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# Hybrid Power Grid Based On IOT

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**Abstract**: With the growing energy demand, there is a requirement for an efficient and effective power grid management system. The use of Electric vehicles has also increased the requirement for a hybrid microgrid infrastructure. The conventional grid structure doesn't have the ability for data collection and data interpretation. Therefore, in this project we aim to develop a hybrid microgrid infrastructure that can cater the modern day needs by providing a solution to trade energy between neighbors, advanced electricity distribution system and hybrid grid for renewable sources.

**Keywords**: Micro grid, IoT, SCADA, Protocol, Smart Meter, Power theft

## I. INTRODUCTION

There are various combination of energy and all of them are alternative to each other like solar energy, wind energy, fuel cell, etc. But the need of controlling of hybrid energy system arises when it is installed for domestic or commercial purpose. At this point IoT plays and important role in controlling system. The main criteria being switching between the two sources of energy i.e., solar and wind energy without any inconveniences through a website using ESP8266 module which controls the sources of energy. The transmitted data is controlled remotely using IoT. This enables user to have flexible control the sources of energy, manually and remotely using smart phone or personal computer. This system is very efficient, cheaper and flexible in operation.

## II. LITERATURE SURVEY

The energy sector has evolved over the time. Industrial revolution has always played a key role in the energy sector development. Integrating renewable sources into the existing grid and to manage the energy consumption is the key factor to be achieved. IoT - Internet Of Things enables us to monitor the sensor data and automate the system. IoT uses sensors to collect real time data, process the data and control the actuators. IoT can be applied to different industries and sectors, this paper is a survey of how IoT is integrated within the energy sector. Architecture of the smart grid using IoT has been discussed. Data Centre acts as the central IoT hub that communicates between the Power plant, Distribution networks and Smart buildings. The challenges in integrating IoT into power grid is also discussed. Privacy, security, decision making optimization and energy consumption are few of the challenges that has to be solved in order to integrate it. The consumption of electricity can be mainly classified into two domestic usage and industrial usage [1] One of the challenges in IoT based smart grids is the cloud computing limitations. The latency in the system causes slow response from the IoT system. This paper proposes few ways to overcome the limitations of present cloud computing infrastructure. The new technologies like 5G, AI – Artificial Intelligence, IoT – Internet of things support the development of the smart grid. The architecture uses these technologies in order to provide fast and reliable communication between the smart devices. The micro grid systems, metering systems, surveillance systems are all connected to the Cloud. The algorithms for edge computing in the cloud has been discussed. Laplace Mechanism, Gaussian Mechanism and pre-process level mechanism are few of the algorithms proposed for use in edge computing. Data security in this model is improved by the Laplace mechanism and gaussian mechanism. Even when an attack takes place the leakage of data is minimal [2].

This paper proposes a smart energy management system based on the IoT framework that can be integrated into the smart grid structure. This system is called as Smart Energy Management system. Each appliance is connected by a smart meter and these meters are connected to a smart gateway that acts as an access point and a server. The smart meters collect data from the respective appliance using Hybrid Power Grid Based On IoT 2 the sensor module. The communication module takes care of the transmission and receiving of data between the smart meter and smart gateway. The control module controls the ON/OFF state of the appliance. It consists of relay circuit in order to control IARJSET
the appliance. The algorithm used in this system considers the factors like cost optimization, Decision making and demand response. Smart sockets are nothing but the smart meters integrated into the electrical sockets. These sockets collect data and send it to the smart gateway. The communication technology used here is Zigbee between the smart meter and smart

 

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gateway. The energy monitoring system displays the electrical parameters like voltage, current, power and their respective RMS values. The web dashboard enables the user to monitor the data and also visualize it using graphs. [3]. Electricity power theft is also one of the main concerns in a power grid distribution system. This paper proposes a neuro fuzzy logic based on Machine learning. The system studies the consumption pattern of the residential users at different scenarios like during peak hours, day time usage, night time usage. These patterns are recorded and analyzed every day to understand the general usage pattern of that particular residential area. The electricity consumption data is preprocessed by this system and then the machine learning model is applied on it. Smart meters are used at each house to collect the consumption data and send it to the framework. Whenever there is a electricity theft in that particular area the change in consumption pattern is recorded and analyzed such that the next time when there is an electricity theft the system could detect it effectively. Such pattern recorded by this system counts to a number of thirteen different theft patterns [4].

Microgrid structure enables us to trade energy within the micro grid and also between the other microgrids. The dependence on the main grid reduces if there is a mechanism to trade energy between neighboring houses and other microgrids. This paper provides the simulation results of the energy trading platform implemented at a wider scale. The results display the feasibility of the energy trading platform at a large scale. Also, the challenges in the peer-to-peer trading platform. These transactions are distributed in the network. This mechanism enables end user to become a producer. Hence, we can call them as a prosumer. These transactions between the prosumers are recorded as smart contracts. The co-simulation model is implemented in both Python and MATLAB. The input output data is given through python commands. The local exchange model is developed [5]. Most clients are not content with the utility of electricity distribution in a country like India, due to traditional meter reading approaches that demand a huge labor and lengthy office time to accumulate meter readings for the remittance process. In this paper, a smart energy meter reading and monitoring system based on IoT with PLC and SCADA is proposed. There are many important advantages to the system, such as radio communication, remote supervision, anti-tamper system, and economical. The bill can be paid out using the client support system online. It helps the end user to substantiate the electricity consumption and invoice once they log in to the system, while the invoice is sent biweekly or on the interest of the user. An assortment of standards can be achieved by smart energy meters available on the market, thereby offering a high degree of versatility in measuring and analyzing energy usage. Sensors can be much more flexibly mounted on the shop floor if Wi-Fi modems are used [6].

By engaging a micro-gird key element point of view, this article tried to superscribe the system convolution. Furthermore, the incorporation of renewable power units was scrutinized and probed by computerization of the established architecture through MKEM approach to test system stability. The system was looked over under various PV perforation with different PV regulations to denote the productiveness and execution of the proposed substructure, as well as the working approach. The result showed that the proposed model could decrease energy price and power losses. In addition to the foregoing necessities, the prop up devices such as inverters with efficient controls are required to allow enhanced operation of the generated energy. In this paper, the suggested model has been put into effect using 100% PV perforation and varying readings of solar performance [7]. The smart network is the future grid which solves the issues of unifacial data and energy intensity, energy losses, increasing electricity consumption, credibility and surety in the conventional power grid. It helps smart grid by allotting smart devices or IoT devices for the supervising, observation and administering the grid, as well as correspondence, computerization and pursuing of such devices. This realizes the IoT smart grid system which improves and enhances various network functionality at power production, transferal , supply, and implementation. Smart grids, critical infrastructure, and the IoT nodes use new and specifically defined communication protocols such as low-power wireless personal area networks and IPv6 whereas the traditional computing systems are based on TCP/IP protocol stack that is centered around the standard Ethernet based data exchange. Different and novel protocols incorporate unforeseen and original vulnerabilities and place cutting-edge demands on IDS [8].

The paper proposes a prototype of a cost effective electrical smart power meter which has been mapped out to be integrated in an IoT scenario. The wM- Bus radio module used by the smart power meter allows the inclusion of them in a common IoT scenario as the advanced metering infrastructure, already used for the smart metering of water and gas consumption. Future developments will concern the improvement of other power quality metric on board and the evaluation of the smart power meter in a real city IoT scenario. Fig1. Principal services of a smart city Hybrid Power Grid Based On IoT 3 The generic term Low-Power Wide-Area Network identifies a group of technologies that perfectly meet the needs of the IoT. The reduction of the complexity and cost of the network infrastructure it is also fundamental to obtain a low cost per end-point [9], Electrical power grids can be modelled with different components and its states described by the power flow equations. With enough known inputs, these equations can be used to calculate the state variables of the system, from which all power flows and line currents can be derived. The system of equations is under-determined. Accurate monitoring of imbalanced grids as well as achieving full state estimation should be part of our

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future work. Considering practical use, the estimation accuracy should be increased in case of bad data, either by modifying the presented scheme or by selecting an appropriate method to identify and correct errors beforehand [10].

In this paper, a detailed survey of smart grid technologies and applications has been done. Where it explains The Smart Grid which is a system that helps to manage power flow and protect against problems. It is a system that uses innovative products and services to help control and monitor the electrical grid. It also uses intelligent technologies to help the grid selfheal if it is damaged. It's made up of lots of different technologies including Smart meters, automated meter reading, Vehicle to grid (V2G), Plug-in hybrid electric vehicle technology, Smart sensors, and Sensor and actuator networks (SANETs) in smart grid. It's also being used to control things like Advanced Metering Infrastructure, Intelligent electronic devices, phasor measurement units, Wide area measurement systems (WAMS), Local area networks (LAN), Home access networks (HAN), Neighborhood area networks (NAN), Wide area networks (WAN), Cloud architecture of smart grid. Smart Grid applications such as Home and building automation, Smart substation, and Feeder automation (FA) are explained. Benefits of Smart Grid such as Self-Healing, Motivates and including the consumer, Provides Power Quality for 21st Century Needs, accommodates all generation and storage options, enabling markets, optimizes assets and operating efficiently and benefits for consumers, for utilities and other stakeholders are discussed. The benefits of the Smart Grid are that it can help to manage power more efficiently, and it can help to establish standards for compatibility among different smart grid applications. Local opportunities for smart grids such as Integrated communications, Sensing and measurement, Advanced components, Advanced control methods, Improved interfaces, and decision support [11].

A wide variety of applications can be derived from the Internet of Things (IoT). Smart grid applications can utilize IoT in multiple ways including power plant monitoring, power generation, and consumption prediction, power consumption monitoring, energy storage monitoring, advanced meters, electric vehicle charging, power demand side management, and various energy production applications. In this paper, by using IoT capabilities, they have designed and implemented an intelligent energy metering platform consisting of smart plugs, gateways, and a cloud server and proposed a way to monitor energy consumption and keep track of power line parameters so that it can receive warnings and/or control the energy usage. The Gateway function allows you to connect to a sensor node (on 192.168.4.1) and assign it a name. Then you send the node's name, IP address, SSID, and password of your local network to the sensor node.The sensor node will then send you its IP address in a POST message. You then update the Gateway's database with the sensor node's IP address. Next, the sensor node will start a web server and send its IP address to the Gateway. The Gateway will then read the sensor node's data. Finally, the Gateway will send all the sensor node data to a server in a single message. The Gateway will then sleep for T seconds. The proposed system would allow electric appliances to be turned off during peak hours and turned on at non-peak hours, to save electricity and reduce the amount of load on the electricity grid [12]

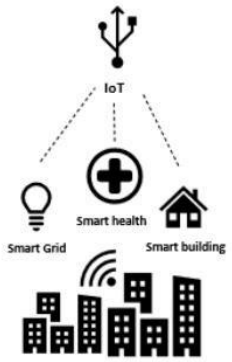


Fig 1:Principal services of a smart city

The smart grid is a technology that will change the way we use energy, and it will do this by solving many of the problems with our current power grid. It will provide more reliable energy, help us conserve energy, and help us stay safe. Massive amounts of data can slow down IoT and cloud-based designs, particularly when it takes a long time for information to travel from one place to another. Real-time services exist so that you can get energy and information quickly and easily. EC is designed to be a cost-effective way to do this, by providing resources at the edge of the network. This paper provides a comprehensive review of the Smart Grid systems, based on IoT and Edge Computing. The EC-IoT-based SG system is designed to help businesses manage their data and communications. First, it is implemented using devices and sensors that are connected to the internet. These devices collect data about the environment and communications within the

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company. This information is then used to improve the efficiency of operations. The development in the rising technologies, the framework for Edge Computing-IoT-based SG systems, and requirements to implement the Edge Computing-IoT-based SG system are highlighted. Framework for Edge Computing-IoT-based SG systems is examined, and important requirements to implement the Edge ComputingIoTbased SG system are outlined. Finally, some critical issues and challenges faced in the implementation of Edge Computing-IoT-based SG systems are identified. Some important open research issues are also identified [13].

Renewable energy is becoming more popular because it is good for the environment, and also has low transmission losses. A Hybrid Power Grid Based On IoT 4 new way of producing energy is being developed that will use many different kinds of renewable sources. This is called a 'transformation,' and it is a big task but it is possible with the help of new technologies. This paper provides a review of the current international research on this topic. Renewable energy sources, like solar and wind, are becoming more integrated into smart grids, which means that more traditional centralized power systems are being replaced by more distributed systems. This means that more people can use electricity more easily and without having to worry about the power going out. Power management is no longer as attractive as it once was. This is because the system's disadvantages, such as the cost, security issues, and control of a complex network, make it less desirable. Blockchain technology can help make sure that energy is used efficiently and without any cheating. With encryption, cryptography, and consensus protocols, your data is more secure. In a new decentralized energy system, this combination can help keep energy systems more reliable and efficient. It is being used in systems that are designed to help promote the participation of small consumers and producers in the smart grid [14].

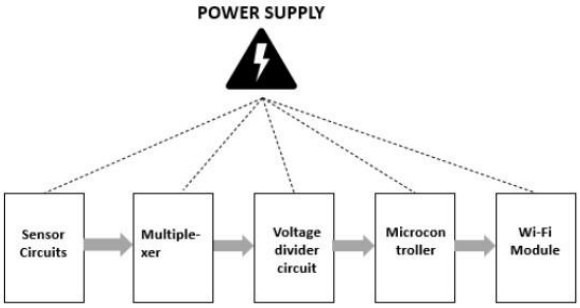


Fig 2:Structure of sensor node

The power quality and reliability problems that plague traditional power grids are a big challenge for both service providers and consumers. However, technological advances in the Internet of Things era provide better solutions to manage these challenges and enforce measures of a Smart Grid. Advanced Metering Infrastructure and Smart Metering technologies are enabler technologies that can modernize the conventional power grid by exposing the hidden details of electrical power. The paper aims to explore the role of Smart Metering in power quality and reliability monitoring in IoTenabled systems. Power grids use power quality and power quality to measure how much power is being used and how much power is being produced. People are working on ways to use IoT, which is a type of technology, to improve power grids. IoT can help us figure out how much power is being used and how much power is being produced, and it can also help us enforce the measures of standards of grid security. There are a lot of different ways to transmit power, some of these technologies, like Smart Metering, are already available and other technologies, like routing algorithms, are still being developed, but may be useful in the future [15].

In this paper, an agent-based trading platform is proposed to integrate energy storage systems into micro grids energy management systems. It discusses two market models for managing energy needs in micro grids - the global model, in which the energy imbalances are managed by exchanging energy between different micro grids, and the local storage market model, in which energy mismatches are managed by allowing some external storages to trade their services within the micro grid. It also proposes a bidding algorithm that allows ESS owners to outperform their competitors by learning their bidding strategies. The algorithm is implemented on a 123-bus distribution system with multiple micro grids and community based ESSs. There are different bidding strategies that energy sellers can use when participating in the trans active energy market. This study looked at how to allocate losses among energy transactions between electric service providers and micro grids using a complex loss allocation method. The potential benefits of using energy storage systems in distribution systems, and argues that they could be a viable way to large-scale deploy these systems [16], This paper deals with the loss of power by the power theft at different intervals of the line. The smart grid is a advantageous weapon to the present community as it gives bidirectional information among purchaser and distributor. The traditional meters

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provide information about usage of the energy but the smart meters can provide the information exactly where is a robbery of the power. This system examines and detects the data at every interval which gives precise result with least errors. It also ensures the preservation of the energy, reducing manual work by providing digital information to the board. Automated control of the meter is provided which also helps the consumers to keep a chart of the energy consumption and usage of the energy accordingly [17].

This paper deals with the supervision of the usage of energy by using smart meters. The customer can have a pre planned way of usage of the energy as they will be receiving the amount of energy already being consumed and use it according. The information is sent to the board in the other hand which reduces the manual work of checking the meters. By using IoT the devices can be automatically turned off/on to save the energy by the consumer from anywhere. The information from the meter is sent to the consumer's cell phone through Arduino and Wi-Fi module. The consumer can turn on/off the entities through the application in the cell phone which connects/disconnects the circuits as the information is received to the Arduino through the cloud which eventually controls the relay [18], This paper deals with various IoT framework being merged with smart grid. In a tri-layer framework, the initial layer consists of all the devices that are connected to the system, Smart devices are the devices that can transmit the data over Internet. The second layer consists of communication linkers which charts the information received from the initial layer to the final abstraction layer. The abstraction layer then extracts and authorizes the obtained information. In the quad layer framework, the initial device layer is divided in two layers, the thing layer consists of entities that detects any changes in surrounding and gathers information and the gateway layer that authorizes the linking of elements in the Thing layer. The additional layer that is the management layer gain the information and examines it. It also deals with the problems faces such as access to personal information of the consumer as the meters collect all the types of data. As the devices connected to the grid are more, there will be more information collected thus causing congestion. There will loss of data due to time lag which should be handled in a precise way [19].

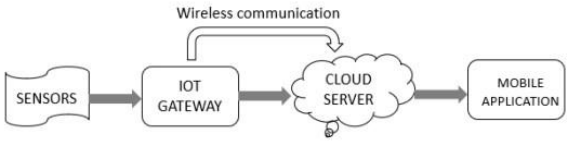


Fig 3:IoT layers

This paper discusses about the importance of merging IoT in the smart grid systems.Smart grid is a dispersed system where the current flows from the producer end to the receiver end and the other way around. IoT is found advantageous in ways such as to analyze and Hybrid Power Grid Based On IoT 5 report the consumption of the energy on a regular basis at every depot. It collects and transfers the information of the meter digitally by reducing the amount of manual work, it also prevents physical examination of the authority to examine the working of meter. The information is authorized frequently to check any loss in energy and beeping the alarm if there is any kind of theft. Smart grid merged with IoT conserves huge amount of energy. [20], This paper deals with the implementation of smart grid to large area such as residential community. It mainly focuses on the interactions of the devices, rules to be followed and the test bed status which maps the purchaser energy usage pattern. The universal home gateway shares data with cloud server where the examining is done. The system authorizes the energy and manages the consumption of energy. By avoiding the usage of energy at peak time can be ensure to reduce the consumption of energy. A mobile application is provided to provide data to the consumer about the energy consumption. The IoT system is develop using XMPP to ensure energy management [21].

## III. CONCLUSION

A hybrid power grid using Internet of Things (IoT) technology can offer several benefits compared to a traditional power grid. One of the main benefits of a hybrid power grid using IoT is the ability to integrate renewable energy sources, such as solar and wind power, into the grid. This can help to reduce the reliance on fossil fuels, which can have a positive impact on the environment and contribute to the transition to a more sustainable energy system. IoT technology can also enable real-time monitoring and control of the power grid, allowing for more efficient and reliable operation. This can help to reduce downtime and improve the overall reliability of the power grid. In addition, a hybrid power grid using IoT can facilitate the integration of distributed energy resources, such as small-scale solar panels and battery storage systems, into the grid. This can help to increase the resilience of the grid by providing backup power in the event of an outage or

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other emergency. Overall, a hybrid power grid using IoT technology has the potential to provide a more efficient, reliable, and sustainable power grid, but it will also require significant investments in infrastructure and technology to implement.

## REFERENCES

[1]. Pawar, Prakash. "Design and development of advanced smart energy management system integrated with IoT framework in smart grid environment." Journal of Energy Storage 25 (2019): 100846,

[2]. Hossein Motlagh, Naser, Mahsa Mohammadrezaei, Julian Hunt, and Behnam Zakeri. "Internet of Things (IoT) and the energy sector." Energies 13, no. 2 (2020): 494.

[3]. Chen, Songlin, Hong Wen, Jinsong Wu, Wenxin Lei, Wenjing Hou, Wenjie Liu, Aidong Xu, and Yixin Jiang. "Internet of things based smart grids supported by intelligent edge computing." IEEE access 7 (2019): 7408974102.

[4]. Blazakis, Konstantinos V., Theodoros N. Kapetanakis, and George S. Stavrakakis. "Effective electricity theft detection in power distribution grids using an adaptive neuro fuzzy inference system." Energies 13, no. 12 (2020): 3110.

[5]. Hayes, Barry P., Subhasis Thakur, and John G. Breslin. "Co-simulation of electricity distribution networks and peer to peer energy trading platforms." International Journal of Electrical Power & Energy Systems 115 (2020): 105419.

[6]. Amudhevalli, R., and T. Sivakumar. "IoT based smart energy metering system for monitoring the domestic load using PLC and SCADA." In IOP Conference Series: Materials Science and Engineering, vol. 1055, no. 1, p. 012154. IOP Publishing, 2021.

[7]. Worighi, Imane, Abdelilah Maach, Abdelhakim Hafid, Omar Hegazy, and Joeri Van Mierlo. "Integrating renewable energy in smart grid system: Architecture, virtualization and analysis." Sustainable Energy, Grids and Networks 18 (2019): 100226.

[8]. Alhasnawi, Bilal Naji, and Basil H. Jasim. "Internet of Things (IoT) for smart grids: a comprehensive review." J. Xi'an Univ. Archit 63 (2020): 1006-7930.

[9]. Abate, F., M. Carratù, C. Liguori, and V. Paciello. "A low cost smart power meter for IoT." Measurement 136 (2019): 59-66.

[10]. Menke, Jan-Hendrik, Nils Bornhorst, and Martin Braun. "Distribution system monitoring for smart power grids with distributed generation using artificial neural networks." International Journal of Electrical Power & Energy Systems 113 (2019): 472-480.

[11]. Dileep, G. "A survey on smart grid technologies and applications." Renewable energy 146 (2020): 2589-2625.

[12]. Yaghmaee, Mohammad Hossein, and Hossein Hejazi. "Design and implementation of an Internet of Things based smart energy metering." In 2018 IEEE International Conference on Smart Energy Grid Engineering (SEGE), pp. 191-194. IEEE, 2018.

[13]. Mehmood, M. Yasir, Ammar Oad, Muhammad Abrar, Hafiz Mudassir Munir, Syed Faraz Hasan, H. Muqeet, and Noorbakhsh Amiri Golilarz. "Edge computing for IoT-enabled smart grid." Security and Communication Networks 2021 (2021)

[14]. Biegańska, Marta. "IoT-Based Decentralized Energy Systems." Energies 15, no. 21 (2022): 7830.

[15]. Al-Turjman, Fadi, and Mohammad Abujubbeh. "IoT-enabled smart grid via SM: An overview." Future Generation Computer Systems 96 (2019): 579-590.

[16]. Nunna, HSVS Kumar, Anudeep Sesetti, Akshay Kumar Rathore, and Suryanarayana Doolla. "Multiagent-based energy trading platform for energy storage systems in distribution systems with interconnected microgrids." IEEE Transactions on Industry Applications 56, no. 3 (2020): 3207-3217.

[17]. Barman, Bibek Kanti, Shiv Nath Yadav, Shivam Kumar, and Sadhan Gope. "IOT based smart energy meter for efficient energy utilization in smart grid." In 2018 2nd international conference on power, energy and environment: towards smart technology (ICEPE), pp. 1-5. IEEE, 2018.

[18]. Sulthana, Naziya, N. Rashmi, N. Y. Prakyathi, S. Bhavana, and KB Shiva Kumar. "Smart Energy Meter and Monitoring System using IoT." International Journal of Engineering Research & Technology 8, no. 14 (2020): 5053.

[19]. Ghasempour, Alireza. "Internet of things in smart grid: Architecture, applications, services, key technologies, and challenges." Inventions 4, no. 1 (2019): 22.

[20]. Akshata A. Gawande, Heena Sheikh, "IOT Based Smart Grid System", International Journal of Emerging Technologies and Innovative Research (www.jetir.org), ISSN:2349-5162, Vol.8, Issue 1.

[21]. Viswanath, Sanjana Kadaba, Chau Yuen, Wayes Tushar, Wen-Tai Li, Chao-Kai Wen, Kun Hu, Cheng Chen, and Xiang Liu. "System design of the internet of things for residential smart grid." IEEE Wireless Communications 23, no. 5 (2016): 90-98