JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 08, ISSUE 04, 2021

A Review on Communication Techniques for Efficient and Reliable Operation of Smart Grid

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Abstract- In india, the power sector is growing rapidly and operating and managing such a system is a challenging issue. The power network can be assumed as a "muscle system" of human body, as it carries Megawatts of power for large distances. Similarly, the complete associated power system monitoring and controlling is similar to a “nervous system”. India is in need to meet demand of electric power for a economy which is rapidly growing. Enhancingpower system industry to meet the power requirement has increased challenges for the engineers. Smart grid is introduced to address challenges of previous system. The system withsmart grid is an advanced infrastructure of power grid, which use high power converters, automation, advanced communication architecture, smart metering technologies, energy management techniques to increase reliability by maximizing efficiency of the power grid. Communication architecture and correct information are main two components of the current electric systems, but the smart grid needs more complex communication methodsin power systems. Present work deals with the different methods that are using in the smart grid to enhance its infrastructure and functionality. This paper aims to provide the information on different mtehods that are currently using in smart grid to make them more efficient and reliable.

***Keywords*– Smart Grid, Renewable Energy Sources (RES), Distributed Generation (DG), Demand Side Management (DSM).**

I. INTRODUCTION

Smart grid is advanced form of energy delivery systems. it is more competent, low cost and more flexible with energy management system than the old grid systems . Smart grid systems are formed with centralized and distributed generating stations which are used for the control of low voltage & high voltage distribution. These generating stations control the fluctuations in voltage level through the centralized automation system of the industrial and residential and users, to provide electrical energy to consumers [1]. The smart grid system is also known as a next generation Power systems network which provide more reliable and secure electrical energy by sharing the information between the consumers, suppliers and to the power generators with the help of communication technologies and digital computing systems. The smart grid introduced new strategies in methods in networking tomake grid more efficient and reliable in Distributed generation for energy storage and Demand Side Management (DSM) to balance the load. Moreover the DSM technologies are introduced to modify the behaviors of different types of users by charging them when they use more electricity in peak hours. DSM technologies shown the significant importance on less number of consumers [2].

The smart grid components are connected via the communication system and sensors at nodes, which provides the connectivity among them for transmission and distribution of energy for commercial, residential and industrial users. In smart grid, real time and authentic information is the major part to deliver the reliable energy to the users from the generators. Smart grid avoidsthe capacity constraints, natural incidents, equipment failures and catastrophe, which are main reasons of energy outage and disturbance with the help of online monitoring of the power systems.

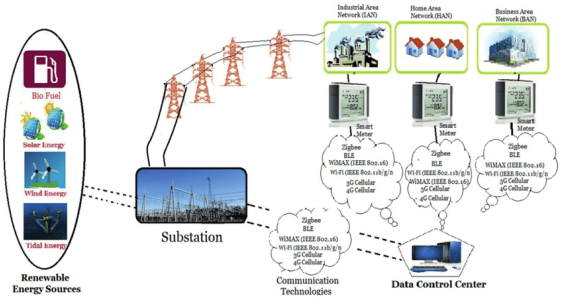

Fig. 1. Smart Grid Communication Infrastructure

ISSN- 2394-5125 VOL 08, ISSUE 04, 2021

Smart grid systemcomponents are connected with the communication systems and connectivity between them is provided by sensors for transmission, distribution and monitoring of electrical energy usage among residential, industrial and commercial users. The main point in smart grid is authentic and real-time information to deliver the reliable energy to the consumers from the generating stations. The natural incidents, capacity constraints, catastrophe and equipment failures can be avoided by smart grid through online monitoring of the power systems, which are major reasons of outage and disturbances in energy.

Architecture is proposed in smart grid by National Institute of Standards and Technology as shown in Figure 2. The Smart system ishavingtwo main components as Networks and System. Components of system are divided in Energy Resources that are renewable, suppliers, Electric Utility Operation Centre Household Appliances and Smart Meters.

Home Area Network (HAN) is used as a medium to provide power to house hold appliances and control the consumption of power with smart meters in Electric Utility Operation Centre. 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 Meters are embedded system which is standalone. Electric utility centre collects the Power consumption reports from these smart meters. Smart meter regulate the power consumption and collet the power usage report and also send the any error and emergency notification using the GPRS technology. Service providers are providing the electricity to the users for their individual devices and after signing contracts. Smart meters are used for interaction with the internal components/devices;maintain the utility bills and users interaction. HAN and WAN are two network types for communication used in Smart grid. For connecting home appliances with the smart meter HAN will be used. 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 side for making connection between smart meters, utility server and suppliers the Wide Area Network (WAN) is used. The Supplierscollectthehourly electricity usagereportsfromthe smart meter and notify meter .The notification from the devices that are in the HAN will be received by smart meter and through WAN the smae information is passed to the suppliers.

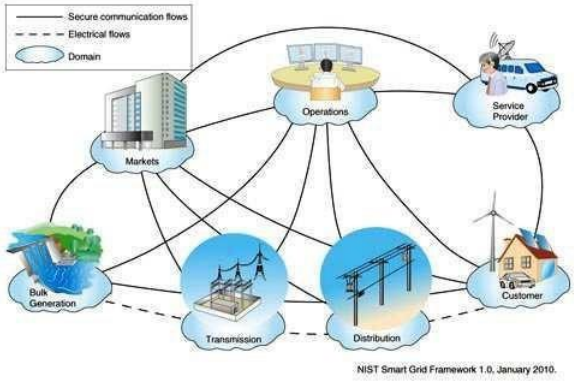

Fig. 2. Different Domains in Smart Grid

II. SMART GRID COMMUNICATION TECHNIQUES

With the updating in technologies and application to achieve the advanced smart grid infrastructure to analyse huge amount of data for controlling and real time pricing. Wireless and Wired are the two basic types of communication media, can be used to transfer information between the smart matters and suppliers. The 2 types of information systems used in smart grid.

1. Smart meter using wireless communication technologies such as Zigbee, Low PAN etc. for the electrical appliances.
2. Sharing data between smart meter and the utility data centers using cellular technologies.

A. ZigBee

Zigbee is comparatively usedata transfer rate, low power, cost and complexity. Zigbee used in smart grid for energy monitoring, automatic meter reading and home automation. It has16 channels, each use bandwidth of 5 MHz and the output maximum power is 0 dBM. The transmission range is between 1m -100m with the 250 Kb/s data rate. The protocol used by zigbeeis IEEE 802.15.4 SPRP.

B. WirelessMesh

It is a combination of different nodes that are grouped together and work as a self-reliant router. Self-healing nature of these nodes ishelpful for communication system to find an active node. Wireless mesh is used in small business operation and remote areas for affordable connections.

C. GSM

GSM is Global System for Mobile communication is used to transfer data and voice services and connect cellular network with mobile phone. The Characteristics of GSM is elaborated in Table 1.

ISSN- 2394-5125 VOL 08, ISSUE 04, 2021

D. Cellular NetworkCommunication

These are used to develop a dedicated path for communication system to enable deployment of smart meter over a wide area. Various cellular networks developments like 2G, 2.5G, 3G, LTE and WiMAX areused to share data between smart meter and the utility data center. Characteristics of communication techniques are elaborated in Table I.

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

III. DATA MINING TECHNIQUES FORSMARTGRID

Large number of artificial intelligence and statistical techniques are developed by the researcher for implementation for data mining. However there are various methods which are widely used like Fuzzy logic, Expert System, Artificial intelligence, Neural Networks, Tie series and vectormechanics.

A. Expert SystemTechniques

For accurate forecasting data, some fundamental rules are used. These rules are developed by the experts of the software field that make expert systems for automatically forecasting with any human assistance. Load forecasting techniques for short term is introduced by the authors for observations taken hourly. The proposed techniques were tested by Taiwan and United States with low errors inforecasting.

B. The RegressionTechnique

This is extensively used metod to create a relationship between the load forecasting functionaldesignsandtheotherfactorslikecustomerclass, data type and weather. The main disadvantage of this method is that the weather component relation with the load demand is not stationary and this technique is unable to find the physical variations in [3] different models of regression are represented by the authors for next day peakforecasting.

C. Support VectorMachines

Support vector machines are most power full techniques that are used to solve the problems of classification and regression in [4] 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 boundaries are created by the SVMs with the help of simple linear functions for a new space.

D. The Time SeriesTechnique

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 considered. Moving Average and auto regressive models are highly used examples of time series method in which future load will be estimated with the earlier entities combination. This technique widely used for the load processing, forecasting, economics and digital signal.

E. Fuzzy LogicTechniques

Fuzzy logic maps the input results to the output such as curve fitting. For managing transformer load from high to low and low to high, certain qualitative range is assign to input. In [5] advantages of fuzzy logic are described that take a noise free input,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.

IV. CONSUMPTION PREDICTIONTECHNIQUES

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 computerequirements.

ISSN- 2394-5125 VOL 08, ISSUE 04, 2021

A. Auto Regressive Integrated Moving Average

ARIMA use earlier linear combination of univariate time series data to predict future electricity consumption. 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.

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.

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.

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.

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 enoughstrong.

V. PRIVACY PRESERVINGTECHNIQUES

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 thesetechniques.

A. Privacy-preserving techniques usingaggregation

Aggregation technique is used in smart grid to perform a different functions such as remove the unnecessary packets that are travelled 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 [6] 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 [7] 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 [7]. 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 [8] to encrypt the smart meter and utility center communication authors used homomorphic Paillar system. The proposed solution is considered more effective in the term of computational cost and guarantee that intruders would not disclosethe communication between the smart meter and utility center.

B. Privacy-preserving techniques withoutaggregation

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 [9] authors discriminate the high level and low level frequency data and AssignID to each type such as high frequency ID (HFID) and low frequency ID (LFID). High level

ISSN- 2394-5125 VOL 08, ISSUE 04, 2021

frequency data contain different information and end user analyses 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 [10] the blind signature technique isproposed 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 [10] in this technique only communicating parties are mainly involved these are smart meter and the control centre 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 centre is also secure and fully trusted. The Comparison betweendifferent techniques is shown in Table II and Table III.

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

IV. VISUALIZATION TECHNIQUES INSMART 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 also some traditional methods. The 2D chart, 3D surface contour and single line diagram are known as traditional methods.. 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 & SCADA network system is as shown in Figure3.

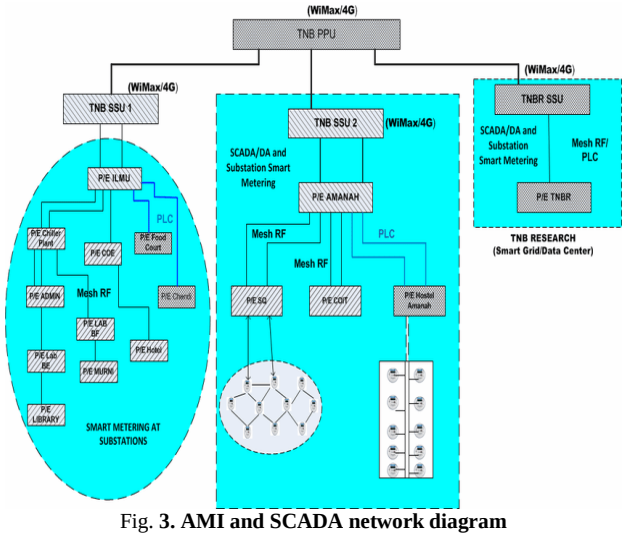

Fig. **3. AMI and SCADA network diagram**

ISSN- 2394-5125 VOL 08, ISSUE 04, 2021

A. Single LineDiagram

Single line diagram use to show the complete overview of the AMI/SCADA network. SLD 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.4.

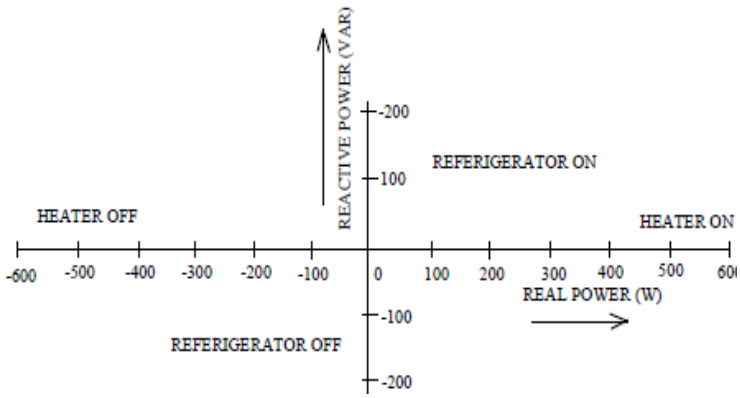

Fig. 4. AMI and SCADA network diagram

B. SpatialAnalysis

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.

C. Non-invasive loadmonitoring

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.

V. 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 safety, reliability and efficiency 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 Technologiesand 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 andapplications.

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