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Big Data in Smart Grid Environment

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Abstract The smart grid refers to the new power grid with an emphasis on connected devices. It represents a new era in the energy industry, as it transforms the one-way infrastructure to a dynamic two-way system. It modifies the conventional power grid by integrating advanced communication to improve the entire system control, efficiency, reliability, and safety. Many power utilities are transferring to smart grids to improve the reliability of power supply, incorporate distributed generation resources, use power plants efficiently, prevent outages, optimize unit commitment, forecast demand, and enable customer participation. This paper provides the application of big data in smart grids.

Keywords big data, smart grid

Introduction

Electricity is one of the most essential necessity of the modern society. The electricity industry is going through a global transformation as the generation, transmission, distribution, and control infrastructure are aging while energy consumption keeps rising. Traditionally, utility companies used to generate electric power in one location and then used their own dedicated grid to deliver electricity to customers. The traditional energy distribution system is designed to support unidirectional energy flow from suppliers to users. That model has changed. Today, intelligent devices and big data technologies are being used to modernize the energy delivery of traditional power grids. This leads to smart grid, which combines many generation sources working together and delivering energy in multiple directions [1]. This enables effective operation of electric power systems that deliver affordable, reliable, sustainable, and quality energy to end users. With the development of renewable energy (such as light energy and wind energy) and energy efficiency technology, the traditional power system is evolving to smart grid. Figure 1 compares the traditional and a smart grids [2].

Concept of Smart Grid

The smart grid is a revolutionary upgrade to traditional power grid and it adds communication capabilities and intelligence. It is the energy infrastructure of the future that optimizes the generation, distribution, and consumption of electricity through the introduction of advanced ICT technology. The term "smart" in smart grid refers to the additional information layer that allows for two-way communication between consumer devices and transmission lines. This information layer is useful in many different areas because it allows for better response time during an emergency, more efficient use of resources, and even improve the delivery of the network through automation. The conventional electricity grid is enhanced with the incorporation of the digital technology to improve reliability, security, and efficiency. The smart grid includes subsystems such as smart meters, SCADA, smart appliances, renewable energy resources, energy efficient resources, power generations, substations, distribution, transmission, and networking systems. New uses of the smart grid include electric vehicles and connected houses. A typical smart grid is illustrated in Figure 2 [2].

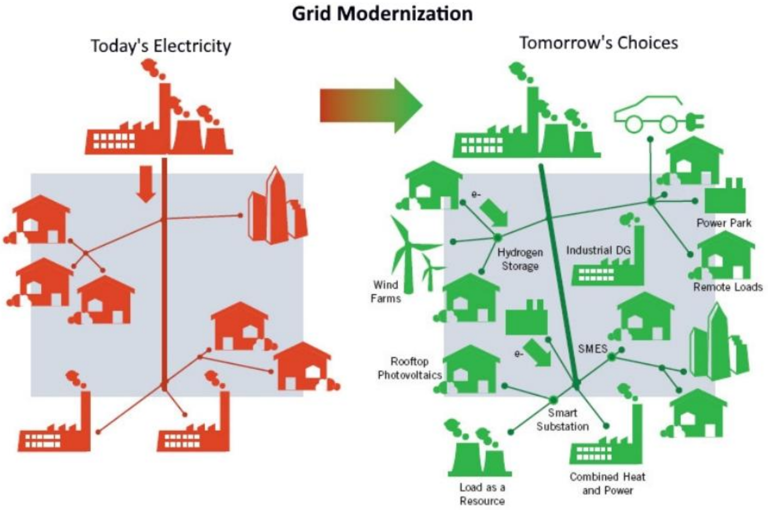

Figure 1: Comparing the traditional and a smart grids [2]

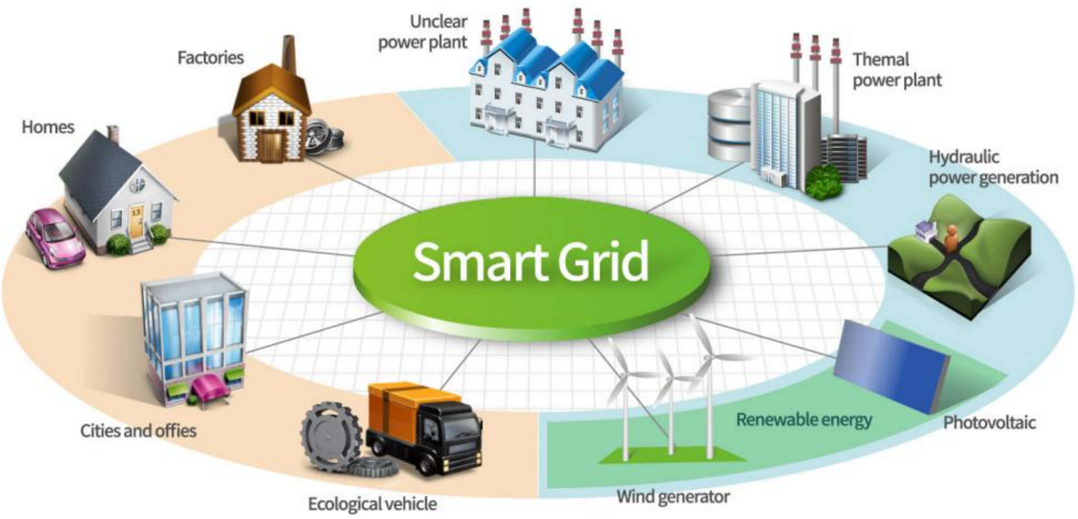

Figure 2: Elements in a smart Grid [2]

Smart grid is the abundant source of information, which covers massive quantity of data from process of electricity generation, transmission, distribution and consumption. Smart grid systems collect the data to bring smartness to the gird. The data are collected from smart meters installed in the power system, electricity market, GIS, meteorological information system, social media, etc. The data are collected and transmitted with help of smart meters, which use wired and wireless technologies. Utility companies are replacing traditional meters with smart meters. The huge amounts of data from smart meters used for monitoring and control purposes need to be sufficiently managed to increase the efficiency, reliability, and sustainability of the smart grid.

Bıg Data Characterıstıcs

Big data (BD) is a relatively newer technology that can make use of smart grid services. The three main sources of big data are machines, people, and companies. As shown in Figure 3 [3], big data can be described with 42 Vs. The first five Vs are volume, velocity, variety, veracity, and value [4].

- *Volume*: This refers to the size of the data being generated both inside and outside organizations and is increasing annually. Some regard big data as data over one petabyte in volume.

- *Velocity*: This depicts the unprecedented speed at which data are generated by Internet users, mobile users, social media, etc. Data are generated and processed in a fast way to extract useful, relevant information. Big data could be analyzed in real time, and it has movement and velocity.
- *Variety*: This refers to the data types since big data may originate from heterogeneous sources and is in different formats (e.g., videos, images, audio, text, logs). BD comprises of structured, semi-structured or unstructured data.
- *Veracity*: By this, we mean the truthfulness of data, i.e. weather the data comes from a reputable, trustworthy, authentic, and accountable source. It suggests the inconsistency in the quality of different sources of big data. The data may not be 100% correct.
- *Value*: This is the most important aspect of the big data. It is the desired outcome of big data processing. It refers to the process of discovering hidden values from large datasets. It denotes the value derived from the analysis of the existing data. If one cannot extract some business value from the data, there is no use managing and storing it.

On this basis, small data can be regarded as having low volume, low velocity, low variety, low veracity, and low value. Additional five Vs has been added [5]:

- *Validity:* This refers to the accuracy and correctness of data. It also indicates how up to date it is.
- *Viability:* This identifies the relevancy of data for each use case. Relevancy of data is required to maintain the desired and accurate outcome through analytical and predictive measures.
- *Volatility:* Since data are generated at a rapid rate, volatility determines how quickly data change.
- *Vulnerability:* The vulnerability of data is essential because privacy and security are of utmost importance for personal data.
- *Visualization:* Data needs to be presented unambiguously and attractively to the user. Proper visualization of large and complex clinical reports helps in finding valuable insights.

Instead of the 5V's above, some suggest the following 5V's: Venue, Variability, Vocabulary, Vagueness, and Validity [6].

Industries that benefit from big data include the energy, healthcare, financial, airline, travel, restaurants, automobile, sports, agriculture, and hospitality industries. Big data technologies are playing an essential role in smart grid.

Smart Grid Big Data Analytics

Data analytics is playing a vital role than anything else in the modern industrial era, especially in electricity industries. Every day, data is growing bigger and bigger, and big data analysis (BDA) has become a requirement for gaining invaluable insights into data such that companies could gain significant profits in the global market. The data collected in the smart grid through smart meters and other sensors installed is huge and heterogeneous. The processing of such data is not possible without the use of big data analytics. Big data analytics has potential to unlock groundbreaking opportunities in smart grid that enhances a multitude of technical, social, and economic gains.

Once the big data is ready for analysis, we use advanced software programs such as Hadoop, MapReduce, MongoDB, and NoSQL databases [8]. Big data analytics refers to how we can extract, validate, translate, and utilize big data as a new currency of information transactions. It is an emerging field that is aimed at creating empirical predictions. Data-driven organizations use analytics to guide decisions at all levels [8].

Data scientists know how to use tools that identify patterns and relationships that may otherwise remain hidden. A smart grid produces a lot of unstructured data which are challenging to analyze. The application of big data analytics in smart grids is a comprehensive and complicated field. It involves mathematics, ICT technologies, computer science, electrical engineering, etc. Smart grid data analytics has the potential to help utility companies address key operational, financial, and customer challenges. The opportunities for smart grid data analytics are growing because there is exponentially more data available.

Benefits

Smart grids offer a lot of benefits to energy consumers, producers, and operators. It improves the efficiency, dependability, sustainability, and economics of electric services. Other benefits include better integration of renewable energy, bidirectional power and data flow, data-driven pricing, a power consumption tracking, better security, more efficient energy transmission, lower management costs, less operational costs, and improve energy management. Smart grids will contribute to the shift to green energy, sustainable consumption, and a cleaner planet [9].

Smart grid data analytics will have a huge impact on the future. While smart grid big data analytics has the potential to transform the utility industry, it should be used properly to maximize its value. The right analytics platform allows utility companies to distribute resources more efficiently, cut costs, and discover better ways to serve customers [10]. Big data analytics coupled with grid visualization can lead to better awareness, predictive decisions, realistic consumption forecasts, cost reduction, personalized energy services to consumers, etc. The smart grids play a major role in the integration of the smart cities concept by putting into effect the smart energy conceptual element. Thus, the demand for cost-effective and sustainable power supplies has led the market for smart grid analytics. Smart grid data analytics can detect theft and fraud. It also helps by supporting smarter decisions about outage planning, fuel procurement, rate and regulatory factors.

Challenges

With the increasing demands for electricity, the need for integrating distributed renewable generation, the increasing popularity of electric vehicles, and the active participation of consumers, the power grid is facing big challenges. The high cost of the initial investment in the smart grids system is a major hindrance. The smart grid data analytics market is currently fragmented and highly competitive. Smart grid implementation involves challenges such as outdated technology, transmission and distribution losses, power quality, renewable energy incorporation, and security [11].

Applying the science of big data for better planning and operation of the smart grid is a challenging task. Three other main challenges of big data in smart grids are: security, quality, and processing location. The use of big data technology in smart grids comes at the price of increased security vulnerabilities. Smart meters can be a privacy concern if data is not securely transferred. Any violation of integrity may cause security vulnerabilities. Power consumption data should be of high quality to ensure correct data analysis and proper decisions [12].

Conclusion

The production and consumption of electricity, regulations, and electricity market are all changing. A smart grid is an intelligent energy network delivering energy in an optimal way from source to consumption. It is the power system embedded with an information layer that allows for two-way communication. It introduces ICT into electricity grids.

There are both economic and environmental benefits for transition from the current conventional power grid to a smart grid that monitors system stability, integrates distributed energy, and schedules energy consumption for household users. Businesses have already started moving towards a smart grid in order to win. More information on the application of big data in smart grid can be found in the books in [13,14] and a related journal: *Journal of Big Data*.

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