, Agriculture, Factories, Transportation, Buildings, Cities, Culture and Tourism, Emergency, Health Care, User Interaction, Environment and Energy [14]. IoT implementation in Smart Grids can be grouped into three types. First, IoT is applied to gather information from equipment through various communication technologies. Second, IoT is applied to monitor equipment conditions through various smart devices. Third, IoT is applied to control SG through the application interface.

IV. Integration of IoT into Smart Grid

Smart Grid has a broad implementation in retrieving, transmitting and processing information, and has network functions. IoT technology provides real-time network connections between users and devices through a variety of communication technologies and IoT smart devices, to get data sharing in two directions, real-time, and high speed to increase the efficiency of Smart Grid [15]. The Smart Grid system that is integrated with IoT has been regulated and implemented, but the full capabilities of instant knowledge and sustainable large-scale data processing have not been exploited optimally. IoT implementation covers several areas such as Adjusting home consumption with dynamic scheduling, electricity monitoring, system monitoring and maintenance, demand and management, charging and parking of electric vehicles, [16]

For a better description of the IoT in Smart Grid, see figure 1.

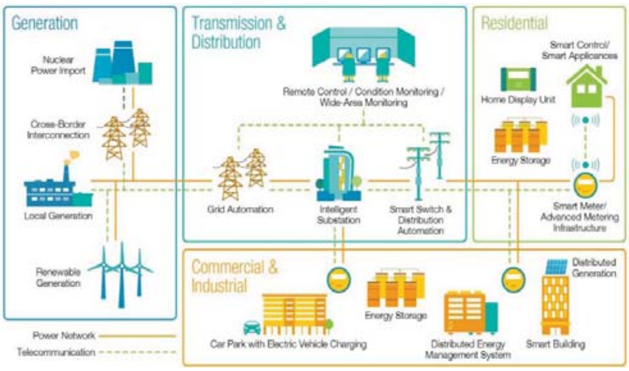

Fig. 1. Integration of IoT-in Smart Grid systems [17]

V. IoT in Smart Grid Integration Architectures

A. *Four layered IoT in Smart Grid Architectures*

The four-layer architecture for IoT in the Smart Grid system consists of the terminal layer, field network layer, remote communication layer, and master station system layer, see Figure 2 [18].

The terminal layer consists of IoT support devices used to run various Smart Grid functions, such as electricity generation, transmission, distribution and utilization of electricity. IoT devices includes: remote terminal units, information gathering devices, smart meters, and various intelligent electronic devices. This layer collects information from various IoT devices and transmits the collected data to the field network layer. The field network layer can be wired or wireless. Depending on the type of IoT devices, the appropriate communication network is used to transmit the collected data to a remote communication network layer.

The wired or wireless remote communication network layer consists of various communication networks that support Internet connections, optical networks as cable networks and 2G, 3G, and LTE as wireless networks. This layer functions as a middleware between various IoT devices and the master station system layer. The master station system layer functions to control and manage all Smart Grid functions. the master station system can also be considered as an interface for implementing Smart Grid integration with IoT.

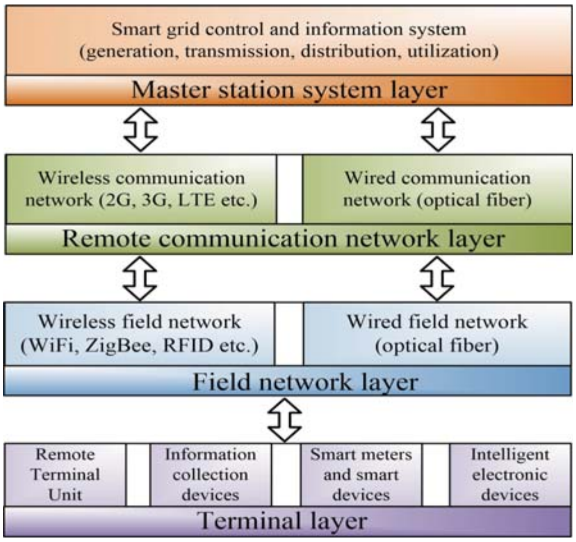

Fig. 2. Four-layer architecture for IoT-in Smart Grid systems [18]

B. *Web-Enabled Smart Grid Architectures*

An architecture for SG systems that is integrat with IoT is proposed based on web of things (Figure 3). The web of things consists of several diverse web services using various IoT devices where the web browser functions as an interface to the web service [19]. In general, there are two types of electrical energy sources, non-renewable and renewable energy sources. Non-renewable energy sources such as thermal power plants (coal or oil) release carbon emissions into the environment, there are also nuclear power plants. Environmentally friendly renewable energy sources consist of hydroelectric power, wind power, solar power, geothermal and tidal sources, also biogas and biofuel.

The energy source in this architecture is connected to individual smart digital energy meters. This smart digital energy meter serves to collect energy consumption data. Meter readings from non-renewable and renewable energy sources are brought together by separate IoT gateways that communicate regularly with these smart meters. The data collected from the IoT gateway is updated to the server regularly, and the server provides web services on this IoT device. This web service also includes houses location information connected via meter information and Smart Grid.

In addition, scheduling and controlling energy sources for each home can be done by switching source controllers remotely through web services provided by IoT devices. By connecting to various internet-connected devices, users can access this service. The energy source for each house can be switched through a source changer that is controlled through an IoT device after receiving instructions from users through the server.

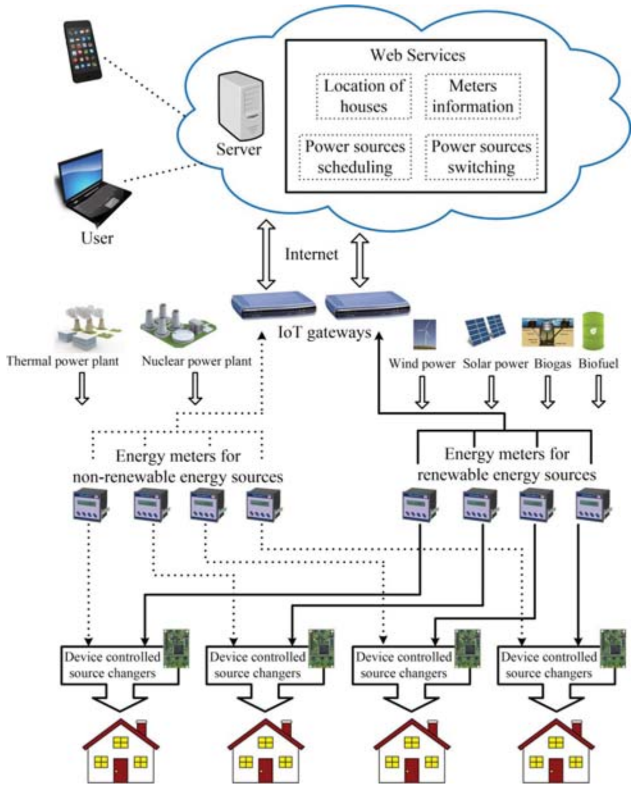

Fig. 3. Web Enabled Smart Grid Architectures [19]

VI. BIG DATA AND CLOUD FOR IOT-AIDED SG SYSTEMS

Integration of IoT technology with Smart Grid results in the need to manage very large volumes of data, with regular processing and storage [16]. These data include consumer energy demand, energy consumption, advanced meter recording, blackout management records and forecast of grid conditions, network component status, and power line faults. This causes electricity companies to have hardware and software capable of storing, managing and processing data collected from IoT devices effectively and efficiently.

the Supervisory Control and Data Acquisition (SCADA) System in Smart Grid, is a central element of decision making [16]. SCADA collects data from IoT devices that are distributed throughout the grid, monitors and controls them online and real-time. In addition, it helps to manage power flow throughout the network to improve consumption efficiency and reliability of electricity supply. In general, SCADA is located on various sites of the electricity company. With the increasing size of SG, electricity companies face challenges in keeping the SCADA system constantly updated and upgraded. To overcome this problem, cloud computing is one of the best solutions for hosting a SCADA system. Cloud computing provides on demand access to a collection of shared computing resources, such as storage, servers, networks, computing, applications, and services.

Fig. 4. SCADA System Control Center in the UK[20]

VII. CONCLUSION

Smart grid is a future electric grid based on sensing technology, communications, digital control, information technology (IT) specifically the Internet of Things (IoT) and other field equipments that function that solves the various problems such as information flow, energy wastage, growing energy demand, reliability and security in the conventional power grid. The Internet of Things (IoT) supports Smart Grid by using smart devices or IoT devices such as sensors, smart meters, and actuators to monitor, analyze and control the grid, as well as to connect, automate, and track various devices. There are multiple architectures of IoT integrated Smart grid system that helps and improve various network functions from power generation, transmission, distribution, and utilization.

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