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Iot Based Microgrid For Energy Management System

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Abstract: In this paper, There's implementation of IOT based communication technologies in microgrid with energy management system. Various wireless and wired communication techniques with IOT-based grid applications, network issues and challenges is addressed. The micro-grid based electricity generation and management in advanced way with the help of controlling digital communication to the power grid. In smart grid system there is two way communication is possible which provides a sustainable energy system. For implementation of IOT based communication in microgrid, the flow of energy is managed from the grid to the load side and data is captured as per frequency of requirement. These data is transmitted over a suitable communication channel to the cloud server where all data is taken in SCADA system with the help of PLC in representable form. The main objective is to optimize the data of microgrid efficiently and so that the decision of managing the energy at common busbar can be taken and expedite for real time monitoring.

Index Terms - Smart Grid, Communication Technology, IOT

I. INTRODUCTION

In our traditional power system the power is flow from generating station to end users and the flow of communication is only one way communication. Due to this one way communication of any grid system there are many technical, economic and environmental issues are arise. So to overcome all that issues Smart grid system is come in existence new generation of power system demand more efficient, more reliable, scalable, controllable and also cost effective solution. In this smart grid system two-way communication is possible that means that the information and power both can flow from user to source and source to user by this way controlling part is shifted from generation side to user side also. By this way energy management is became more comfortable for both side because due to dual way communication they know about the other side scenario. Smart grid system also work towards the green environment system by using renewable energy sources like wind ,solar, biomass etc. which keep environment clean. The renewable generating stations need less time and space for installation so we plan them nearby load distribution centers to reduce transmission losses and increase reliability. [1-4]

For adopting this smart grid system we are moving towards smart metering and smart meter management system, by this collection of data became easier and obtain that data through real time monitor, control and sometime grid selfheal because of two way communication channel. The communication technologies make a huge change in conventional power plant to smart grid system. Due to that smart system the real time data will collect, process, store and analyses with the help of communication technologies. [5-7]

IOT-based smart grid has several applications and Networks. Online monitoring of power lines through IOT communication devices and sensor monitoring of power line possible. Faculty condition report directly send to control unit for appropriate action for faulty condition.Through IOT nodes user energy consumption data will collected so Demand side management is more effectively adapt by IOT based smart grid system. User can minimize the energy consumption by that and so grid load will reduce.In Neighboring Area Network(NAN) many IOT nodes are used which sense and actuate the signals of appliance like Smart TV, Smart Refrigerator, Lighting control system, Smart Air-conditioning system and make home management system to make Smart Home. Renewable Energy generation grids are utilized in IOT based system because

IOT sensors are collect the data of weather and predict appropriate utilization of renewable sources integrate the distribution of energy sources.[8-9] In IOT based smart grid system another utility is Smart vehicle through IOT sensors detect the battery charging and discharging status and inform the load condition of vehicles to power grid.

There are many protocols are working in different data layers for communicating data information. In data link layer protocol stack for host is XML/Sematic layer for EXI IOT node similarly in application layer protocol stack for host is HTTP for CoAP IOT protocol.RFID/4G/BLE/IEEE 802.15.4 protocol is used in Physical layer, IEEE 802.15.4 protocol is used in datalink layer, IPv4/IPv6/6LoWPAN Protocol are used in Network layer, UDP protocol are used in Transport layer. Many Protocol are used for IOT communication Network and they have different architecture. [10-12]

There are several types of networks classified based on their area and premises. One example is the Wide Area Network (WAN), which connects a large number of devices over a wide geographical area. It is designed to handle significant amounts of data and provide centralized control. Scalability and self-configuration are essential features of WANs. Additionally, WANs are often deployed outdoors, making it crucial for them to be robust and resilient to node and link failures. However, privacy and security vulnerabilities are a concern in WANs.Another network type is the Home Area Network (HAN), which is specifically used within a residence. HANs are responsible for monitoring and calculating the power consumption of home systems, enabling consumers to have real-time awareness of their energy usage. The coverage area of a typical HAN is around 200 square meters.It's important to note that these descriptions are general and may vary depending on specific network implementations and technologies house area network(HAN), Building area Network(BAN), Industry area Network(IAN), Neighboring area network (NAN), Field area network (FAN)and Wide Area Network(WAN). NAN network consist hugBAN is work like HAN but in large scale the exchange of data is possible due to utility or by system. Many Hans connected in One BAN network. Data rate in BAN network is more than HAN network. Next network in queue is FAN. FAN is mostly used to detect abnormal cases quickly by collect monitor and analysis the data. For transmission and distribution FAN Network is used and communication through SSs and SMs communication [13-16]

The growth of WLANs (Wireless Local Area Networks) was significantly enhanced with the introduction of the new wireless networking standard IEEE 802.11n in 2009. This development led to the widespread. Adoption of WLAN technology in homes and small offices. Nowadays, most laptops, tablets, and smartphones come equipped with WLAN components, enabling easy wireless connectivity. Additionally, public places such as coffee shops, hotels, and shopping malls also provide WLAN access to their customers. To establish a WLAN connection, several components are required, including Wireless Network Interface Cards (NICs) and Access Points (APs). These devices work in conjunction with an Internet Service Provider to facilitate wireless communication. WLANs offer varying data rates, with lower-speed WLANs typically providing speeds of about 1 and 2 Mbps. However, with the advancements brought by IEEE 802.11n and subsequent standards, higher data rates are achievable. WLANs can now offer speeds of up to 1 Gbps and even higher.[17-21]

Among the earlier standards, IEEE 802.11a provides a maximum speed of 54 Mbps. Alongside this maximum rate, transmission at speeds of 48 Mbps, 36 Mbps, 24 Mbps, 18 Mbps, 12 Mbps, 9 Mbps, and 6 Mbps is also supported. This range of supported transmission rates allows for faster data transmission, enabling efficient wireless communication.

Overall, the widespread adoption of WLANs, especially after the introduction of IEEE 802.11n, has revolutionized the way we connect and communicate wirelessly. The increased data rates provided by newer standards have greatly enhanced the speed and efficiency of wireless networking, making it an integral part of our daily lives.

In wireless communication electromagnetic signals can transfer without any medium. In the below table various type of communication technologies compare. The data access by wireless communication technologies in any remote location, installation cost is less, operation cost is less, use for wide area network this all are advantage of wireless network. In wireless communication security is main challenge [22-27]. In most of wireless communication utility must be rented through cellular satellite service provider. Wireless communication system classified into simplex, half duplex, and Full Duplex.one example of wireless communication system is satellite communication in which the signal is send to nearby satellite and it amplify the signal and send it to receiver end.it having two main component space segment and ground segment. Next wireless communication is infrared communication which is utilized for short communication range like security control, TV remotes control etc. In this type of communication electromagnetic spectrum is used for communication. Wi-Fi is another more popular communication medium in which low power wireless communication. The network allow user to connect through nearby router.

This paper contains following information about the novelty in project and system analysis

- The system is interfacing of micro-grid attached with PLC and SCADA
- The PLC system directly communicate with ESP32 module for wireless communication.
- The novelty in the system is that the LORA module is connected with the micro-grid through PLC for data\communication in remote PC and mobile system.

II. System Description

The system description is given below in fig. 1 where the solar energy in connected to Bay-1, wind power is connected to Bay-2 and conventional energy source in connected to Bay-3. All these bays transfer the energy to the bus bar. The data related to the energy is collected using sensors and processed to the PLC which is connected to the SCADA. The SCADA is connected to the IOT System. In SCADA, the energy management system is connected which is the ladder logic program designed in SCADA system. The trend and historian also designed in SCADA to track and analysis if any fault occurs in the system. The energy is measured in terms of KW, KVAR and KVA. The power factor angle also calculated in the algorithm based on the current scenario in the energy management system. The source is adjusted based on the energy requirement in the bus-bar.

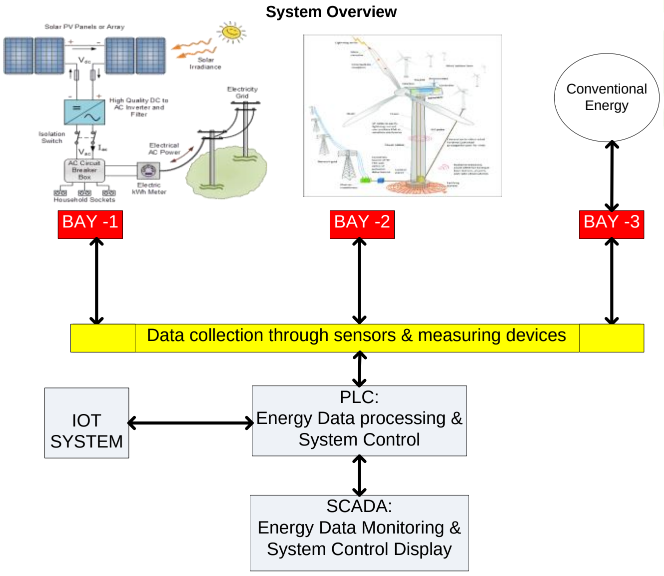


Fig. 1. IoT with PLC-SCADA integration at microgrid

TABLE I
WIRELESS COMMUNICATION TECHNOLOGIES

Tech.	Range	Equip. Category	Band width	Max Data Rate
NB-IOT	<35KM	CAT. NB1	200KHz Carrier Band Width	<250Kbps UL <170Kbps DL
eMTC	<100KM	CAT.M1	1.08MHz	<1Mbps UL /DL
LTE	<100KM	CAT 1	1.4-2.0MHz	<10Kbps DL <5Kbps UL
EC-GSM-IOT	<35KM	N/A	200KHz	<140 Kbps
GSM	<35KM	N/A	200KHz	<500Kbps
LORA	<100KM	N/A	<500KHz	<50Kbps

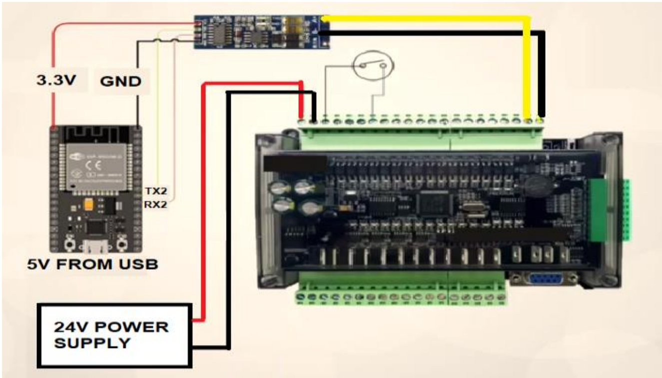


Fig. 2. ESP Connection with PLC

III. System Design & Development

The PLC is directly connected to the ESP module as shown the connection diagram below Fig. 2. The ESP module is connected with the LORA module. LORA Module is a long range module. The RFM95 LORA trans receiver module communicates with ESP32 using SPI communication. The wire length connection with LORA module depends on frequency level i.e. 868MHz for 3.4 inch, 915MHz for 3.22 inch and 433MHz for 6.8 inch. For our project, 3.4 inch of wire is directly soldered to the ANA PIN i.e. the antenna pin which provides the better range for communication. The LORA module communicated with the mobile for collecting the data related to the micro-grid. Different carrier communication is done with the help of mentioned technology in Table I.

The PLC is connected with hardware prototype developed shown in Fig. 4. The system is developed a small prototype of micro-grid which consist of three small transformers which feed to the copper bus-bar and this copper bus-bar is feeding energy to the load side. For analysis and algorithm testing, each bay is connected with voltage sensor and current sensor and load is also connected to voltage sensor and current sensor. This current sensor and voltage sensor is feeding data to the PLC. The PLC communicate the data with SCADA system.

IV. SYSTEM SOFTWARE FUNCTIONALITY

The Advanced Metering Infrastructure (AMI) is a system used to connect smart meters, collect data,

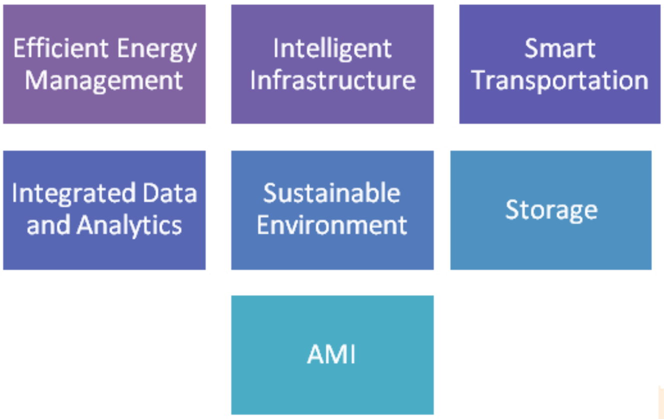


Fig. 5. Smart Grid Functionality.

manage and control various functionalities related to electricity usage. It enables advanced metering capabilities, providing valuable information about household load, electricity usage patterns, power quality, and proactive identification of failure

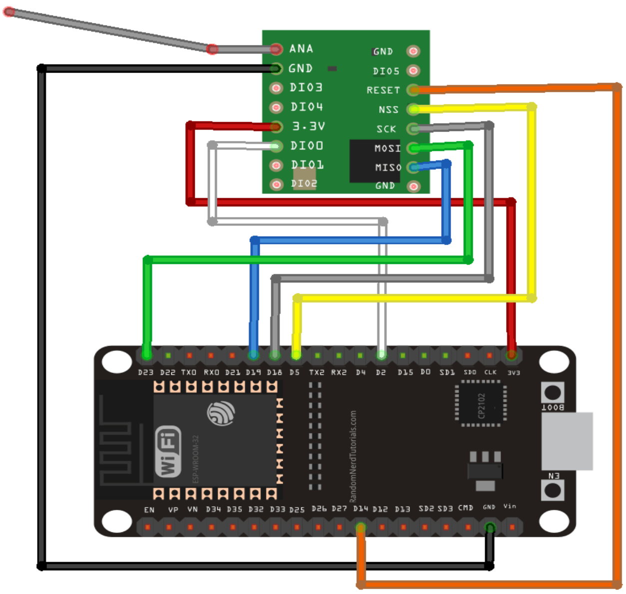


Fig. 3. ESP Connection with LORA module

TABLE II
COMPARISON TABLE OF SMART GRID VS CONVENTIONAL GRID

Sr. No.	Comparison Attributes	Smart Grid	Conventional Grid
1	Meter	Digital Meter	Electromagnetic meter
2	Meter reading	Automatically	Manually
3	Power flow	Both way	Single way
4	Infrormation flow	Bidirectional	unidirectional
5	sources	Renewable energy source mostly	Nonrenewable mostly
6	scale	Small and medium	large
7	communication	Double way	Single way
8	Userparticipation	active	Non active
9	Controll technique	Automated ,self-healing property	Manual, self-healing is not possible
10	monitoring	Yes	No
11	Plant Control	Decentralized	Centralized
12	Location	Both(nearby,Remort	Far away from

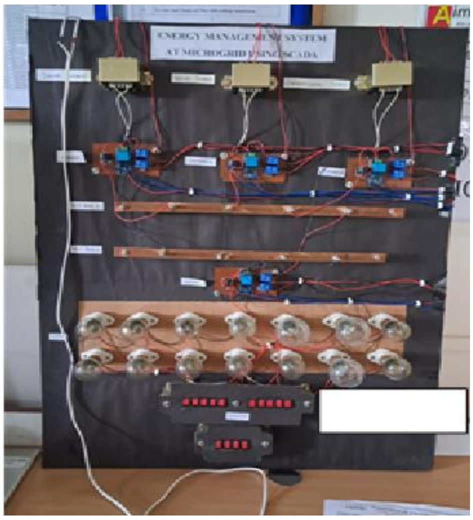


Fig. 4. Hardware Prototype

conditions. However, the large volume of data collected through the AMI system requires effective management and analysis. This data is typically sent to a centralized system for billing purposes and load analysis.

The AMI system as shown in fig. 5serves several purposes, including:

Data collection: Smart meters within the AMI system gather data on electricity usage, which includes information about the load of appliances, consumption patterns, and power quality parameters.

Functionality management:

The AMI system enables remote management and control of various functionalities, such as remotely disconnecting or reconnecting service, implementing time-of-use rates, and providing real-time data to consumers.

Failure identification:

The system proactively identifies failure conditions, such as power outages or meter malfunctions, allowing for faster response and resolution. To handle the substantial amount of data collected by the AMI system, it is sent to a centralized system. This centralized system performs two key functions:

- Billing purposes: The collected data is utilized for accurate and timely billing. It enables utilities to calculate electricity usage, determine billing rates, and generate invoices for customers.
- Load analysis: The data collected from numerous households allows utilities to perform load analysis, which involves studying consumption patterns, peak usage periods, and identifying trends. This information helps utilities optimize power distribution, plan for infrastructure upgrades, and implement demand response programs.

Generation, distribution, and demand management.

It's worth noting that the specific implementation and functionalities of an AMI system can vary among different utility providers and regions. The system design and capabilities may be tailored to meet local requirements and regulations. [1-2]

- By leveraging the AMI system and its data, utilities can improve operational efficiency, enhance customer service, and make informed decisions regarding power
- Communication for any grid system make it smart grid this communication is mainly two type wired and wireless communication system. Also they have further classification of public and private mode of communication.
- Energy efficient system will develop by making a balance between the demand and supply of electricity to give the brief detail of utilization pattern to costumer so that they are shift their load in off peak hours. This will also reduce the consumer bill amount and efficient use of electricity make possible.
- for preventing and optimized solution for large area wide area monitoring possible by centralized system.
- Cyber security is required for reliable communication and control system to operate grid collected data and protect smart grid infrastructure.
- Energy storage and transportation is also possible through electrical vehicle and pumped hydroelectric storage facilities.
- There are many modifications from conventional grid system to smart grid system, which will explain through fig.5 and also by comparison table-II. In any smart grid system user is not only service taker but he can also take participation in generation of its own electricity through renewable energy sources.

V. System Analysis

The Hybrid AC/DC modelling is used in simulation performance where conventional grid source, diesel generator, photo-voltaic cell, battery energy storage system, Linear loads and non-linear loads are connected. These data are collected at receiving end PC through the LORA module where software part analyses the data based on the requirement. The common thing which is to be taken care of is the cable configuration. The cable configuration is 1/0 Cu, TW. R = 0.394/XL=0.1168/Z = 0.411/km (Primary grid 13.8 KV), another cable configuration is 4/0 Cu, TW. R= 0.198/XL = 0.1089/Z = 0.227/km (Secondary grid). The micro-grid operated in grid-connected mode and will operate in islanded mode. There are 14 buses consider in this micro-grid system, Bus-1 is fed with battery energy storage system through DC to AC converter, 900/220V 55KVA transformer.

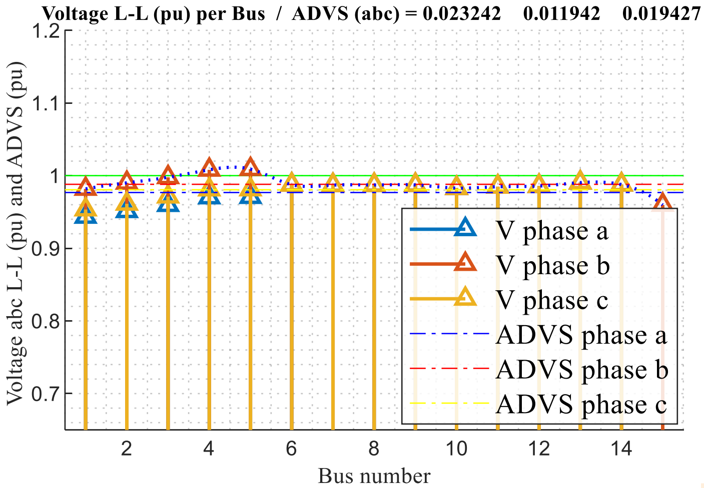


Fig. 6(a). Bus voltages.

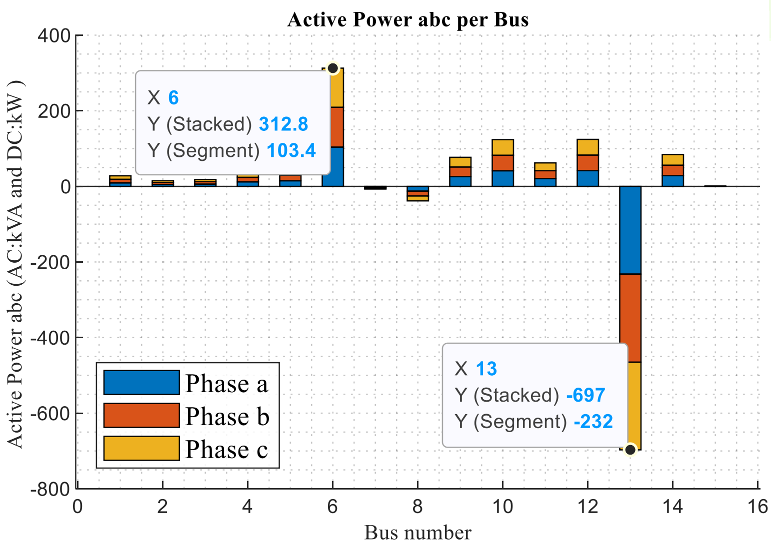


Fig. 6(b). Active power per bus.

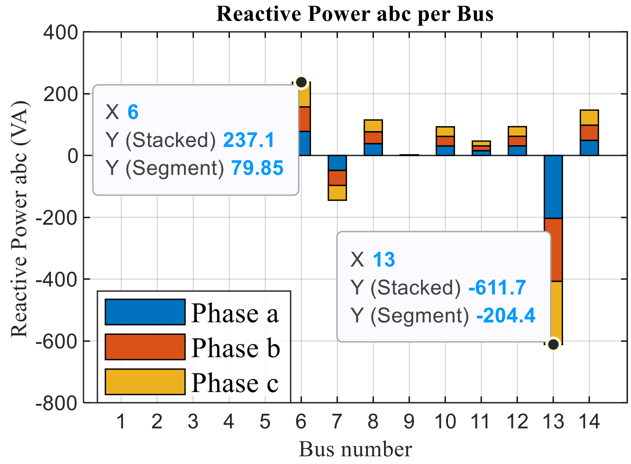


Fig. 6(c). Reactive power.

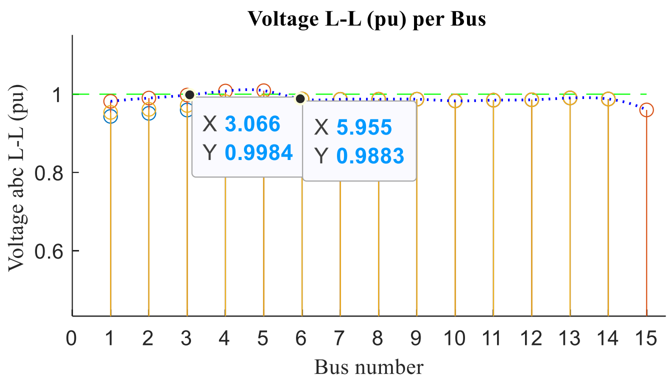


Fig 6(d) Voltage at each phase of each bus

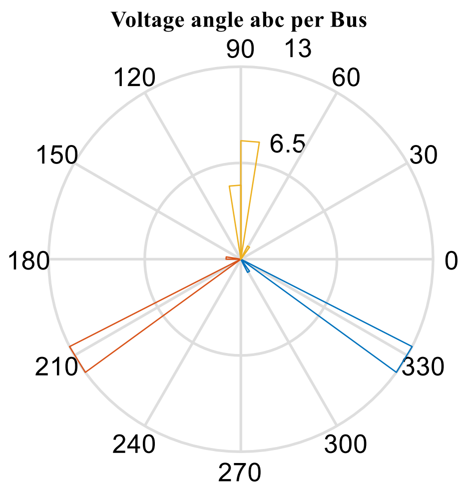


Fig. 6(e) 3-phase voltage angle per us.

Bus-7, Bus-8 and Bus-13 are generation bus while other buses are load buses. Each bus Line to Line voltages are same near to 1pu. ADVS voltage is shown by dashed line as shown in the fig. 6(a). Fig. 6(b) shows the active power and dc bus power which is varying equally in each phase. As marked in the figure, the 103.4 KW of power achieved at y-phase at bus-6, while total power is 312.8 KW of active power.

Fig. 6(c) shows the reactive power per phase in each buses. There's 79.86KVAR of reactive power at y-phase at bus-6. And total reactive power is 237.1KVAR in bus-6. The similar measurement is done with each busses. Fig 6(d) shows the line voltage in per unit per bus. The voltage variation is not too much to be a disturbing parameter. It is 0.9984pu in bus-3 while it is 0.9883pu in bus-6. Therefore it is found that the bus voltage is varying near to the 1pu in each buses. Fig 6(e) shows the voltage angle which is varying near to 6.5 degree almost in each phase at every bus which shows that the voltages at each bus in not in unbalanced condition.

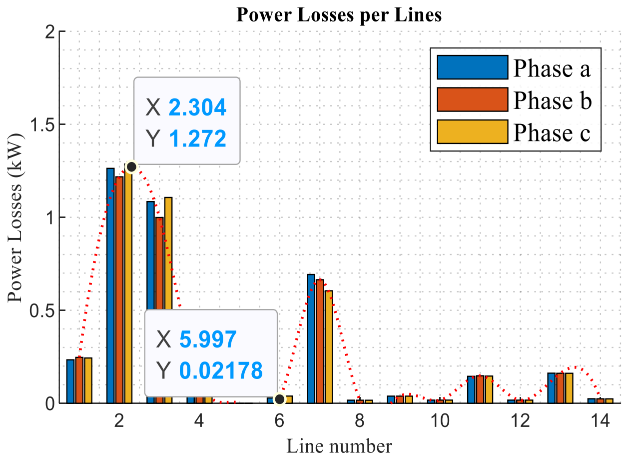


Fig. 6(f) power losses per lines.

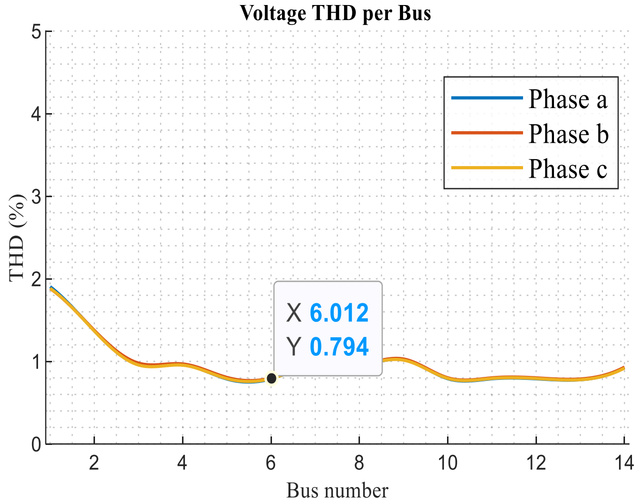


Fig. 6(h) THD at each busses.

Fig. 6(f) shows that the power losses in significantly is less than 2% of the total power. It is observed that the 1.272kw power loss is observed at bus-2 while it is very less at bus 6 which is approximately 0.02178kw. This can be considered as an significant achievement while optimizing the power in such micro-grid.

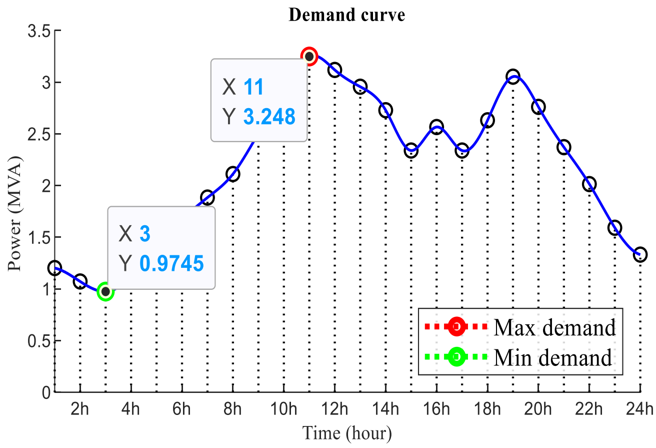
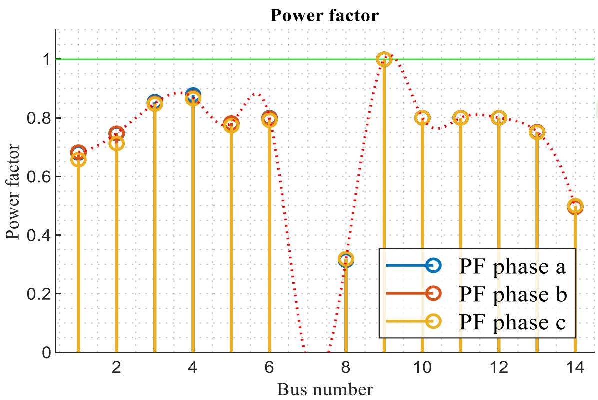


Fig. 6(i). Smart Grid Functionality.

Fig. 6(g) shows the power factor variation at each phases at different buses. It is found that the power factor is varying too much which is near to the 0.3 at bus-8 while it is near to the unity at bus-9. Since bus-8 is fed by DG set, therefore it does not supply the bus



with sufficient power and power factor.

Fig 6(h) shows the voltage THD per bus. As per observation found, the THD is varying 0 to 2% which is very low as per standard of IEC 61000-3-2. Therefore, the THD is in limit.

Fig. 6(i) shows the variation in demand curve of the whole system which is varying from minimum demand of 0.9745 MVA to Maximum demand of 3.248 MVA. Still the design of the system is considered here with 20% maximum demand. Therefore the curve in maximum demand in within the design limit.

VI. Conclusion

The system is designed to implement the IOT based system using LORA module which is data processing module to PC and Mobile. The data from above PLC is collected at another PC that is 1 km away and all data related to micro-grid is discussed in system analysis. All data of the bus fetched correctly without loss of any data during communication from PLC to IOT device. The system is yet to be tested under harsh weather condition. And fault condition is taken into consideration but the most possible parameters are taken into analysis like as line voltage, active power, reactive power, power factor, demand and THD. Most busses parameter are within the range of the system design.

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