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Power Grid Based on Internet of Things

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Abstract: The widespread popularity of smart meters enables an immense amount of fine-grained electricity consumption data to be collected. Meanwhile, the deregulation of the power industry, particularly on the delivery side, has continuously been moving forward worldwide. How to employ massive smart meter data to promote and enhance the efficiency and sustainability of the power grid is a pressing issue. To date, substantial works have been conducted on smart meter data analytics. To provide a comprehensive overview of the current research and to identify challenges for future research, this paper conducts an application-oriented review of smart meter data analytics. Following the three stages of analytics, namely, descriptive, predictive and prescriptive analytics, we identify the key application areas as load analysis, load forecasting, and load management. We also review the techniques and methodologies adopted or developed to address each application. In addition, we also discuss some research trends, such as big data issues, novel machine learning technologies, new business models, the transition of energy systems, and data privacy and security.

Keywords: Communication technology, deployment, design, issues, protocols, smart meters.

I. INTRODUCTION

Digitization of the energy industry is the key to a successful energy transition. To this end, all consumers and generators should be able to communicate permanently with each other so that the energy system as a whole function safely and efficiently. Smart meter technology can make a contribution to this. Unfortunately, the rollout selected in Germany initially affects only about 11% of all consumers. The objective of this paper is therefore to determine the current status of this technology in companies and to pursue the research question of which factors influence acceptance and use. For this purpose, an extensive literature search with more than 50 keywords was conducted in scientific databases. After reviewing and cleaning the literature, 47 papers were selected for the literature review and considered in detail. The literature review was conducted using eight evaluation criteria: Origin and year of publication, identification of trends with Big Data and AI (artificial intelligence), type of organization, type of data, collection method, number of participants, type of data collection, and analysis method. In order to evaluate the main statements and results of the considered works, we also performed a Strengths–Weaknesses–Opportunities–Threats Analysis (SWOT).

Smart meter is an advanced energy meter that measures consumption of electrical energy providing additional information compared to a conventional energy meter. Integration of smart meters into electricity grid involves implementation of a variety of techniques and software, depending on the features that the situation demands. Design of a smart meter depends on the requirements of the utility company as well as the customer. This paper discusses various features and technologies that can be integrated with a smart meter. In fact, deployment of smart meters needs proper selection and implementation of a communication network satisfying the security standards of smart grid communication. This paper outlines various issues and challenges involved in design, deployment, utilization, and maintenance of the smart meter infrastructure. In addition, several applications and advantages of smart meter, in the view of future electricity market are discussed in detail.

This paper explains the importance of introducing smart meters in developing countries. In addition, the status of smart metering in various countries is also illustrated.Reducing the power supply-demand gap and increasing reliability of power supply are the challenges of current energy management. Implementation of smart grid, smart meters and smart metering can be a possible solution for power demand reduction, efficient power supply management, and optimization of management resource usages. Smart meters include sophisticated measurement and calculation hardware, software, calibration and communication capabilities. For interoperability within a smart grid infrastructure, smart meters are designed to perform functions, and store and communicate data according to certain standards. In this work we discuss smart meter and various elements of smart metering, current state of the technologies related to smart grid, advanced metering infrastructure (AMI), and meter data flow in smart grid. We also discuss standards related to smart meter, meter data format and data transmission, functions of smart meter, and functionalities of smart meters, currently deployed by utilities around the world.

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II. LITERATURE SURVEY

Electricity is an important form of secondary energy, which plays a vital role in modern economic and social development. The demand for industrial electricity grows rapidly with the development of an economy. Furthermore, residential electricity consumption is also increasing significantly with the improvement of living standards [1–3]. The electric power industry has become a fundamental industry and important public utility supporting the development of national economies [4,5]. At present, the recovery and steady growth of the world economy has led to rapid increases in the demand for energy [6]. Meanwhile, the world is facing serious resource shortages, environmental pollution, the greenhouse effect and other difficult challenges. Therefore, it is urgent to develop cleaner energy production and smart energy systems to alleviate these problems [7]. Information and communication technologies (ICTs) have been widely used in electric power systems, making power systems more digital, more intelligent, efficient, and robust [8]. The smart grid is expected to become a general trend in the development of electric power system [9–11].

As typical representatives of the new generation of ICTs, cloud computing, big data analytics and internet of things related technologies have widely penetrated the construction and development of smart grids [12]. Therefore, the data generated by a smart grid increases dramatically, and the forms of data are increasingly complex [13,14]. The data generated in power generation, power system operation, and electricity consumption combine to form electric power big data [15,16]. Electric power big data has great potential to support the optimization of electric power systems and various management decisions. However, it also places great pressure on data transmission lines and increases storage costs. In addition, the data are not all valuable; the existence of redundant data also obviously influences the efficiency of big data analysis. Smart meter big data, including voltage, current, and electricity consumption data, is an important component of electric power big data [17].

This data can provide valuable knowledge for marketing strategies development and demand side management (DSM) of power companies. For example, analysis of electricity consumption data can support electric load forecasting, anomaly detection, and demand response program development [18–20]. Ideally, power generation and system operation can be optimized in near real time, electricity demand can be predicted precisely, electricity can be dispatched in timely fashion, electricity consumption patterns can be discovered accurately, and more effective pricing mechanisms can be developed. However, smart meters record electricity consumption details of consumers in near real time and transmit data to data centers frequently [21]. For example, suppose there are 100 million smart meters in a smart grid and each record consist of five KB. If the data are collected every 15 min, the total amount of data will reach 2920 TB per year. Efficient data compression methods can relieve transmission pressure, reduce storage overhead, and enhance data analysis efficiency. Thus, a comprehensive study on the compression of smart meter big data would be beneficial at this time. Currently, compression techniques involving smart meter big data have been an important research area for smart grids [22,23]. There have been some research works on electric power big data [24–26].

Zhou et al. [24] provided a review of big data driven smart energy management, and the authors presented a system architecture and its related industrial energy management tools. Tu et al. [25] focused on electric power big data and summarized the latest applications leveraged by big data technology in smart grids. [26] presented a detailed review of big data analytics for dynamic energy management in smart grids. However, specific research on smart meter big data is rarely reported. To the best of our knowledge, this is the first comprehensive review on the compression of smart meter big data. The objective of this study is to highlight the key research issues in smart meter big data compression methods, including lossy and lossless compression. This paper aims to provide a better understanding of the full potential and to improve data analysis efficiency of smart meter big data, as well as to reduce the transmission pressure and the storage overhead.

III. METHODOLOGY

Of all design considerations, selection of the communication network and design of the communication devices are very important and must satisfy multiple complex requirements. As discussed earlier, utilization of the smart meter system involves a huge amount of data transfer between the utility company, smart meter, and home appliances in the network. This data is sensitive, confidential and access to this data should be restricted to a few personnel. With these restrictions on data, security guidelines are formulated for transmission, collection, storage, and maintenance of the energy consumption data. The communication standards and guidelines were formulated to ensure that data transfer within the network is secure. It is equally important that this data must represent the complete information regarding the energy consumption by the customer and status of the grids without any potential manipulations or miscalculations. So, this data must be authenticated and should reflect information about the target correct devices.

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In general view, efficient management of the grid can be an alternative solution instead of revamping the existing grid. But, in view of technical advantages and enhancements to operation capability, integration of the smart grid stands as a valuable solution in managing the existing grid. However, the design, deployment and maintenance of the smart meter system involve many issues and challenges. Implementation of smart meter system in the distribution system involves several billion dollars of investment for deployment and maintenance of the network. Indeed, justifying the investment is difficult. So, this investment has to be realized as a function proportional to the projected increase in the energy demand and portion of the distributed generation. Initially, the process of replacing the existing energy meters with a smart meter system will be a challenge for utility companies.

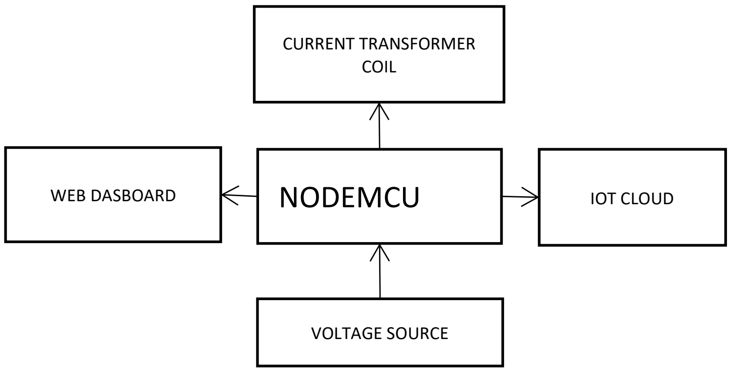

Figure 1: Smart meter

Lack of proper infrastructure for synchronizing this new technology with the existing ones might interrupt the introduction of smart meters. Though several devices are integrated with the smart meter system, they can be used to their fullest extent only when all the appliances and devices in the distribution and metering network are included in the communication network. Integration of the devices becomes even more complicated with an increasing number of customers.

Deployment of communication network in some localities might be difficult due to terrestrial difficulties. Collection and transmission of energy consumption data is a continuous process that is done automatically, but it is a tedious and expense job. In this context, a common notion might arise in several customers is that, smart meters they might essentially create some privacy and security risks as the data and signals are being transmitted. Additionally, this data might also reveal the information about presence of people at their residence, when they were present, and what appliances are in use. In view of this, some customers might be unwilling to communicate their energy consumption data with their neighbor's meter.

Fundamentally, it would be an issue about the choice of parameters to be transmitted and administrator authentication to access that information. In spite these issues, though deployment and maintenance of some communication networks are cheap, utility companies might encounter some challenges in the form of limitations in network coverage, data capacity, and propagation issues. In addition, data concentrators may lead to accommodation and safety issues. In case of wired communication, physical damage to the cable might also cause discontinuity in data transfer.

IV. RESULTS

The main features of the project are node distribution, theft detection, Energy Trading Platform and Smart meters. The figure 5 shows the overall integration of micro and main grid that is the grid. The house 4 will tap the electricity from the transformer lines.

The micro grid is between the House 1, house 2 (consists a solar panel who transfer the electricity to houses who are connected to micro grid) and House 3. With the help of energy trading platform the house 2 who has a solar panel can transfer the electricity.

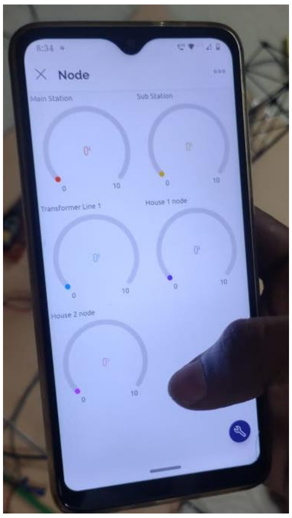

Figure 2: Smart meter

The figure 3 shows the main grid and it consists of High Tension power line, substation, Electric poles, 2 residential houses connected to the main grid. There will be nodes connected between the High Tension power line, substation, electric poles and residential houses which makes up the main grid.

The figure shows the dashboard of the main grid which consists the reading of the nodes between the High tension power line, sub station, transformer lines, house 1 and house 2.

(a) (b)

Figure 3: (a) Smart Meters of house 1 (b) Smart Meters of house 2

The figure 4 shows the smart meters of the house 1, house 2. Where all the smart meters displays the Power consumption, Irms value, Kwh and the live electricity bill.

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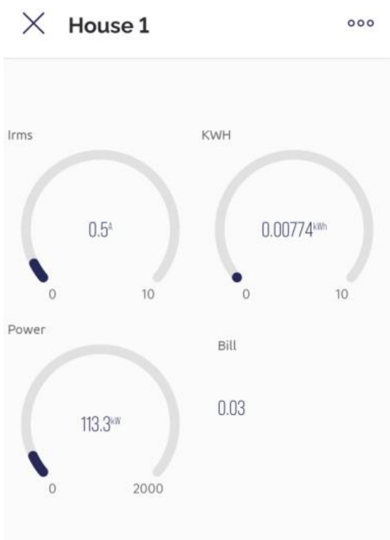

Figure 4: Dash board of House 1 when utilizing electricity

In Figure 5 the house 1 bulb is ON and it is consuming the electricity the details of it with the live reading of the electricity bill and the energy consumption is shown in the dashboard of the smart meter of the house 1.

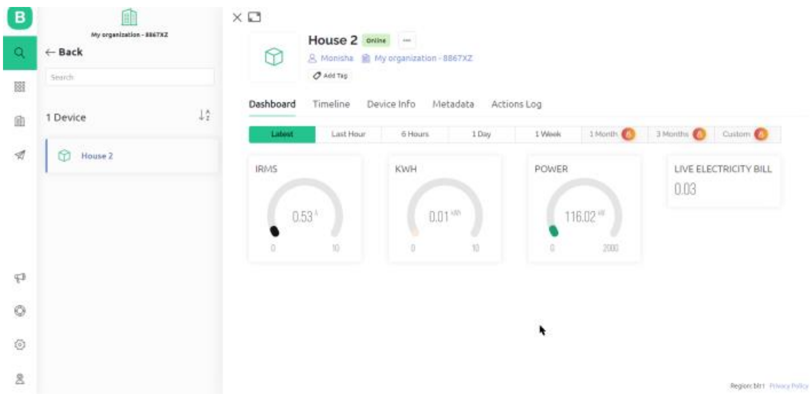

Figure 5: Dash board of House 2 when utilizing electricity

In Figure 6 the house 2 bulb is ON and it is consuming the electricity the details of it with the live reading of the electricity bill and the energy consumption is shown in the dashboard of the smart meter of the house 2.

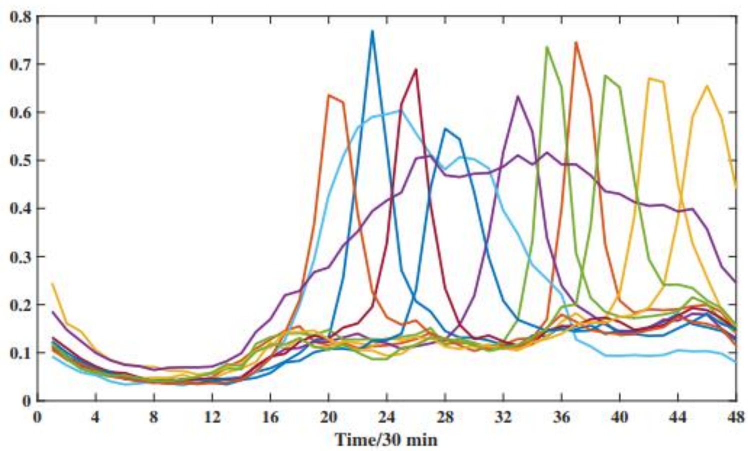

Figure 6: Typical normalized daily residential load profiles.

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V. CONCLUSION

This paper reviews several important aspects of smart metering. It explains advantages of smart meter system in utility company as well as in customer point of view. Various potential communication networks for smart meter communication are presented in detail. In addition, several challenges, requirements and issues in design, development, deployment, and maintenance of the smart meter systems are illustrated. Finally, need for smart meters in developing countries and status of worldwide installation of smart meters are discussed in detail.

VI. FUTURE SCOPE

The smart meter can be further improved to support a significant number of appliances, by changing the algorithm and hardware. The precision of the smart meter's measurement of current, voltage, power, and other electrical parameters can be improved.

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