IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

EFFICIENT MANAGEMENT OF DEMAND RESPONSE BY DATA ANALYTICS OF SMART GRID

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***Abstract*—The future of the power industry heavily relies on the use of modern electric grids integrated with information and communication technology (ICT). Such grids are commonly known as smart grids. The advantage of using smart grids is that they provide a better quality of service in terms of better resource and asset management, detecting faults in the system, efficient energy consumption by reducing the demand and supply gap, and peak load reduction. Information examination has effectively been applied broadly in the force area to offer different types of assistance, for example, income assurance, and information perception. Be that as it may, there are as yet numerous zones which can be profited by utilizing information logical procedures. One such region is the interest reaction the executives in the savvy matrix climate where information investigation can be successful to deal with the general burden on the framework. The substances associated with the shrewd framework contain power age units, transmission and dispersion units, and end-clients. The end-clients may have a place with the various areas, for example, business, private and transportation. The utilization information identified with these clients can be examined to offer numerous subordinate types of assistance in the brilliant lattice and to improve the general nature of administration for the clients. Remembering this, the significant focal point of this paper is on information examination in the brilliant network climate alongside the interest reaction the executives of the associated loads.**

Keywords—Data Analytics, Smart Grid, Energy data, Demand and supply

I. INTRODUCTION

With the advent of new technological breakthroughs, many concepts and techniques have evolved over the years. These technological advancements have revolutionized many application areas which have led to the smart city era. The key aspect of the smart city is to integrate information and communication technologies (ICT) for providing various services (such as–smart healthcare, smart connectivity, smart transportation, smart governance and public safety) and to manage the resources (such as–water, energy, lighting and air quality control) optimally [4]. The benefits of smart cities have attracted many developing nations to adopt this concept in order to provide smart solutions for their citizens. The government of India is planning to develop 100 smart cities over the course of fi e years from 2015 to 2020 with each city set to receive the seed funds of 31 million dollars per year [5].

II. DATA ANALYTICS

Data analytics is generally classified into four broad categories; descriptive, diagnostic, predictive and prescriptive; each of which is defined as follows.

1. ***Descriptive analytics*** provides the information about what happened and helps in creating a plausible explanation for it. This analytics intends to fi out the useful information from the underlying data which can be used for further processing.

2. ***Diagnostic analytics*** helps in understanding the reason behind the occurrence of a particular event and also helps to understand the system behavior by identifying various challenges and opportunities.

3. ***Predictive analytics*** performs probabilistic predictions to identify future trends on the basis of present information.

4. ***Prescriptive analytics*** is used to determine the outcome of the particular events on the basis of given data and devise plans to handle such events.

In the smart grid, these types of analytics are often applied in order to manage the resources and to improve the quality of service for the users . The overall flow of data from data collection to take any decision in a data analytical process in the smart grid. In the first stage, the data is required to be gathered on which the analytics can be performed. As discussed above, this data can be gathered from various sources.

- Smart meters: Due to a sudden rise in the deployment of smart meters in homes, data is generated by them at an expeditious rate.

- Smart devices: To control and forecast the faults in grid equipment, a considerable amount of data is generated by smart devices placed at various entities in smart grid environment.

- Grid equipment: Sensors deployed at various locations in the power network that sense the data values at very short intervals of time.

- Third-party data: Data can also be gathered by third parties to study the effect of various policies like dynamic pricing and use of renewable sources in homes for energy management.

Once the data has been collected, the next step is to pre-process the data so as to remove any inconsistencies from it. As the data is gathered from various sources, it may be in a variety of formats and may contain missing or erroneous values. These data values are then cleaned to remove erroneous values using the processes as described below .

- Extraction: It is reading the data from various sources which can be in a variety of formats.

- Cleansing: Data may contain some missing or erroneous values, so these values are either deleted or corrected which is called cleansing of data.

- Transformation: In this step, the data is converted from the current format into the target repository's format.

- Loading: Finally, the data is loaded into the repositories or warehouses where it is stored for further processing.

Now, from the viewpoint of smart grid, the data analytical techniques such as– consumer, operational and enterprise analytics are applied to the pre-processed data to extract the useful information from it .

- Consumer analytics: It is based on the data gathered from the consumer end. This type of analytics include energy forecasting, consumption analysis and theft detection.

- Operational analytics: It is performed based on the data gathered from sensors deployed in the smart grid or third party data. It includes asset maintenance, outage management and distribution optimization.

- Enterprise analytics: It is the analytics performed for real-time grid awareness, visualization of data, etc.

On the basis of information gained after performing these (or one of these) analytics, informed actions are taken (or decisions are made).

Data analytics helps in catering various issues related to smart grid in the past such as–demand forecasting, interactive visualization and revenue protection . Thus, it is evident from all these studies and projects that data analytics can be applied intelligently to the data gathered from the smart grid environment to provide a robust demand response management solution.

III. Need of Data Analytics

The utilization of renewable energy sources (RES) and EVs to manage the partial home loads has made the load profile of the home users' variable. The sudden changes in the load demands can lead to the instability in the grids if these are not handled promptly. In the absence of analytical and computational support, the current infrastructure is not able to analyze and handle such dynamic changes in the usage patterns of the consumers . As there are millions of users and thousands of control points which generate the data, so it becomes a complex data analytical problem to manage such a large number of incoming requests. This is evident from the fact that nearly 1 billion smart meters would be deployed throughout the world at the end of 2020. These devices generate an enormous amount of data which needs to be gathered and processed efficiently. By analyzing this data, power companies or utilities can minimize their losses and provide a better quality of service to the consumers. GTM research forecasted that the spending on data analytics by power utilities would go upto $20 billion by the end of this decade . Data analytics can change the perception of both the consumers and utilities, the way they use the power. Data analytics plays a crucial role in managing the future needs of the customers and influences many areas in the smart grid environment.

Data analytics acts as a key player in the smart grid by analyzing the collected data. For instance, revenue protection or loss/theft detection is one such area where analytics can save hundreds of millions for the utilities because of the stealing and mismanagement of power. The analytics performed for providing demand response management can help to optimize the electric consumption of the users for reducing the burden on the smart grid. This analytics can forecast the energy demands and helps in scaling down the energy requirements at peak hours by providing benefits to the customers during off-peak hours. In the future, a better understanding of customer behavior can prove invaluable to the utilities. After considering all these aspects of data analytics, it can be inferred that an intelligent data handling technique is the need of the hour as it is important to analyze and manage the data generated in the smart grid environment.

IV. Challenges and Constraints

Following are the major challenges that need to be addressed in order to manage the demand response and to perform data analytics on the data generated in smart grid environment.

i) Data sharing, security and privacy: A huge amount of data is available with retail energy providers and energy managers (like home security, improvement and telecommunication providers). This data is not shared with one another unless it is in the economic interest of all the parties. The customer's data security and privacy should also be maintained so that the customer feels safe to share its data with these vendors.

ii.) AMI data integration: Utilities need to capture the data generated by the AMI. This data needs to be integrated with other parts of utility enterprise like customer systems and operation system which has its own challenges. This data can help in leveraging the customers by designing personalized plans for them based on their preferences.

iii.) Analytics on demand response: The demand response analytics studies the customer behavior in various scenarios. The problem in performing this analytics is the variability in the response of the customers. Customer usage pattern depends on many factors like electricity price, user preferences and weather conditions. These factors must be taken into account while managing and analyzing the demand response.

iv.) Infrastructure requirements: The data generated by the consumers is huge and changes with time, thus it is difficult to analyze. As the homes and vehicles have limited computational resources, the data needs to be stored and processed on the scalable infrastructure.

v.) Dynamic change management: The dynamic change in consumers requirement must be incorporated with the smart grids so as to prevent the load fl in it. Although, one change may not affect the grid stability, however, if these changes are happening with a large number of customers, then it can lead to grid breakdown.

vi.) Real-time grid awareness: The utilization of solar PV, PHEVs and other DERs infl the grid stability due to their intermittent nature. They create extra pressure on the distribution systems. Thus, managing these resources in real-time is important for the grid stability.

viii.) Lack of standards for communication interoperability: The requirement of a robust and real-time data communication standard still persists for both real-time communication and application interfacing for seamless data exchange between generation, transmission, distribution and customer applications .

ix.) No Unified place to access and implement the strategies on the data.

V. Results and Discussion

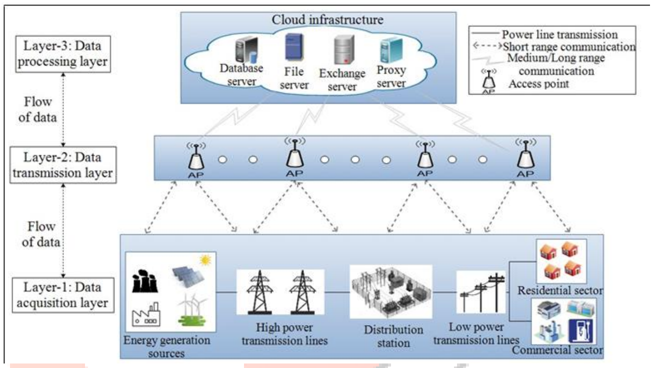
A tensor-based data management technique is proposed to reduce the dimensionality of data gathered from the Internet-of-Energy (IoE) environment in a smart city [1] The core data is extracted from the gathered data by using tensor operations such as matricization, vectorization and tensorization with the help of higher-order singular value decomposition. After reducing dimensionality of data, it can be used for providing many services in smart cities and its application

A. *Data Processing and Management*

For this purpose, SVM-based classifier is used to classify the end-users (residential and commercial) into normal, overloaded and underloaded categories from the core data. Once such users are identified to take part in demand response mechanism, utilities can devise particular solutions to handle their demand response in order to alter their load requirements so that the overall load in the smart city is optimally managed. The results obtained on Open Energy Information and PJM dataset clearly indicate the supremacy of the proposed tensor-based scheme over the traditional scheme to classify the end-users.

B. *Figures and Tables*

To manage the demand response of loads in a smart city, data about the loads connected to the IoE network needs to be stored in an effective way so that it can be processed easily. The framework for gathering such data in the IoE network has been shown in Figure



In this figure it can be seen that the complete data gathering and processing phase has been divided into three layers viz. data acquisition, data transmission and data processing. The fi layer is the data acquisition layer where the data from different entities is gathered using the help of sensors installed at these entities. These entities include generation, transmission and distribution units, and end users such as smart homes, commercial loads including charging stations and industries. Different types of sensors such as smart meters, phasor measurement units (PMUs), advanced metering infrastructure (AMI), intelligent electronic devices (IEDs), etc. are deployed on these entities to gather different types of data related to energy. The second layer is the data transmission layer that forwards the data sensed by the sensors to the data processing layer with the help of access points (APs). These APs can be in the present in the form of roadside units or wireless routers deployed at various locations in the city to provide communication connectivity in IoE network. For this purpose, small, medium and long range communication technologies are used as given in Table

Communication	***Technologies***	***Protocols used***	***Frequency bands***	***Data rate***
Shortrange	DSA	IEEE 802.11af	476-494 MHz	1 Mbps

	DRSC/WAVE	IEEE 802.11p	5.850-5.925 GHz	3-27 Mbps
Medium/Long range	Wi-Fi	IEEE	2.4 - 5 GHz	1-54 Mbps
	WiMAX	IEEE 802.16	1.25-20 MHz	30 Mbps -
	LTE/LTE-A	-	20-100 MHz	300 Mbps -

The third layer is the data processing layer which is used to store and process all the data gathered from the fi layer. For storing and processing this data, cloud is one of the most viable options. The benefit of using cloud server for storing the data is that it has abundant resources which can be accessed at anytime from anywhere. Thus, it can continuously process the sensed data and the utility can also access the data pertaining to various entities at any time. Moreover, the cloud platform can easily be scaled if the data entries increase rapidly. Once the data is gathered at the utility server, it is stored in tensor form so as to reduce its dimensionality and then it is processed to apply demand response mechanism. For managing the demand response, the SVM classifier is used on this data to identify the users whose demand needs to be managed in order to maintain the overall load in a smart city.

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