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Necessity of Internet of Things in Smart Grid

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ABSTRACT

Aim of this paper is to gives the overview of the importance of deployment of Internet of Things in Smart Grid so that available power from the grid can be efficiently managed. Also, this paper covers the application of IoT in three levels of generation, transmission and distribution. Besides, it explains about implementation of IoT in renewable energy sources. This paper also describes simulation of single phase AC micro grid in MATLAB/Simulink to understand the importance of IoT implementation.

KEYWORDS: *Smart Grid, MATLAB, Simulink, NodeMCU, IoT*

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INTRODUCTION

Internet of Things is a network of system elements of grid which is connected to each other using sensors, microcontrollers, NodeMCU. Smart grid refers to an electrical network which consists of digital communications to sense changes in local load. Internet of things in smart grid enables the grid to share information with the help of wireless network like 4G, WiFi.

Today, there is a need to transfer and analyze big data in real time which is measured in electrical networks. This data helps in making decisions. Therefore, there is a need to install IoT based technologies to implement information technology in the smart grid.

Recent researches have shown that non renewable sources of energy, like coal and petroleum, are going to get depleted in near future. Also, V2G enabled vehicles are manufactured these days, which can make returning power to the grid as simple as plugging a device into socket. Therefore, a term is coined “Energy Internet” to deal with problems like efficient management of energy between different loads so that sustainable energy can be ensured in future.

In this paper we describe the necessity of deployment of IoT in smart grids and its applications in generation, transmission and distribution. To analyze benefits of implementation of IoT in smart grid, this paper presents simulation of single phase AC micro grid.

A. IoT in generation level

The resource management for generating stations is done using local controllers. Moreover, the system manager has little control over long distance resources. In addition, with the deeper reach of renewable resources, uncertainty of power availability due to renewable sources is also increasing. Also, loads which are demand response resources is increasing, adding to the uncertain real time electricity prices. Number of renewable sources at demand side is increasing and will have much importance in near future in the grid. Hence, the system manager should be able to accompany with the frequent demand and supply changes.

Thus, IoT can play an important role in integration of non renewable energy resources with renewable energy sources so that generation sector can perform better than ever before and improve sustainability of the system. Till now, the main focus of IoT implementation has been on demand side while supply side has seen some sort of negligence. Implementation of IoT on supply side can provide higher controllability and better performance and efficiency in power systems.

1. IoT and wind energy

The problem with deployment of wind energy sources is the irregularity in generation of power from these sources. Hence, this irregularity in power generation can pose a danger to the security of the system. To prevent this, wind energy can be combined with the rest of the power system in real time so that the irregularities can be supplied by it and prevent system from getting vulnerable.

Also, the wind farms which are installed with IoT devices can be able to schedule correct predictive maintenances which will prevent the equipments from suffering great damages. Machines learning and data mining technologies can be implemented to achieve it. There should be two layers of operation in the smart grid to facilitate easy control.

First is controller layer, consisting of many sensors and actuators. The sensors provide data from each equipment of the wind power plant to the operator or controller. The operator or controller will thus make a decision based on these data and will send respective commands to the actuators. These actuators will respond mechanically to provide the function required.

Second is cyber layer, which is formed by reliable communication network, monitoring system and SCADA. Its prime target is to employ signals between central system and other IoT devices which can facilitate real time data transfer between them. Hence, each wind mill should be equipped with remote terminal unit which can facilitate a local area network to send and receive data.

2. IoT and solar energy

A PV system is formed by PV arrays, wirings, mounting systems and batteries. PV systems these days have newer technologies included like maximum power point tracker, GPS tracker and solar irradiance sensors. Also, there are cooling systems provided in PV system which improves its efficiency. There is a difference between conventional and todays PV system which is earlier it was used to provide power to end user but nowadays a large PV unit is connected to grid.

Temperature and radiation intensity are the two factors which heavily affects power generated by PV. Performance of PV system can be highly improved with dirt shedding mechanisms because the dirt collected on the panel leads to a great drop in power output. Also, at high temperatures the efficiency of PV panel decreases . To counter this, MPPT system is used to tilt the surface of PV panel so that either it gets exactly in front of sun or the brightest area where sunlight is not direct. The storage schemes like batteries are must for a solar power because the solar power is needed to be stored before being used.

Collecting data from all these parts of PV system with the help of IoT as well as having actuators equipped with remote command, facilitates no direct human contact at the site. The data from MPPT as well as GPS solar tracker is collected is used to make decisions on maintenance as well as performance enhancement.

3. IoT and thermal energy

The most basic type of energy harnessed is thermal energy from coal. This is fundamental type of energy needed to keep the grid stable and secure. Future plans consist of transforming coal-based power plants to renewable energy-based power plant. Thermal power plant also operates in low efficiency mode which ensure grid stability.

These things infer that IoT probably has the least application in this part compared to other parts of electrical grids such as renewable generation, distribution, or demand-side. However, IoT can be applied in two fields here. First one is that the data of output of generators, the state of transformers and tap-changers, also the injected power to each branch must be available to the central operational system in real time. Therefore, the IoT implementation in thermal power plants can ease the access to such real-time data. Also, coal power plants have a large number of elements and components. The data of each element must be recorded, monitored and analyzed by the power plant engineers using advanced IoT based sensors and algorithms to conduct preventive maintenance schedules which can mitigate the risk of unplanned outages.

B. IoT in Transmission level

The generation level and distribution level is connected by transmission level. To maintain the system reliable, this component plays an important part. IoT can be applied in this level in two domains. First one is the IoT application in managing the amount of power carried by line and the second is effect of IoT on maintaining system stability. The IoT equipped intelligent electronic devices can be connected to the transmission line to extract the data from it and send to the central network. Phasor measurement units measure the magnitude and angle of voltage and current at a specific point of the line. The frequency can also be found using this device.

Also, the transmission lines which are open are susceptible to damage done by natural disasters. Strong winds and ice can cause wire to withstand high stresses and tension levels. This can cause huge damage to wire leading to their breakening which impacts the transmission and stability of power system. Also, transmission line passes through remote accessible areas by humans, so in order to gain the data of health of wire IoT equipped devices can be implemented at those areas. The addition of IoT can efficiently mitigate the damages caused by natural disasters. The data is collected from the instruments installed at transmission lines and sent to the central operator. In this process, data is sent to the main node device and thereafter must be sent to the central operation center through a communication network like GPRS/WiFi. The IoT devices, which can be installed in transmission lines, are sync node device, tower deviation sensor, temperature and humidity sensors, wind speed sensor, current leakage sensor. Incorporation of these devices will help in getting the data as well as sending commands to the transmission line operation to maintain its stability.

C. IoT in Distribution level

Implementation of IoT in distribution system provides many benefits such as monitoring of consuming behavior of consumers, controlling the required power flow in different areas, fault detection in transmission and implementing self-healing technologies. Also, feeders and buses of distribution level should be IoT enabled to gather and share data through network communication schemes to central operator to make him or her able to monitor as well as take decisions on distribution. It should also be noted that for improving the stability of grid, self-healing technologies are very important schemes for the distribution grid in the coming age. Also, these self-healing technologies should act in real-time to ensure the previous functionalities are approached as quickly as possible to maintain reliability of the grid.

1. IoT in microgrids

A microgrid represents a small-scale set of loads which are localized on a specific feeder of distribution network and is capable of meeting some or all of its demand through small scale generation sources such as small-scale wind mills, PV panels, turbines, diesel generator, or gas turbines. To store the extra power generated by the renewable sources when demand is low, an energy storage facility is required. Battery is mainly used for storage purpose of energy which also ensure frequency stability of the grid. Apart from batteries, fuel cells and flywheel units are also used at many places. The microgrid can be used to sell the extra power generated to the main grid during low demand with the help of a network which can determine real-time power prices. The combined operation of micro grids along with energy storage system can be a hybrid model to alleviate the dependency on the main supply grid.

Present microgrids are suffering from three major problems which are the efficiency, power quality, and security of interconnected microgrids. Application of IoT in these domains can help to solve these issues, which can lead to more reliability on micro grids which is desired by the power system companies. Independent management of energy is also required for micro grid other than main grid. The main grid should have no control and effects on micro grids. The contingencies should be balanced by storage units connected to the micro grids. These schemes also have limited potential in terms of quick recoveries, the microgrid's operator has to implement unplanned load shedding or undesired outages of power. For interconnected microgrids, the application of IoT improves the observability and controllability of the central operator on microgrid components as well as it can take the properties of all micro sources into the consideration for the complete power system generation. These implementations will lead towards better performance of power system as well as greater penetration of renewable energy resources in the grid. Also, the microgrid's operator can implement better renewable energy generation and better storage collaboration to increase the profits of the microgrid equipped with real-time prices of the power distribution market. Also, real-time monitoring helps in implementing strategies to provide better power quality to industrial as well as domestic uses. It should also be noted that, when two or more microgrids are connected to each other as it can severely impact reciprocal stability due to scale incompatibility. Hence, any great imbalance in any of them can pose a risk to the security of other micro grids present in the system. Therefore, a real-time frequency and voltage stability control procedures should be added to meet the demand without any interruption. These things stress upon the necessities of utilizing the internet oriented environment so that it can take advantage of its IoT equipment installed. The data must be acquired from all sensors to inform the real-time state of critical parameters to the controlling devices. The data made available by IoT devices should be processed using technologies like machine learning, artificial intelligence and cloud computing to determine the action plan required to accomplish required tasks.

2. IoT in smart cities, buildings, and homes

Smart city refers to an urban area that takes advantages of different types of IoT sensors and ICT infrastructures to share information which is employed to manage resources and assets efficiently. This information encompasses data collected from citizens, devices, and assets. The data must be analyzed to monitor and control transportation systems, electricity generation micro sources, water supply networks and waste management, as well as affairs corresponded with different energy consumption in a city. In particular, the incorporation of IoT for managing energy consumption in smart cities is targeted. The smart cities are made up of smart public places and smart buildings. For example, the lighting system of the roads can be supplied using hybrid systems which can be monitored and controlled using an IoT-based environment and it can be supported by the main-grid when real-time generation is not adequate. From a distribution operator point of view, the incorporation of parking lots for electrical vehicles is also important, particularly for EVs with the vehicle-to-grid capability. The pervasiveness of EVs has had an accelerating trend during the last decade and will have a boom in the future. Furthermore, the modeling of EVs behavior is extremely sophisticated due to its highly stochastic nature. They may charge or discharge their batteries whenever they want. Hence, if the EVs are able to connect to a cloud-based controlling 28 server when they are at a specific region, they can inform the operator about their charging or discharging decisions. In addition, the capability of real-time control over them can be accessible through parking lots' control systems. This implication of V2Gs in power systems will be a controversial issue in near future. Hence, the power system's operators would rather take advantages of IoT infrastructures to not be obliged to resort to undesired measures such load shedding and curtailment which may be led to paying detriments to the loads or unsatisfactory of customers.

In this study, the incorporation of IoT from the energy point of view is investigated. Smart metering infrastructure is one of the fundamental parts of smart buildings. The real-time electricity and gas price must be acquired for energy management center to adjust the generation and consumption accordingly. All energy-related equipment and devices must be equipped with IoT technologies to send and receive real time signals. A wireless platform can effectively create an access point for all devices to share information in a cloud data center. In addition, some devices can have accessibility to LTE and 5G protocols to enable the owner's and controllers to have a remote control using mobile HMIs. The V2Gs can be charged automatically at midnight based-on real-time electricity price monitoring and can sell its excess stored energy to the main grid at peaks. Thus, an intelligent cloud computing environment with a wide bandwidth and high-speed communication infrastructure is needed which can be materialized by IoT technologies and development of ICT.

3. IoT in active distribution networks

Active distribution network refers to a distribution grid which enjoys the presence of medium-scale or small-scale distributed energy resources such as diesel generator, gas units, wind and solar units, micro-turbines as well as energy storage facilities such as batteries, flywheel, and fuel cell. These generating sources are also referred to as virtual power plants. In addition, some of these generating units can be used in the form of combined heat and power utilities. In such a situation, a lot of micro sources (small-scale generation resources) are involved which can affect the generation schedule in large-scale. This matter will have more implication on the system in the next decades. As an instance, the California power system is struggling with a huge penetration of solar energy in demand-side which has caused duck curve phenomenon. The more efficient exploitation of renewable resources along with the economical operation of fuel-fired resources in such distribution networks must be managed by local distribution network operator which have a connector role between demand-side and supply-side. In this regard, the instantaneous generation of renewable resources must be provided for the operator using IoT-based AMIs and proper controlling action must be carried out automatically based on predefined settings.

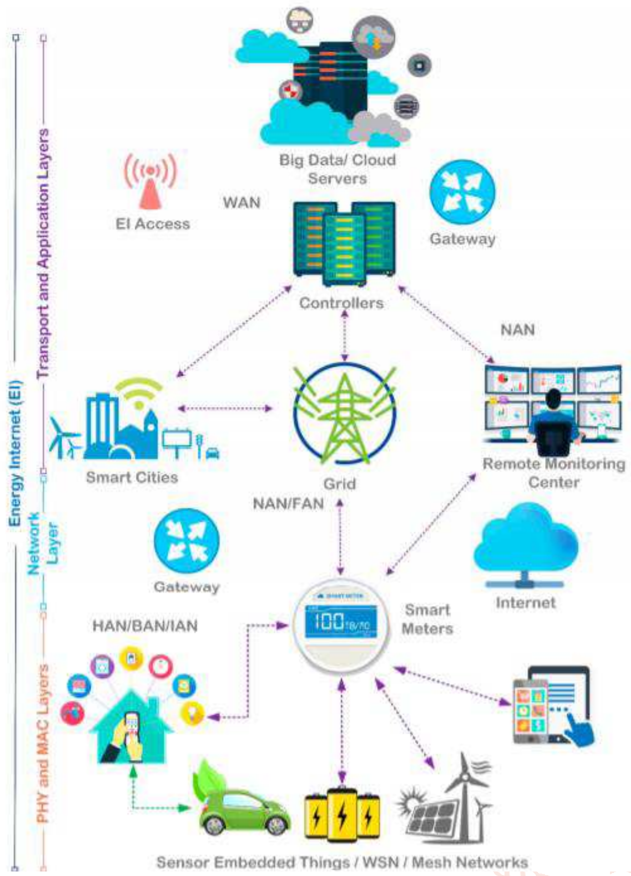
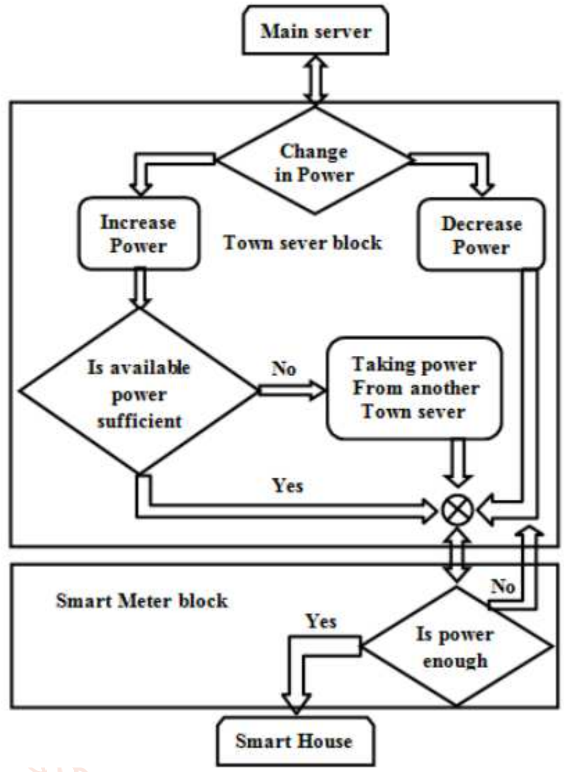


Figure 1: IoT schematic for smart grid implementation

Single Phase AC Micro Grid The simulation model consists of a single phase power supply, a power grid with transformers used to receive and inject power to and from the grid. There is a solar PV panel equipped with batteries as storage facility to supply the loads as well as store the power when demand is low and then supplies power back when demand rises. Total number of loads connected to the grid is three which are houses and are of domestic nature. There is a breaker connected to load 3 which is used to disconnect it from the grid. There is a battery controller equipped to maintain the state of charge required during day and night time according to the intensity of solar irradiation and demand.



Simulation Result

As we can see in figure 2 and figure 3 we can observe the power variations in different components of the micro grid. The battery controller performs its operation from 0h to 12h and from 18h to 24h. The sufficient amount of current is supplied by the battery when available power from micro grid is insufficient in the cases when demand is greater than supply. The solar power generation is nil from 20h to 4h in ideal situations, so the same is observed in simulation also. Solar power generation reaches its peak amount of 5kW during 14h to 15h. At 8h, house No. 3 which acts as load is turned OFF for 10 seconds with the help of circuit breaker. A spike can be seen in the active power of the secondary side of the transformer and the stored electric power of the energy storage which in this case is battery. The battery control is not performed during 12h to 18h. Hence, SOC (State Of Charge) of the installed battery is set to a constant value and it does not change with effects of charging or discharging of the battery. At the times of power shortage in the micro grid, the system power from PV panel supplies the extra power required. When there is extra power in the microgrid because of less demand or more generation, surplus power is supplied back to the main grid.

Conclusion

Thus, with the integration of all the system elements we will be able to gather the data of power flow from supply, power demanded by load networks and power compensated by renewable energy sources like solar, wind, tidal etc. This data will help in keeping track of right amount of power needed in areas from the supply at a given time, so that right amount of power is supplied to each area and thus stop wastage of electricity as well as efficient management of power to ensure sustainability in the long run.

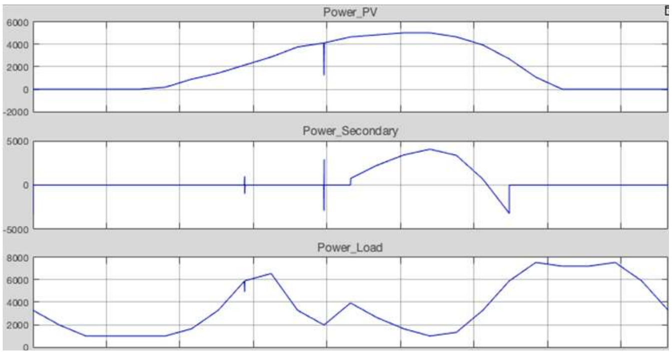


Figure 2: Simulation result

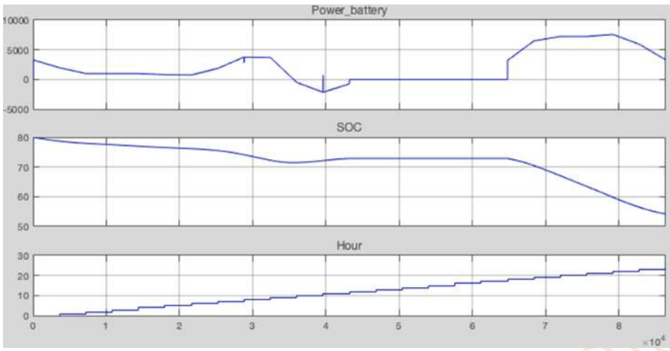


Figure 3: Simulation result

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