2021 1st International Conference on Power Electronics and Energy (ICPEE-2021)

Study of Energy Management System and IOT Integration in Smart Grid

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2021 1st International Conference on Power Electronics and Energy (ICPEE) | 978-1-7281-8774-7/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICPEE50452.2021.9358769

***Abstract*—Increasing energy demand, rising energy costs and unpredictable energy markets are factors that have led consumers and utilities to search for optimal ways of controlling, monitoring and saving of energy. The power system has to continuously improve to adapt to new types of loads and generating techniques, which increases the complexity of the system. For achieving the expected goal, communication technology that connects the controller units and electrical devices / sensors for different end-users and utility play a crucial role. Internet of Things (IoT) is the fastest growing and modern communication method used to provide information for decision making in a smart grid for the prosumers and end-users. In this paper, the application and integration of IoT for managing, controlling and monitoring of electrical energy is studied.**

***Index Terms*—Internet of Things (IoT), Smart grid, ,Energy management system Demand-side management**

I. Introduction

Electrical energy is a critical issue in today's society. The global share of electrical energy out of the total energy consumption is expected to increase from a current share of 20% (2019) to 23%–27% by 2040 [1]. Starting from generation to end-user there are obstacles that reduce the efficiency and effectiveness of the system. Some of the factors can be reduced by using modern controlling and monitoring systems. The variation in energy costs, demand, energy markets are the driving factors that shift energy consumers and producers to find favorable ways for controlling, monitoring and saving of energy.

At generating centers, the knowledge of available resources and capacity will help the supplier to change energy according to end-user demand. The smart control and management system help consumers like institutes, building and apartments to manage their own electrical devices through Energy Management System (EMS). EMS is applied for controlling and managing electrical energy to operate at a optimal state. The security and safety of electrical facilities can be improved by using different types of sensors to collect data in EMS.

As discussed in [2], the modern power systems trend has to be: decentralized, democratized and decarbonized which are known as 'three D's' in planning. The purpose of these trends is to optimize power system reliability, cost of electricity, resiliency, CO_2 emission, etc. Penetration of distributed generation such as renewable resources in modern power systems play an important role in the emerging of a smart grid. In the smart grid, the electric consumer is required to harvest energy from renewable sources (wind turbines, photo-voltaic panels and solar collectors) [3], that is available in abundance and have less operation cost.

Energy demand is the most crucial issue and introduces different features for development of smart cities [4]. Smart cities will derive information from the intense deployment of IoT technologies along with the intelligent EMS. Intelligent EMS is minimizes energy consumption by improving utilization, forecasting maintenance needs, reducing energy costs and increasing the reliability and stability of the system [5] under various conditions.

The IoT now has important applications in all aspects of our lives including military, business, health [6], security [7], [8]. IoT also finds applications in EMS, to balance power between inadequate power supply (high demand) region and surplus power in another place through the provision of information about power handling. At generating stations, IoT provides information as a backup to balance the supply and demand by controlling [9], [10] the generation system for stable operation.

The combination of IoT technologies with artificial intelligence is also applicable in home automation, transportation, energy management and etc., in modernized communities. In smart electrical systems, producing and selling power to grid during no load time and buying from grid during peak demand [4] is expected from the consumers. This paper has different sections as: Section II deals with energy management in smart grid. In third section, IoT applications in EMS is discussed. Section IV deals with ways of IoT integration with EMS. The paper ends with a conclusion.

II. Energy Management in Smart Grid

Energy management of power system includes planning and operation of energy production and consumption units. The objectives of EMS is conservation of the resource, cost savings and climate protection, while providing regular access to the energy need of users. The efficiency of energy management is of high importance in a smart grid. The concepts like smart microgrids and multi-energy systems are integrated with the latest communication technologies to face system challenges. According to the control structure, EMS is categorized as:

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- **Centralized Energy Management Systems (CEMS)**: controlled by a central system. Scheduling and monitoring of the system operation depends on measured data and system composition.
- **Distributed Energy Management Systems (DEMS)**: is decentralized. It operates more autonomously and independently.

In CEMS and DEMS, the communication system has an important role to connect the controller units and sensors. Flexible controlling of distributed energy sources is very difficult in a centralized power system structure, requiring control of each power unit. So the power system is changed into a more decentralized form rather than a centralized structure to manage these distributed energy resources efficiently [1].

Further distributed energy sources are composed of different small independent power grids called as microgrids. The main objective of EMS's in a microgrid is to operate the electrical system reliably and economically. In microgrid EMS, the scheduling and controlling are used for short term optimal operation and power balancing [1], due to unpredictable nature of the energy sources.

The conventional power system needs to be modified in various aspects such as Demand Side Management (DSM), power monitoring, shorter down-times, reduced grid losses, etc. Prosumer Microgrids (PMG) are equipped with a smart network, transferring information in real-time, that allows the consumers and utility to operate using active parameters such as: electricity tariff, sensors, alarms, etc. In a smart system, PMG has alternative sources of energy and satisfies its requirements from renewable sources or through the main grid. Due to its flexibility an energy user prefers PMG [3]. Demand-side energy management strategy are categorized as:

- Event-based / Event-triggered DSM: It is based on remote sensing and can control facilities at the consumers end. An online energy management algorithm is applied to provide effective management of the events and control.
- Price-based DSM: It responds to real-time pricing in the energy market. Price-based DSM is further classified as:
  Reactive scheduling: It responds to changes in electricity price,
  Proactive: It forecasts the load and tariff for the next day and schedules accordingly, a day ahead.

As discussed in [9], [11], the smart grid is changing the electric system towards a bi-directional flow system for data and power while using available transmission network. The smart grid also integrates all the involved utilities. The real-time microgrids and smart grid development are evaluated by data flow between utility and end-user. In smart grid, consumers can produce electricity from renewable resources and sell it back to the utility during less consumption / surplus power. Smart grid focuses on reducing energy costs and load scheduling to minimize peak demand. The efficiency of the smart grid is affected by the variation of tariff, loads and weather conditions. Intelligent Energy Management (IEM) adjusts the system status depending on variation of these constraints. IEM device is installed with electrical facilities to decide system tariff depending on availability of the source, service time, peak load and base load. Determining system energy dispatch and satisfying customer energy demands are also another task of IEM. Moreover, it should inculcate effective energy savings in energy management strategies and increase efficiency of the system [3]. Using IEM in smart grid is used to: reduce energy costs, increase energy efficiency, reduce carbon footprints and enable statutory compliance.

Building Automation and Control Systems (BACS) is a crucial element for monitoring and control facilities in modern buildings. BACS is integration of various controllers and sensors distributed in the building. With technical building management functions, the BACS monitors and controls: room temperature, hot water, and all electrical devices. As discussed in paper [3], BACS and Technical Building Management (TBM) functions are standardized by EN 15232. Depending on feasibility of service and combination stages, the BACS standard control and TBM function are categorized into:

- Class A: Highly efficient energy systems
- Class B: Moderate energy systems
- Class C: Normal energy system
- Class D: Non-efficient energy system

The modified EMS combined with distributed control systems in BACS gives direction for simple application of demand response and active DSM systems.

Buildings which consists of modern automation and integration, to measure, control, monitor, optimize operations and maintenance for all devices are known as smart buildings. Building type, condition of climate, equipment profiles, customer interest for energy usage, residence life standard, etc., are the parameters that affect energy consumption in buildings. Characteristics of smart buildings in the smart grid should make energy demand reliable and minimize greenhouse gases, by monitoring and managing commercial, industrial, and residential electrical facilities [2].

A smart community is a modern concept, composed of Smart Transportation System (STS), Smart Water Management System (SWMS), smart grid, etc. A smart grid is also further categorized to different smart microgrids which comprise of different smart buildings that are controlled separately as shown in the fig.1. Smart grid is used to reduce energy theft, improve system security and reliability, prevent extreme blackouts, improve power quality, detect and locate power imbalance [12]. The concept of smart buildings is further grouped depending on application area [4]:

- Pillars applications: targeted towards street / road lighting control by tracing the lamps' failures and report necessary information to the respective sector.
- Electrical Vehicle (EV) applications: acquire data of charging stations, parking spaces, supply equipment for charging vehicles, etc.

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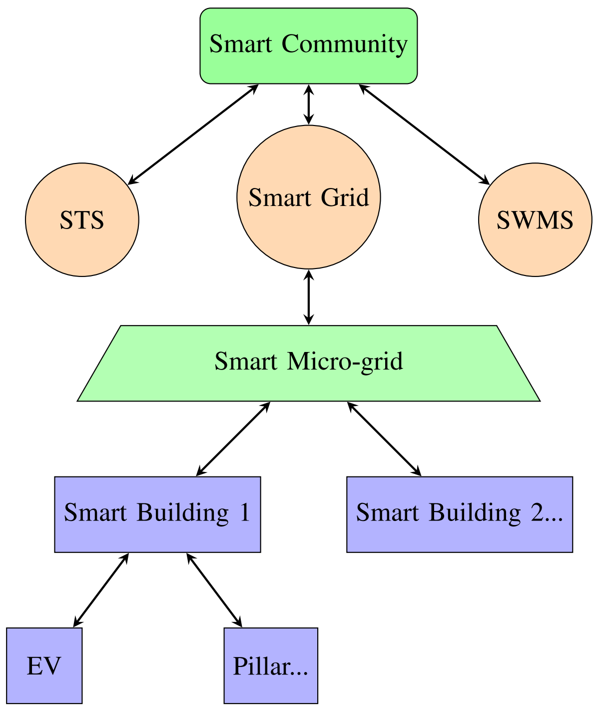

Fig. 1. Smart community structure

III. Internet Of Thing (IoT) in EMS

The concept of IoT was introduced by international telecommunication union in 2005 [9], connecting people, ideas and different things. It connects entities with each other at different times and places, through connecting mobile receivers at a short distance with sensors. IoT is a network between things with things and things with humans. It is a platform where anything can be inspected, supervised, and executed, from anywhere through the internet [13]. The tasks of IoT in the smart system is to recognize / detect, communicate and interact.

In the decentralized structure of the power system, the IoT features are needed to optimize the cost of the system energy for consumers and prosumers. IoT based EMS is designed to manage the activities of the grid at distribution and smart buildings level. IoT-based smart energy meter solves the problem of prepaid energy metering by decreasing the complexities and the non-technical losses while ensuring the reliability of data. A smart IoT based EMS will be used as a safeguard for processing and control of data for end-user services by remote-controlled home appliances [14], [15].

IoT is an emerging technology applied with BACS by integrating all facilities in the buildings and subsystems in a simple manner with DSM by substituting new features and IEM in the PMG [3]. The revolution of IoT technologies in the BACS is evaluated as having remarkable potential to introduce an active, accessible and integrated EMS for all end-users nd stakeholders. The latest communication-based concepts such as multi-agent systems and IoT are getting involved with the microgrid concept. Smart microgrids is characterized by efficient energy management strategies and algorithms. Using IOT, supports the flexible and safe operation of the distributed energy sources and helps to utilize the maximum amount of green energy.

The smart building market is gradually shifting towards wireless technologies and attention is being given to implementing IoT. The variation and heterogeneity of hardware and software separated from the basic features of IoT needs the use of a standard unified model, in order to increase its operating efficiency and security. As discussed in [16], [17], techniques of harvesting of energy from environmental and wireless method is another application of IoT. If the environmental energy source is not sufficient, sensors can harvest wireless power from wireless chargers.

As IoT technology is applied to smart microgrid environment, crucial data will be obtained for monitoring, controlling, operations, efficiency and reliability, for reducing costs of the system and improving customer satisfaction [18]. Introducing IoT for micro grid can be identified as a turning point in the evaluation of future electrical networks [1]. Advanced sensor technologies and wireless communication technologies help these concepts to increase their performance and reliability in smart grid applications. The management of distributed energy resource is a complex and tedious process in a microgrid and it depends largely on information exchange. The invention of IoT in the energy sector, the rules of IEM and internet technologies raise an idea of improving energy efficiency and environmental utilization of a smart building.

The communication system in IoT is divided into different regions [11], [19].

- **Local Area Network (LAN)**: This includes and describes the communication scheme between consumers and smart meters along with appliances.
- **Neighborhood Area Network (NAN)**: It basically represents a communication medium that contains flow-gates to execute data aggregation, encoding data coming from sensors.
- **Wide Area Network (WAN)**: It is performed to communicate data between the cloud and utility.

A web-based system can be utilized for integrating the IoT architecture with other systems. An important function of these components should be fast speed and absolute virtual distribution. The consumer can update the energy consumption data, energy cost, CO_2 emissions, etc., using the internet from anywhere in the globe [4].

A. Features of IoT

The feature of IoT in EMS is categorized as follows [12]:

- **Heterogeneity:** Heterogeneous wireless and embedded devices are used to receive different parameters such as weather, temperature, humidity contents as well as the availability of light, etc.
- **Scalability**: To adapt to the variations of different parameters, sensors are located in the sensing layer, IoT system

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adopts a growing fractal feature for the different arrangements. The structure begins from a wireless switchboard that is used for data analysis [11] at room level and micro electricity meter and smart meter, at floor and building level.
- **Interoperability**: To provide a reasonable explanation of data in different devices, the standardized data format is predefined. The row data is computed from the devices then computed data is sent to the next device using a standard format.

B. Security of IoT in smart grid

At any level of consumers the IoT based smart grid set up impacts the prospects of future of the grid and the utility. For security service, the IoT system is characterized by:

- Integrity of data
- Authentication
- Privacy of users data
- Data confidentiality
- Control access of data received

IV. Methods of IoT Integration with EMS

Consumers are a fundamental part of the PMGs and uses its infrastructure, specially communication and automation networks, to provide active, real-time platform for effective DSM. New challenges in control and building automation systems require attention to the methods and tools to control, monitor, minimize energy consumption and data flow [3]. The communication facilities in PMGs are categorized as:

- Data exchange between a smart grid and microgrid, based on a typical ICT and Transmission Control Protocol (TCP)/ Internet Protocol (IP).
- Internal data exchange between devices and modules, connected with microgrid features. As discussed in [20], the attention is given to the scalability of IoT, data collection for energy from building using Message Queuing Telemetry Transport (MQTT) protocol.

To generate feasible data for analyzing, the business intelligence system is used for information generation that is categorized into four levels: Homeowner, Community representative, State representative and Country representative.

As discussed in [13], [14], consumed electricity and cost of energy are calculated by the system and the result is sent to a server in a pre-defined way. Node Micro Controller Unit (NodeMCU) is used with micro-controller and Wi-Fi modules. By means of its micro-controller application, readings of energy meter data are collected and saved in NodeMCU, then the data is conveyed to a remote server on the internet via Wi-Fi. Consumers can observe real-time data on the server to attain exact value of consumption, by controlling electricity as per their budget.

An online energy management algorithm based on event-triggered mechanism is proposed in [3], to provide flexible management of different activities and control events. The issues of security and data privacy are protected using Hypertext Transfer Protocol Secure (HTTPS) and encrypted authentication. The other challenge in these areas is how to monitor in real-time and observe electricity parameters. For optimization and load monitoring in smart buildings, explored Home Automation (HA) protocols (X10 and Insteon Powerline protocol) is used. Flexible real-time electricity monitoring and controlling in buildings enables consumers to audit their consumption. According to [13], [20], the architecture / prototype was designed, built and tested, taking input data of electrical power parameters. Using micro-controller ESP8266, in the main circuit board of the user we can connect it via WiFi to local internet server and data of building can be accessed from anywhere.

Semantic web advances give an alternative to access all data of the community like physical, social and specialized frameworks. Semantic technologies are used for selecting a prototype for urban energy systems and evaluate the energy efficiency of a given area [4]. The multi-agent system is an interconnected and decentralized system of different software-based agents that is suitable as compared to SCADA applied to a microgrid distributed system [1]. A smart grid that incorporates ICT/ IoT with artificial intelligent is the next generation for the existing power grid. In smart building connected with a smart city in a smart grid, installed IoT end devices generate considerable amounts of data that must be transmitted, stored, and operated in powerful cloud computing.

Private EMS provide more alternatives and accurate data services [21]. The EMS can interrelate with cloud based data storage to transfer different data, but data that are sensitive or private to EMS are not visible to others. Different types of information is collected and manipulated through the cloud to provide information based services to the users. Cloud can be accessed from anywhere in the network and use data collected by the individual EMS to provide more efficient services. Clouds in the networking system can be categorized [21] as:

- Private cloud, owned by private EMS.
- Service provider cloud, owned by an organization like electricity operator
- Smart city cloud, police and the fire department are categorized under this cloud group.
- Public data cloud, can be owned by large institutes.

The internet / network connectivity in cloud analytics and cloud-centered data science analytics are limited which leads to unsatisfactory or poor performance. Due to this IoT implementation is applied for smart home services in a smart grid [2]. Collecting, transferring, storing, sorting and manipulating large data, is done in cloud analytics. Different stakeholder are anticipated to gain reasonable profit from the analytics:

- Energy providers and Utility companies
- Energy Service Companies (ESCOs), building components manufacturers, construction companies
- Investors and financiers
- Local authorities and different institutes.

In other cases there is a challenge during the use of data platforms for different applications [22] like:

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- **Variety**: To handle data of different types, formats and arrangements using well-organized techniques.
- **Volume**: To collect, process and analyze large volumes of information.
- **Velocity**: Energy-related data which is fed to the system are both real-time (smart meters, sensors, weather, energy costs, users' behavior) and static data (EP Certificates, SECAPs, demographics, cadastre, etc.). This data arrives in large number of bytes / sec.
- **Veracity**: A specific significance is put under variable quality and accuracy of data.
- **Value**: The available data can be passed through the platform, visible and real-time Application Program Interfaces (APIs), as well as provide necessary analytic interfaces.
- **Data leakage**: There is a chance that data collected from the user can expose critical information about their consumers.
- **Cyber- attacks**: Cyber attackers can damage by breaking the IoT enabled smart grid devices. Due to attacks, data transferred between the stakeholders causes wrong decisions by the operating device.

The revolution of IoT is evaluated by computational power, memory used and scope of data, quality of device management for the system, etc. The capacity of IoT systems makes it inconvenient to trace the required action manually for each device, due to this drawback autonomous operation and self-adaptation are required for IoT [23].

CONCLUSION

In this paper, applications of IoT in EMS for the smart grid is studied. It is used to make the system more reliable and effective than a conventional EMS. Smart homes can control and monitor electrical equipment by installing sensors and devices to optimize the usage of energy, thereby reducing the consumption cost. In EMS integrated with IoT, the end-user can manage and take decisions about his electric consumption from remote areas through the internet. The utility or prosumers also can forecast the future generation and load capacity in the network by gathering real-time energy data through IoT.

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