Various Types of Smart Grid Techniques: A Review

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***Abstract*– For many years, there has been no reforms are done in the main architecture of the electric power grid. The twentieth century centrally controlled grids are unable to fulfill the need of 21st century requirements. Smart grid is introduced to address the challenges of the previous grid. The smart grid is a modernized infrastructure of electric power grid that use high power converters, automation control, modernized communication architecture, smart metering technologies, modernized energy management techniques, network and energy availability to enhance the reliability and efficiency of the electric power grid. Communication architecture and correct information are main two components of the current electric power systems, but smart grid need much larger and more complex communication architecture for power systems. This paper deals with the different techniques that are used in smart grid to enhance its infrastructure and functionality. Our main focus in this paper is to provide the contemporary look at the different techniques that are currently used in smart grid to make him more efficient and reliable. It is expects that this paper will bring a better understating of the different techniques, to overcome the smart grid potential advantages and research challenges and raise interest in the research community to explore this research area.**

***Keywords*– Distributed Generation (DG), Demand Side Management (DSM), Renewable Energy Sources (RES), Home Area Network (HAN), General Packet Radio Service (GPRS) and Auto Regressive Integrated Moving Average (ARIMA)**

I. INTRODUCTION

The smart grid creation has been globally deployed for long term changes in the form of energy usage. Smart grid is updated form of delivery systems for electricity in which optimization and protection of the operation that performed on the connected element from one end to other end. Smart grid framework is more competent, low cost and more flexible with environmental energy management system than the previous ancient grid systems [1]. Smart grid systems are the combination of distributed and centralized generators which are used to control the low voltage and high voltage distribution. These generators control the high or low level voltage through the automation systems of the residential and industrial users, and provide energy to end-use consumers for their, electric vehicles, house hold devices, energy storage devices and other appliances [2]. The smart grid is also referred as a next generation Power systems that provide more secure and reliable energy and share the information between the consumers, suppliers and to the power generators with the help of communication technologies and digital computing systems. Smart grid introduced to way communication that is more advanced in communicates than the power systems that are currently in used [3]. Smart grid introduced the new network strategies to make grid more efficient in Distributed generation (DG) for energy storage and Demand Side Management (DSM) to load the balance [4]. Furthermore DSM technologies are developed to alter the behaviors of different users by charge them when they using more electricity in peak hours. DSM technologies showed the significant importance on less number of houses [5]. In [6] authors studies the Renewable Energy Sources (RES) and find that the integration of the RES reduce the system loss and increase the reliability, efficiency and security Smart grid infrastructure is fully advanced for sensing and communication computing abilities that are shown in Fig. 1.

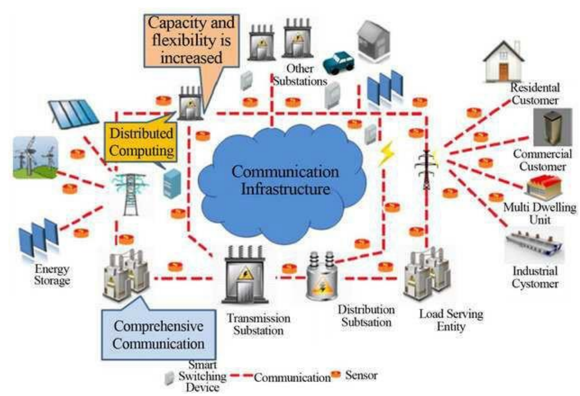

Fig. 1. Smart Grid Communication Infrastructure

The component of the smart grid infrastructure is connected through the communication path and sensor nodes provide the connectivity between them for transmission and distribution for residential, industrial and commercial users. In smart grid authentic and real-time information is the main point to deliver the reliable energy to the users from the generators. Smart grid avoid the capacity constraints, catastrophe, natural incidents and equipment failures that are main reasons of energy disturbance and outage using the online monitoring of the power systems [7].

Smart grid architecture is combination of 7 domains as shown in Fig. 2 , this architecture is proposed by the National Institute of Standards and Technology (NIST). Smart grid can be categorized in two main components Networks and System. System components are categorized in Electric Utility Operation Center, Household Appliances, Energy Resources that are renewable, Smart Meters and suppliers.

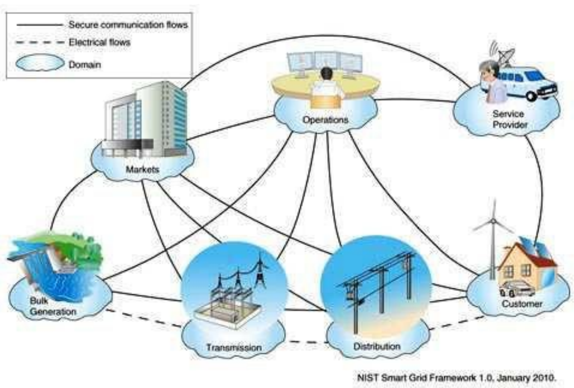

Fig. 2. Smart Grid Domains

In Electric Utility Operation Center Smart meter are used to control the consumption of power and provide power to the house hold appliances via Home Area Network (HAN)[8].Solar energy and wind energy are renewable energy resources that are used to provide the power to the house hold appliances through local generated energy. Smart Meter is a standalone embedded system. Main components of smart meter are analog and digital ports, serial communication, real-time clock, volatile and nonvolatile memory and microcontrollers [9]. Smart meter are used to identify the consumption and send the consumption detail using the network to the server for billing purpose. Power consumption reports are collected by the Electric utility center. Smart meter are used to regulate the power consumption and collet the hourly power usage report and also send the emergency and error notification using the GPRS technology. Service providers are providing the electricity to the users for their individual devices and after signing contracts. Service providers used smart meter to interact with the internal devices and maintain the utility bills and interaction with the users [10], [11]. Smart grid use two different network types for communication one is HAN and WAN. HAN is used to connect the home appliances with the smart meter. There are different technologies that are used as a home area network such as Zigbee, Wireless Ethernet or Wired Ethernet and Bluetooth. At the other hand Wide Area Network (WAN) is used to make a connection between smart meter, suppliers and the utility server. WAN use WIMAX, fiber optics or 3G/LTE/GSM for communication. Smart meter is working as a gateway between the home appliance and the suppliers. Suppliers collect the hourly usage reports from the smart meter and notify meter .Smart meter receive notification from the devices that are in the HAN and send it to the suppliers using WAN. Fig. 3 describes the basic architecture of usage of HAN and WAN [12].

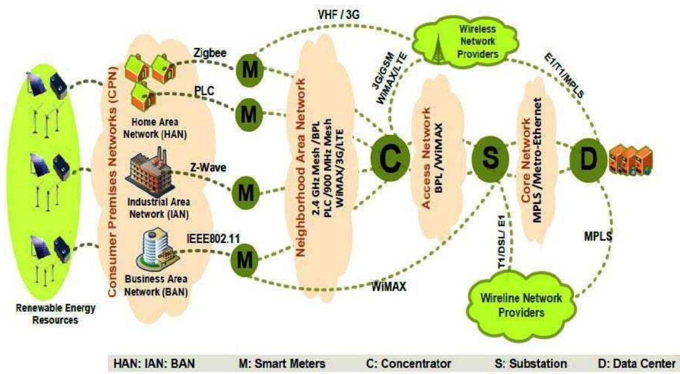

Fig. 3. Network Architecture

II. COMMUNICATION TECHNIQUES FOR SMART GRID

Communication system is main component of the smart grid communication infrastructure. With the updating in technologies and application to achieve the advanced smart grid infrastructure to analyze huge amount of data for controlling and real time pricing [13]. Wireless and Wired are the two basic types of communication media, can be used to transfer information between the smart matters and suppliers. There are two types of information structures are used in smart grid. The first is from the electrical appliances to the smart meter using wireless communication technologies such as Zigbee, Low PAN etc. Second flow is used to share data between smart meter and the utility data centers using cellular technologies [14].

A. ZigBee

In wireless communication technologies Zigbee is comparatively use low power, cost, data transfer rate, and complexity. Zigbee used in smart grid for automatics meter reading, home automation and energy monitoring. National Institute for Standards and Technology (NIST) declared ZigBee Smart Energy Profile as a most applicable communication infrastructure for smart grid network. Zigbee has 2.4 GHz bandwidth and 16 channels, each channel use 5 MHz bandwidth and the maximum output power is 0 dBM. Maximum transmission range is between 1m -100m with the 250 Kb/s data rate. ZigBee use regulated protocol positioned on the IEEE 802.15.4 standard [15].

B. Wireless Mesh

A Wireless Mesh network is a combination of nodes that are joined in the groups and working as a self-reliant router. Self-healing property of these nodes are help full for a communication signal to find a route through active nodes. Infrastructures of mesh network are decentralized because each node sends information to the next node. Wireless mesh is used in small business operation and remote areas for affordable connections [16].

C. GSM

GSM is Global System for Mobile communication is used to transfer data and voice services. GSM is a cellular technology that connected mobile phone with the cellular network. Characteristics of GSM are elaborated in Table I.

D. Cellular Network Communication

Cellular networks are also be a good option for communication between far nodes for utility purpose. Cellular networks are used to build a dedicated path for communication infrastructure to enable smart meter deployment over a wide area. Different cellular networks technologies such as 2G, 2.5G, 3G, WiMAX and LTE used to share data between smart meter and the utility data center [17]. Characteristics of communication techniques are elaborated in Table I.

III. DATA MINING TECHNIQUES FOR SMART GRID

Large number of artificial intelligence and statistical techniques are developed by the researcher for implementation for data mining. However there are different techniques that are widely used such as Expert System, Neural Networks, Fuzzy logic, Tie series, Artificial intelligence and vector mechanics.

A. Expert System Techniques

For accurate forecasting some basic rules are used these rules are produced by the experts of the software field that make expert systems for automatically forecasting with any human assistance. Expert software developer runs the expert system and that program follows the rules that design by the software developer in [18] short-term load forecasting techniques is proposed by the authors for hourly observations. The proposed techniques were tested by Taiwan and United States with low errors in forecasting.

B. The Regression Technique

The Regression Technique Regression is extensively used technique to create a relationship between the load forecasting functional models and the other factors such as customer class, data type and weather. The main drawback of this technique is that the weather component relation with the load demand is not stationary and this technique is unable to find the physical variations in [19] different models of regression are represented by the authors for next day peak forecasting.

C. Support Vector Machines

Support vector machines are most power full techniques that are used to solve the problems of classification and regression in [20] authors proposed this technique by approaching statistical learning theory. Neural networks are used to define function for input space and perform nonlinear mapping using SVMs. Linear decision bounders are created by the SVMs using simple linear functions for a new space [21]. In [22] authors used SVMs methods for short-term load forecasting and compare the results of SVMs with the autoregressive method and find that the SVMs is much better than the autoregressive method.

D. The Time Series Technique

The Time Series Technique used signals in time series for load forecasting. Changes in weather strongly effect on the consumption of the energy when the weather component are not available [23]. Auto Regressive and Moving Average models is widely used example of time series technique in which future load can be estimated with the previous entities combination. This technique is used in the field of load forecasting, digital signal processing and economics.

E. Fuzzy Logic Techniques

Digital circuit and Boolean logics are used in fuzzy logic technique .Truth table is design for the Boolean logic and take input as 0 or 1. Fuzzy logic maps the input results to the output such as curve fitting. Certain qualitative range is assign to input for manage transformer load from low to high and high to low in [24] advantages of fuzzy logic are described that take a noise free inputs , perform the operation in the absence of the mathematical models and map the inputs to the outputs. Due to some reasons fuzzy logics are not used because exact output is needed in many situations. If fuzzy logics are used then after giving inputs, defuzzification process is used to get precise outputs.

TABLE I: COMMUNICATION TECHNIQUES FOR SMART GRID

Technology	Data Rate	Spectrum	Coverage Range	Applications
ZigBee	250 Kb/S	2.4 GHz	30 m-50m	HAN,AMI
GSM	14.4 Kb/s	900 MHz- 1800 MHz	1Km-10Km	HAN,AMI,Demand Response
GPRS	170 Kb/s	900 MHz - 1800 MHz	1Km-10Km	HAN,AMI,Demand Response
3G	384 Kb/s - 2Mb/s	1.92 MHZ - 1.98 MHz & 2.11 MHz - 2.17	1Km-10Km	HAN,AMI,Demand Response
WiMAX	75 Mb/s	2.5,3.5,5.8 GHz	LOS (10Km-50Km) NLOS (1Km-5Km)	HAN,AMI,Demand Response
PLC	2 Mb/s - 3Mb/s	1 GHz- 30 GHz	1Km -3Km	AMI,Scam Detection

IV. CONSUMPTION PREDICTION TECHNIQUES

In this section, we briefly describe the consumption prediction techniques. Basic four methods that are commonly used by many utilities in U.S, these are more preferred over the more advanced techniques due to low cost and low compute requirements.

A. Auto Regressive Integrated Moving Average (ARIMA)

ARIMA use previous linear combination of univariate time series data to predict future electricity consumption vales. Main advantage of this techniques is that it is very easy to use ad does not required any knowledge of underlying domain. ARIMA is used for real time forecasting for electricity load, fuel prices or stock [25].

B. New York ISO (NYISO)

This model is used to calculate the previous five days baseline with the highest load values .these five days are chose from the previous ten days in which event days are on the priority and exclude holidays, weekends and the in which sharp energy consumption downfall was noticed. Furthermore a day is included in which the average use of energy in increased more than 25% from the last day. This process repeats for ten days and from each ten days pool highest consumption days are selected. In addition after selected five days hourly consumption of these days are calculated from the two hour values and compare these results with the base line consumption data [26].

C. Southern California Edison ISO (CASCE)

This model is similar to NYISO in which model estimate the baseline consumption of last ten days, weekends holydays are not included, once the days are selected then calculate their hourly base line is calculated and morning adjustment factor is also used in baseline calculation [27].

D. California ISO (CAISO)

According CASIO model the base line calculated last three days hourly average from the ten selected days. In selected days weekends and holidays are included. This model improves performance by introducing morning adjustments [27].

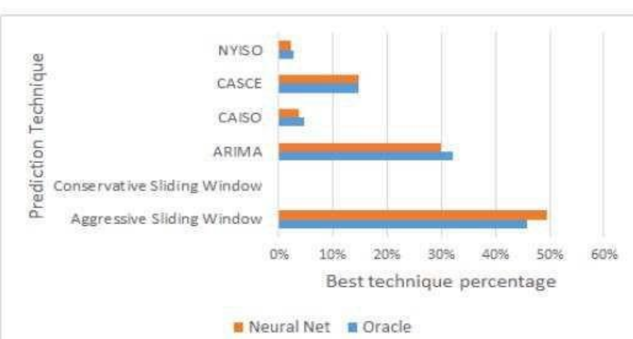

Fig. 4. Network Architecture

Fig. 4 shows the percentage of the ach model in the best versus of times is sleeted by the neural networks. The dominant method shows the aggressive sliding window with 45.79% at the best time. The point show that the considerable weight for the latest values is maximizes the accuracy more than the ARIMA 32.11%.Furthermore the conservative method is performed by the other baselines and its shows that it's performance is better than the NYISO and CASCE. In Addition we conclude that the weekly patterns data set is not enough strong.

V. PRIVACY PRESERVING TECHNIQUES

Many researcher deals with the privacy issues in smart grid and proposed different techniques to overcome these issues. There are two basic categories of Privacy preserving one is with data aggregation and other is without data aggregation. Most of the securities techniques are affiliated with these two main categories. We present many techniques in this section and then we draw a table to show the comparison between these techniques.

A. Privacy-preserving techniques using aggregation

Aggregation technique is used in smart grid to perform a different functions such as remove the unnecessary packets that are traveled between the AMI and the utility server to avoid the bandwidth consumption. But, we are in trusted to use the aggregation for privacy preservation. Many researchers connect aggregation data with the other privacy preserving techniques in [28] authors consider that the data collected from the smart meter are in multi dimensions and categorized in time and space related data. Authors proposed the concept of time and space based aggregation and then introduced the Privacy Preserving Nodes (PPNs) that collect data from different smart meters. Secret sharing technique is proposed in [29] in which cryptographic algorithm are used to share a secret between the group of parties in which no one can change the secret. In this scenario meter reading is considered as a secret data that will be shared between different PPNs. PPNs perform homomorphism aggregation and share data to the requested consumers. Furthermore Zero Knowledge (ZK) protocols are proposed by the authors in [29]. ZK proof protocols only allow one user to prove that to other user about the exactness of the statement without acknowledgment of any statement. Authors use ZK billing protocol that's allowing the smart meter to generate the bill. However this technique is cost effective and required high computational capabilities. Homomorphic crypto system is commonly used in security protocols when using privacy aggregation due to additive and multiplicative properties of homomorphic cryptosystems. In [30] authors used homomorphic Paillar system to encrypt the smart meter and utility center communication. The proposed solution is considered more effective in the term of computational cost and guarantee that intruders would not disclose the communication between the smart meter and utility center.

B. Privacy-preserving techniques without aggregation

When we have no gateway to aggregate data then we often resort a third party that is considered as trustworthy .such a third party is a only allowed party that organize data bind between them in [31] authors discriminate the high level and low level frequency data and Assign and ID to each type such as high frequency ID (HFID) and low frequency ID (LFID). High level frequency data contain different information and end user analyzes this information using efficient techniques .this information is only known by the third party only. However LFID data is known to all the parties, to ensure about the correctness of data the connection between HFID and LFID will be verified by the third party in [32] the blind signature technique is proposed by the authors in which a person get a message that is signed by the other party without acknowledge any information about the message to the other party. In this scenario user use credential identity for the daily power request. User identity is used for billing period in which all consumed credentials are presenting together. Furthermore user centric privacy technique is proposed in [33] in this technique only communicating parties are mainly involved these are smart meter and the control center only these two parties are allow to get the real reading and match these reading with the real identities. At the user side MAC2 is used for message consumption and control center is also secure and fully trusted. Table II and Table III present a details summary and comparison of techniques that are cited above.

TABLE II: SECURITY FEATURES OF THE PRIVACY PRESERVING TECHNIQUES

Privacy preserving techniques comparison	Integrity	Confidentiality	Certification authority
Secret sharing	Encryption	Encryption	No
ZK proof	Encryption	Encryption	No
Homomorphic Cryptosystem	BLS short signature	end-to-end encryption	No
Third trusted party	Timestamp, nonce, MAC,digital signature	Encryption, MAC	Yes
Blind signature	Double encryption	Double encryption	No
User centric privacy	Encryption, HMAC	Encryption	Yes

TABLE III: PERFORMANCE OF THE PRIVACY PRESERVING TECHNIQUES

Privacy preserving techniques comparison	*Computational costs/delay*	*Overhead*	*Scalability*
Secret sharing	N/A	N/A	Yes
ZK proof	Expensive costs	N/A	No(Smart Meter: prover, the company server: verifier)
Homomorphic Cryptosystem	Not expensive	Low overhead	N/A
Third trusted party	long setup time	N/A	N/A
Blind signature	N/A	Depends on power usage	N/A
User centric privacy	HAM signature verification delay:368 msec	20 bytes (8%)/ request message	N/A

VI. VISUALIZATION TECHNIQUES IN SMART GRID

In this section visualization techniques of smart rid are described in which smart grid data are classified in two categories with are geographical information system and some traditional techniques. Traditional techniques are listed as single line diagram, real-time 2D chart and 3D surface contour. GIS consists spatial analysis and spatial temporal analysis that are used to visualize smart grid data. AMI and SCADA are used to visualize data. AMI and SCADA network diagram is shown in Fig. 5.

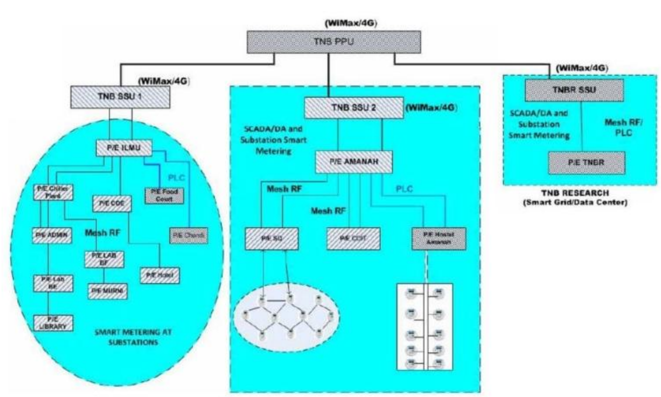

Fig. 5. AMI and SCADA network diagram

A. Single Line Diagram

Single line diagram use to show the complete overview of the AMI/SCADA network. Single line diagram is used to show the connection between the substations and some critical parameters. Macro level view of single line diagram operations are shown in Fig. 6.

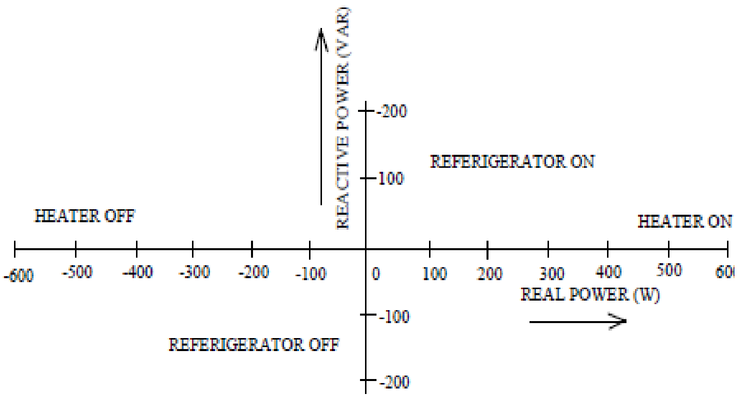

Fig. 6. AMI and SCADA network diagram

B. Spatial Analysis

Spatial analysis is used to extract the additional and new information from the GIS data. GIS used different spatial tools for feature statistics and buffer, intersect, union and different geo processing tools are used in spatial analysis for smart grid systems [34].

C. Non-invasive load monitoring

Utility-installed smart meters will live many variables at once: current, voltage, reactive power and real power. allow us to quickly describe the distinction between reactive power and real power as a result of this distinction lies at the center of the classic" disaggregation technique known as non- invasive load monitoring". Distinguishing between a heater and a refrigerator by comparison real and reactive power consumption. The heater may be a strictly resistive load and thus pulls no reactive power. The refrigerator largely pulls real power however additionally pulls some reactive power. These 2 variables enable us to discriminate between most devices Shows in Fig. 6 [35].

VII. CONCLUSION

The smart grid is an evolution in electric power systems that using renewable source to increase dissemination of distributed generations, furthermore the additional goal is to enhance reliability, efficiency and safety of the current power grid. At the other end timely information collection about the failures of equipment, natural accidents, capacity limitation are exceptionally critical proactive and real time problem diagnose for to overcome the failure in smart grid. In this paper, Communication, Data Mining, Consumption Prediction, Privacy Preserving, Visualization Technologies and their requirement for smart grid have been discussed. Different quality of services mechanism and standard are discussed. Comparison of different application used I these technologies are presented. There are many research issue are discussed and give complete overview that include grid characteristics, research issue and applications.

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