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Big Data based Smart Grid Data Management Model for Improved Monitoring of Power Consumption

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Abstract: Smart grid is treated as the future of the power grid, practices two-way flows of power and data to create an automated extensively distributed power conveyance network. In this composition, we explore how big data environment can be utilized for data management in the smart grid and presented a model called as a big data based smart grid data management (BSGDM). We research the advantages and prospects of both smart grid and cloud computing environment. For the security purpose, we designed a security management organization and also defined applications of BSGDM.

Keywords: The smart grid, cloud computing, security, trading, services.

1. Introduction

In the recent years, the consumption of electricity has changed in nature and in practice. A smart grid is advancement to the electric grid in the 21st century. The smart grid is associated with computation, information and communication technologies which is associated with power generation, transmission and computation [1]. The development of the smart grid combines both the electricity usage and information technology. The advancements in the applications and services make the grid smarter. But, due to the large data produced by the smart grid impacts the tracking and managing the environment. To overcome this issue, we require a cost effective model for data storage, analysis and management [6-7]. Therefore, the introduction of information technology to the smart grid is required to handle the large volumes of data. Cloud computing and big data will serve the purpose of handling large volumes of power grid data [10]. The Cloud data centers are associated with huge infrastructure to provide computing services to the smart grid environment. The Big data based smart grid data management model is required to handle the smart grid data (BSGDM).

This paper is organized as follows. Section 2 discuss about advantages and prospects in BSGDM. Section 3 describes the new model called as big data based smart grid data management .Section 4 presents the relation between cloud and the smart grid. Section 5 deals with the applications of BSGDM and conclusion are drawn in Section 6.

2. Advantages and Prospects

This section explains about the advantages of smart grid data management in big data and also the opportunities of integrating the big data and smart grid.

A. The Smart Grid Environment

Smart grid is treated as the intelligent network model based on the trending technologies, equipment's and sensors to optimize the energy resources and to improve the efficiency, reliability and security. The major aim of the smart grid environment is to integrate the different energy generation platforms in to the system and to monitor the energy production and consumption.

BSGDM can produce possibilities for the success of the environment of the smart grid. The technology allowing individuals and small companies with the ability of producing usable energy lowers entry barriers for new players and liberalizes the marketplaces in the smart grid sector, since the energy produced from the end users can be traded. BSGDM further decreases the access limitations, since it would be much more cost-effective for end users on demand and to use pay- as-you-go on cloud computing to recognize data control, in contrast to the case where they design and implementation their own data model. Furthermore, at the moment cloud computing is one of the most popular places of research where new interesting solutions and applications keep growing. Various programs designed and implemented by companies provide a range of value added services to users. This pattern may also motivate new interesting data models in the smart grid sector, which further enhance the success of the environment of the smart grid [2].

B. Cloud Computing Environment

Smart grid is one of the trending market which utilizes the cloud computing. The smart grid is treated as the alternate solution to the future power systems which concentrates on the higher profits. Smart grid is a combination of power and communication which provides the opportunity to the IT industry to involve in to the new market. Cloud computing is an environment which serves different areas like e-commerce, mobile industries and data management. Microsoft offers Hohm [3] which is an online application used by the customers to monitor and evaluate the power utilization and provides the power saving suggestions. Google offers PowerMeter[4] for monitoring the power utilization and option to discuss with other customers to reduce the power consumption.

3. Big Data based Smart Grid Data Management

Figure 1 show the functionality of the power grid environment which consists of the generation, transmission and distribution phase. Power grid environment is operated with cloud computing and big data domain to operate smartly.

Smart grid environment composed of different participants like power generation, power transmission, power distribution. Local customers, markets and cloud service providers. Generally, electricity is produced at different power plants by different mechanical generators. These power generators are located in less populated areas and contains huge infrastructure. The generated electricity in the power plants is distributed through the power cables for huge distances to connect with the substations. As a next step, the substations convert the high voltage power in to distribution voltage and transmitted in to the customer location [5]. Figure 2 shows the complete process of power generation and distribution process. Table I shows the explanation of smart grid participants

Table I Power grid participants

| Domains	Participants
Power generator	The generation of power in huge amounts, may also store power for the future purposes
Transmission	The carriers of electricity through power cables for longer distances
Distribution	The distribution of power to and from the customers
Customers	The users of electricity, may also manage, store and generate electricity
Markets	The managers and participants in the electricity market
Operations	The organizers of movement of electricity
Service Providers	The companies providing services to end users and applications
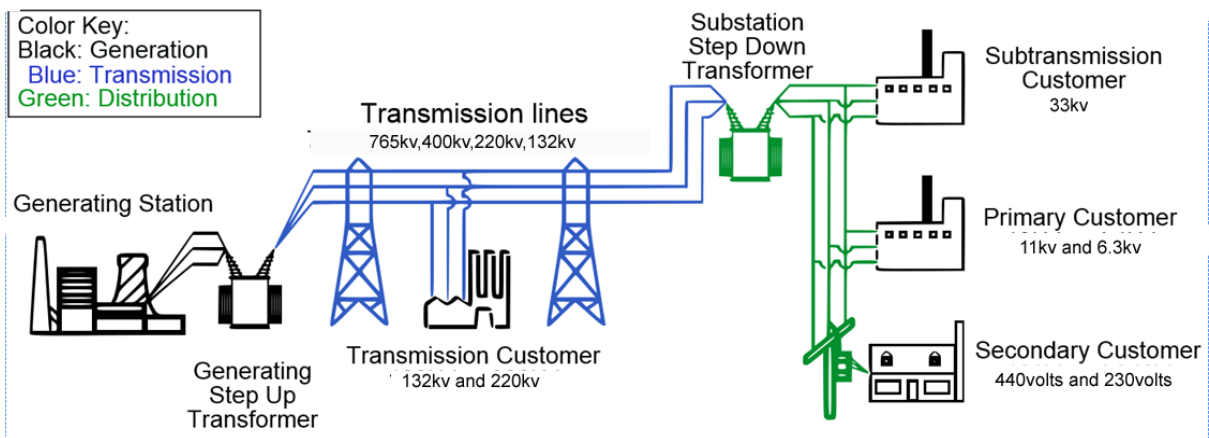
Figure 1 Functionality of the Power Grid

Smart grid infrastructure: smart grid environment is associated with power, data and communication. It provides two-way communication, one is power and another one is data. The power grid operates in a unidirectional mode where power is generated, transmitted through the power lines and distributed to the customers. In smart grid environment, the unused power is returned by the customer to the power grid. For instance, the customers who are installed the solar panels in their houses return the power to the grid. In this research work, the smart grid infrastructure is operated with three modules: smart power, smart data and smart communication.

- *Smart power:* This module is responsible for power generation, power transmission and power distribution and consumption.

- *Smart Data:* This module is responsible for metering, tracking and management of data with respect to smart grid.

- *Smart Communication:* This module is responsible for making communication between the systems, devices and applications with respect to smart grid

Smart grid management system: The smart grid management provides the maintenance of the controls and functionalities [5]. The development of advanced applications and services make the use of technology to operate the grid in smarter way. The smart management module performs smarter operations to operate smarter goals [17]. The smarter goals are power efficiency improvement, demand and supply, operational cost reduction and exhaust management.

Smart grid protection: It delivers the reliability, security and privacy and failure protection. With the help of smart infrastructure, the smart grid provides the smart protection for grid environment and also provides the smart management to deliver the security mechanisms effectively.
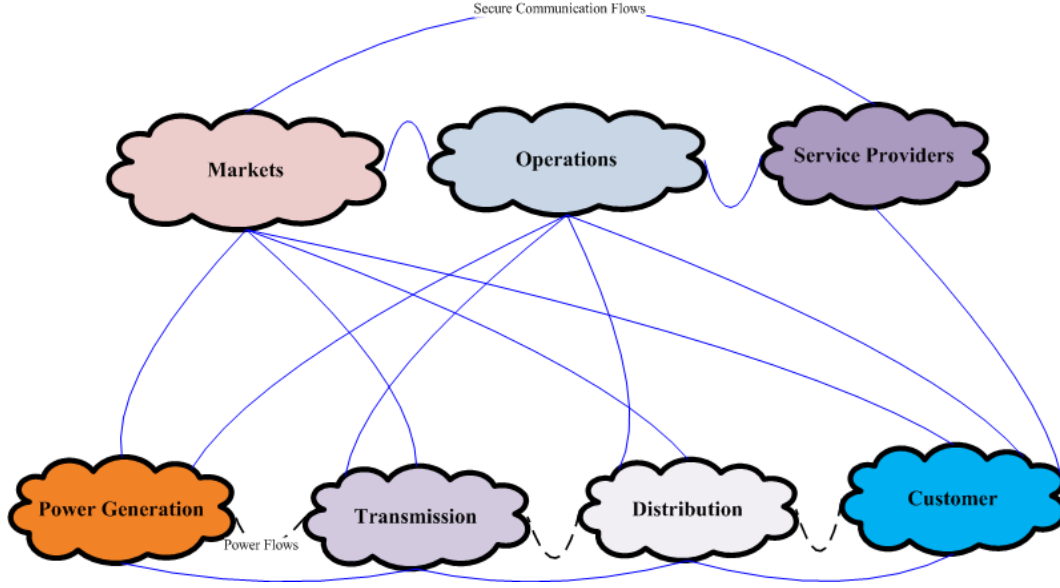
Figure 2 Power Grid Conceptual Model [5]

A. Enhanced algorithm for BSGDM

Algorithm 1: Data Management

Begin

1. Initialize the power grid

2. After activating the power grid, initialize the time T

3. Compute the power distribution based on the data available at the cloud environment

4. Calculate the cost function from Eq. 1

$$C_p = M \times \frac{U}{CP} \qquad (1)$$

Where M represents the amount of power consumption

U represents the utilization of the power by the device

CP represents the device capacity

5. Forward the C_p details to the cloud

6. Cloud analyzes the details of the cost function

7. Compute the grid power utilization

        For each device in the grid compute power consumption do

           Track power utilization

           Retrieve the power utilization data (Instance)

   Store the power utilization data

End

In algorithm 1, the power utilization of each device monitored and analyzed and these information is forwarded to the cloud to compute the cost function for usage billing purpose. As a next step, compare the instance power utilization data with the previous stored data in the cloud. The billing information is stored in the cloud for future purpose.

4. Security management in BSGDM

Guaranteeing privacy, security and QoS would be important to the BSGDM. Privacy and security may be the major concern in outsourcing big data management to the cloud [8]. Moreover, ensuring quality of service is vital for grid operations. For instance, the diagnosis of system failure is not worked properly it leads to unexpected results. So here we are proposing a component called as security management (SM), which is shown in Figure 3. SM resides in the smart grid environment but acts an intermediate between participants in both the smart grid and cloud computing environments.

The SM functionalities are predefined or defined on the go. The SM selects suitable strategies according to the security requirements which is defined by the participants in the smart grid. If there is no strategy it meets the requirements what it is identified, the SM then reminds the participants and let them decide to check the security levels. Here we are focused on three strategies. First choosing the appropriate cloud computing service provider. For instance, for storing and processing the regulated data, the SM selects the private cloud to fulfill the needs of the data management system [8]. In this method the information can be stored, maintained and updated. Second, encryption process is needed for securing of data in data management system. For storing sensitive information, the SM adds an extra layer of data encryption according to the requirements of the participants in the smart grid [9]. Third, let us look at the technique of improving the redundancy of data storing and calculation. For storing the data the SM can use data storage virtualization. It improves the redundancy of data items stores different parts of this data in to different cloud computing service providers. By careful design of redundancy, if any part of data loses occurs, we may still regain all the data for some data computations [16]. The SM creates the duplicates of data and run in different cloud computing service providers and results will be finally delivered back to the participants of the smart grid.
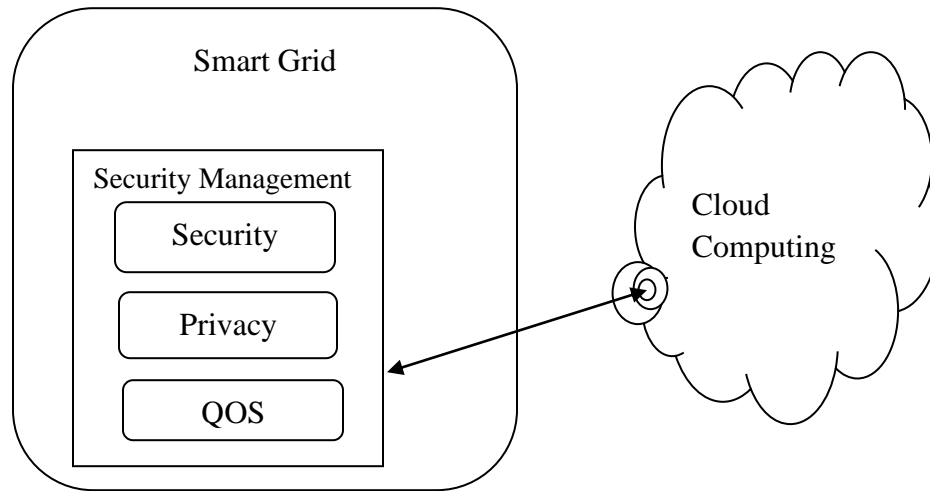
Figure 3 Security Management

5. Applications of BSGDM

In this section we are going to address the four applications of BSGDM. The applications are related to both the smart grid and big data environment.

A. Data and service management in BSGDM

First, usually the user data is stored by, for example, the electricity utility for billing data [11]. However, in the evolving smart grid, user actions will not always related to the electricity utility. For instance, the smart grid highlights a grid pattern, microgrid, which is a local group of power generations, storage and maintenance [5]. A microgrid can operate individually without obtaining power from the utility. The user data and operations in a microgrid may not be stored in the utility because it works individually. Using the cloud computing to store and study this user data would be a good option. The user data storage and analysis are provided by the cloud computing service providers as "pay-as-you-go" theme [12]. The end users in the smart grid environment transfer the user data to the cloud environment and request the related services when needed.

The important feature of the smart grid is that the use of two-way flows of data and power enables many progressive applications to control the functionalities of devices in the smart grid. One key part to recognize this is the smart meter, which can acquire data from user devices and equipment, while also managing the actions of the devices. Many essential features, such as real-

time end user behavior analysis and demand response, are noticed depending on this system. With the progression of the smart grid, more and more features may be developed and implemented.

B. High-level Trading

In the advancing smart grid, a high level trading service is needed to support more flexible power grid asset for dealing functions. As mentioned before, distributed generation of power decreases the power barriers for new players and liberalizes the marketplaces in the smart grid, since individual customers could business their generated power. Therefore, the infrastructure of the smart grid leads too many potential marketplaces [13]. Developing and maintaining a high level trading service is probably costly, especially for small electric resources or individual customers who just want to do dealing without the inspiration to create a trading plan [19]. Providing trading support as a "pay-as-you-go" utility is hence powerful. Data storage, analysis, computation, trading strategy, and even advertising are offered by cloud computing service providers as services [20]. The customers provide the requirement of what they want to buy or sell, and ask the service providers for a trading support. This is similar to online stock brokerage process. The trading support service will find the match for the customers.

C. Grid Operation data Analysis

The advancing smart grid will generate a lot of data due to the wide-scale metering, detecting, and tracking functions [21]. Storage space, real-time analysis, and promotion of such a lot of data is a non-trivial procedure for traditional power sources. Incorporating this procedure to the cloud computing may be a powerful option, since the cloud service providers are usually equipped with a large number of massive data processing and storage centers [14]. Therefore, energy sources can transfer the data to the cloud computing environment, and data storage, analysis, or optimization of the data as services [17]. Furthermore, once such information from multiple power sources is incorporated by cloud computing service providers with privacy rules required, the service provider may be able to provide improved grid operation support based on more ample data.

D. Endorsing, Checking and Marketing Service

The customer power usage information is packed of customer behavior details [15], which can be excavated to offer power endorsements or expert assistance for customers to help them minimize electric bills or help the grid function well. This data can also be used to promote appropriate power saving appliances [18]. From the viewpoint of product sellers, this data can improve the hit rate of marketing. The customer can use such suggesting, checking, and marketing services if they allow the cloud computing service providers to access the customer data with privacy rules required and then ask the service providers to deliver these services. This support can become wiser if more information is incorporated, with privacy required.

6. Experimental Analysis

To evaluate the proposed model, Amazon cloud platform is hired and accessed from windows PC. Figure 5 explains about the power utilization cost based on data provided by the APSPDCL electricity board. The presented data is recorded on 10th September 2020 from 9:00 am to 7:00 pm.
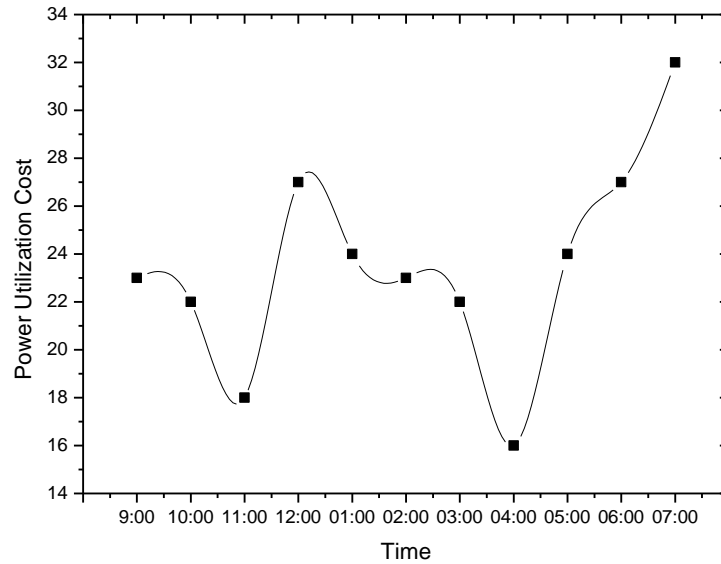

Figure 4: Power Utilization Cost Vs Time

Figure 6 shows the power grid overall utilization. The power utilization is more at the grid from 5:00 pm to 7:00 pm. If the power utilization of the customer is more than the threshold, the penalty price imposed to the customer and the corresponding financial value for that particular period increases automatically [22].
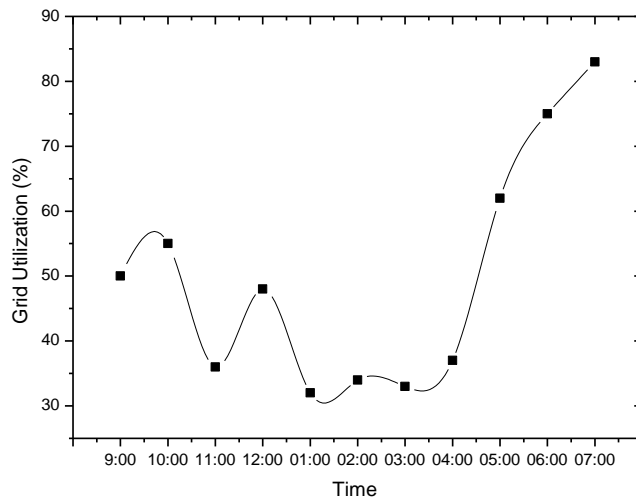
Figure 5: Power Grid Utilization Vs Time

7. Conclusion

In this paper we have discussed the advantages and prospects of using cloud data management in smart grid environments, developed a model called as BSGDM to interconnect the big data and smart grid and presented the applications. Though, there is more scope of using data management of smart grid in cloud, still there is a lot of issues to solve. For instance, it would be more significant to preserve the privacy and security of the grid, then the participants in both cloud computing and smart grid environment has to communicate with the intermediate communication provider domain to achieve the common goal. Therefore, a systematic study is needed to solve optimization problems, implementation cost and some relevant parameters in both environments.

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