IoE Based Factory Energy Management System

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***Abstract*—To ensure sustainable economic development, enhancement of energy demand has become a significant issue worldwide. Different types of energy management system has been proposed and commercialized such as building energy management system (BEMS) in order to maximize energy efficiency. But, factory energy management system (FEMS) is yet to be commercialized. The existing FEMS is inadequate due to that complexity in data management, data loss and proper network protocols. IoE, an internet style solution, provide ample opportunities for revolutionizing sustainable factory energy management system (FEMS). In this paper, potentiality of IoE based factory energy management system has been elucidated focusing on the performance enhancement of existing Factory energy management and removal of complexity in data management. A detailed study of IoE structure, FEMS structure and IoE based smart factory management system is investigated are also illustrated in this paper.**

***Index Terms*—Internet of energy (IoE), Building Energy Management Systems, Factory Energy Management Systems (FEMS).**

I. Introduction

Over the recent years, energy-saving has become a concerning issue as the energy demand is increasing rapidly. It has been reported that the global demand for electrical energy will be grown at more than two thirds by the year 2035 [1]. So, it has become a challenge to ensure optimum power supply to the consumer. To meet the global increased demand, power quality degradation and network congestion is occurring. Besides, the emission of CO2 is increasing which leads to global warming. The Internet of Energy (IoE), a subset of the Internet of Things (IoT), has been emerged aiming towards the optimization of energy resources for energy application and creating a carbon-free global system [2].

IoT is an internet-based framework that provides facilities to exchange services and information among the billions of smart objects through smart devices. Due to the robust development in the area of information and communication technology, the incorporation of IoT has been extensively augmented in every sector such as smart city, smart farming, smart grid, healthcare, and business as well [3]. Nowadays, it extends its conformation in the power sector area. Thus, the concept of IoE is derived as a subcategory of IoT. Basically, integrating IoT in smart grid results in IoE. It is playing an important role to make a system automated and smart. The empowerment of digital transformation is made possible in the power sector area. Some elements in power systems such as renewable energy sources, distributed generation resources,

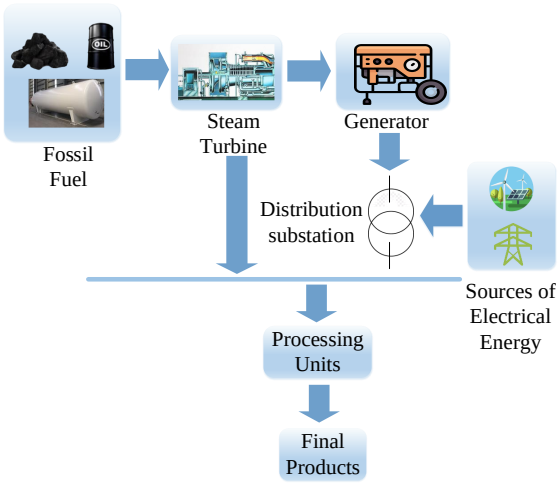

Fig. 1. Power flow scheme of a typical factory.

hydrogen-based generation resources, plug-in electric vehicles (PEVs), and a variety of energy storage technologies for different applications can be monitored or controlled through the internet platform [4]. Recently, researchers have developed some novel concepts in the area of energy research such as the second generation of smart grids (smart grid 2.0), smart energy, future energy networks, industry 4.0 which are connected with internet and telecommunications technologies and are also trying to implement those concepts.

IoE technologies can provide an innovative solution for consumption, utilization, and conservation of energy for industrial operation. Already, different types of Energy management system proposal has been adopted and developed based on IoE technology. Factory energy management system (FEMS) is one of them. It is a promising technology that is employed to monitor and control energy consumption inside the factory. But the proper factory energy management system model is yet to be developed. The energy consumption structure in the factory is slightly different than the building energy consumption. Fig: 1 illustrates the energy flow of a typical factory.

All the energy receiving equipment such as plants, renewable energy sources, fossil fuel transfers energy to the consuming side. After Receiving energy, energy supplying equipment in the factory converts the type of energy into

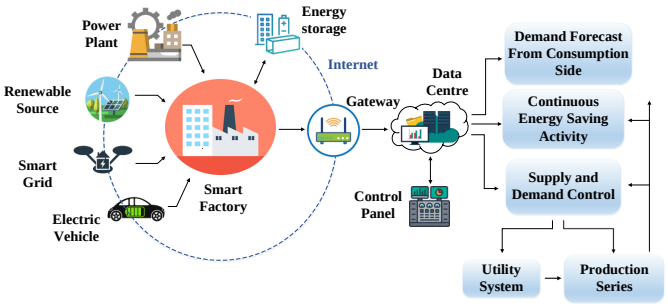

Fig. 2. Architecture of IoE Based FEMS.

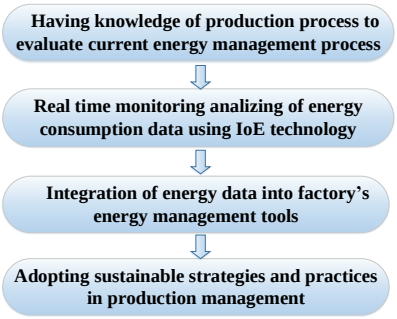

Fig. 3. Paradigm of improving IoE Based FEMS.

another type (electric power, cold and hot water, steam), usable type for downstream equipment, by energy supplying utility equipment, and is then supplied to consuming and production equipment. However, developing IoE based factory energy management system is still a challenge for many researchers. Therefore, to ensure sustainable energy development by minimizing energy loss, we have studied IoE based factory energy management system. The rest of the paper is organized as follows: Section II shows the architectural overview of FEMS based on IoE. In section III, we have discussed how IoE support energy management in smart factory. In the final section, we have finished with some conclusions.

II. Architectural Overview of IoE Based FEMS

The next-generation factory energy management system aims at maximizing the advantage of the dispersion co-generation system with renewable energy and natural gas energy by managing and controlling both energy supply and consumption in the factory [5]. The amount of wasted energy in a factory will be significantly increased if the controlled equipment and management system is poor and inadequate. In Fig. 2 the architecture of IoE Based FEMS is presented. In the above figure, the connectivity of power generation components with a smart factory, bidirectional communication among EV and smart factory, and the other components of factory energy management system such as energy storage device, data center, and control panel are depicted. The communication technology, that is used to provide gateway and networks, are WiFi, WiMax, Zigbee, Bluetooth, cellular, power line carrier (PLC), 2G, 3G, 4G, 5G and optics fiber. in addition, there are some sensors connectivity technologies too such as, radio-frequency identification (RFID), wireless sensors, cameras, barcodes, intelligent electronic devices (IEDs), which are used to collect data from smart devices and machines, etc. The features of IoE based factory energy management system are:

- Forecasting variable renewable energy output, power demand in the factory in different environmental situations.
- Predicting heat demand to realize supply energy cost reduction and supply stabilization.
- To realize the accuracy of improvement in energy demand forecast by adding production result, production plan, and formulation conditions.
- To support continuous energy-saving activity by PDCA cycle and visualizing consumption.

III. How IoE Supports Energy Management in Smart Factory

Evaluation of the improvement in the factory energy efficiency gets obstructed due to the lack of understanding of energy consumption behavior. While obtaining energy data from the smart meter, smart devices, and smart machines, a significant amount of attention and effort must be ensured [6]. Moreover, it is possible to monitor energy consumption data remotely using smart meters and sensors across the factory. These data are then transferred to the data center by the gateway to be stored and analyzed on the cloud. Through mobile applications, all the results and warning messages can be shared and floor supervisors can observe those results. It exhibits a clear picture of energy consumption to the energy management experts and they can make real-time assessments.

Fig. 3 presents a paradigm to support IoE-based energy management in a sustainable smart factory. There are four phases to be followed in the adoption process. The first phase depicts that to evaluate current energy management practices, it needs to have an elaborate knowledge of the production process of a product in the factory. The second phase focuses on collecting (possibly) real-time data by means of IoE technology from smart devices and smart machines and stores them into the data center. Here, monitoring device for each smart machine and there specification, communication system, and also through which gateway data is to be stored has to be defined.

After collecting and analyzing the data, the third phase is to integrate this data into energy management tools (e.g. energy decision support system, simulation tools) to enable the decision makers to understand the behavior of the wastage of energy consumption and thus make the effective decision about the necessity of improvement. Besides, the Selection of the machines having the most sustainable configuration mode can be possible with the proper production planning. The fourth phase includes the adoption of best strategies and practices to improve the energy efficiency reducing the wastage of energy and time in the smart factory. Therefore, implementation of

IoE provides precise information about the amount of supplied and consumed energy at any moment.

IV. Conclusion

IoE based factory energy management system (FEMS) has been highlighted in this study to ensure sustainable economic development maximizing energy efficiency reducing wastage of energy. The architectural overview of IoE based factory management system and its key features are presented here. It shows the connectivity among various elements of FEMS. An intuition of how IoE facilitates and improves energy process management in a factory has been investigated in this paper. Therefore, to accelerate the development of efficient FEMS IoE must be integrated.

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