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IoT Tools for Enhanced Control and Monitoring Islanded Mode Photovoltaic Systems

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Abstract*— Upgradation of technology-based needs also demand the control strategy, availability of energy, optimum use and energy management that can be achieve by the combination of Photovoltaic (PV) system and Internet of Things (IoT). Indian Government providing subsidy to lighting every household at last point of nation. Islanded photovoltaic system is easily be adopted by the consumer but IoT integration can enhance the efficiency, mitigate energy demand and durability of system. In this paper paper investigates the application of widely-used IoT tools in PV system design and deployment.

Index Terms*— IoT, Islanded, Photovoltaic, ThingsBoard, MQTT, Blynk, NodeMCU, NodeRed, Raspberry Pi

I. INTRODUCTION

Decentralized solar energy generation, whereby generation sources (i.e., Solar, wind) are placed near to load center in favor to improve transmission losses which proportional to increases with cable length, is a sustainable alternative. This kind of generation uses renewable sources, make useful to local resources and provides opportunity of employment and income. Decentralization should be made reachable and promote a fair and desirable level of technological, economic and social development in these countries [7]. British technology pioneer Kevin Ashton first time use term "Internet of Things (IoT), it is concept which combining the computers and network. It is made easy to interconnect more and smaller devices economically and easily due to availability of IP-based network, Ubiquitous Connectivity, integration Computing Economics, Miniaturization, Advances in Data Analytics and Rise of Cloud Computing [1]. Hardware system and devices are available in very diversified specifications in terms of communication, memory, data storage, computation and transmission capacities. An IoT platform consists of many types of devices. All types of hardware devices should be in well order through the network and easily accessible via available communication. Typically, devices can be organized by gateways for the communication purpose over the Internet [2]. A standalone offshore wave-wind hybrid power generation system based on the IEC61850 standard [4]. An IoT based small scale PV system monitoring system is designed with low production costs for PV power generation applications, achieve goal costly components such as sensors and controllers are replaced with sensors and controllers that perform the same role but cost less and are readily available [18]. MQTT protocol allows the communication between devices through simplicity of remote web access through Wi-Fi, MQTT client application is based on ESP8266.This paper based on the execution of Arduino, MQTT, NodeMCU and service models for communication between the IoT devices [19].

II. APPLICATIONS OF IOT TOOLS IN PV SYSTEM

Ref.	IoT Tools				
	Data Management	***Data Transfer***	***Storage and Human interaction***	***Micro-controller***	***Sensors***
[4]	ThingsBoard	MQTT	Raspberry Pi + Wi-Fi	ESP32 + OLED display	MH Electronic (V) ACS712 Hall effect (I)
[5]	Blynk software		Wi-Fi	Arduino ESP32	
[6]	NodeMCU	MQTT	Raspberry Pi + Node Red		
[7]	EMONCMS		Raspberry Pi + Node Red	Arduino Uno	MH Electronic (V) ACS712 Hall effect (I)
[18]	ESP8266/NodeMCU		Things Speak		DHT22, ACS712

III. INTERNET OF THINGS (IOT)

The Internet of Things (IoT) is a platform which allow to all things have a presence and a representation in the Internet. The Internet of Things aims to provide different applications and services connect to the physical and virtual worlds, in which device to device, device and cloud. Worldwide acceptation and use of IoT define it is in layers [1-3]. The IoT provide platform to smart microgrids to exchange information with various users and boost up communication through a variety of infrastructures [18]. Figure 1 show shows

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application and structure of Internet of Things. IoT technology is used in tracking important parameter of renewable energy by online and real time. IoT technology can enhance the power quality, analysis and performance of system by real time monitoring, different types of sensors and transducer provide related parameters, which are sent to the microcontroller for analysis. Power generation of systems can be tracked and monitoring using an IoT tools to improve system maintenance [18].

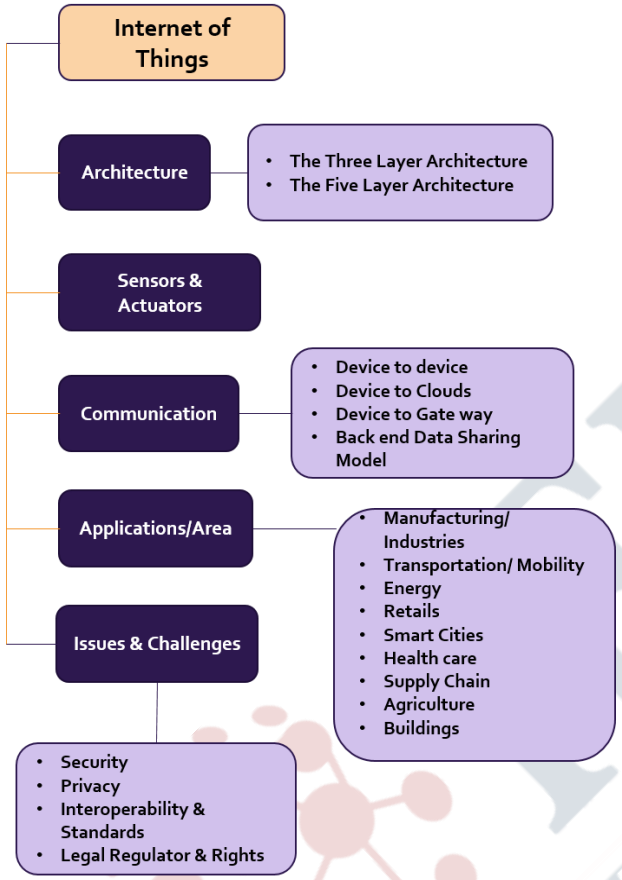


Fig. 1. Concept of Internet of Things

IV. PHOTOVOLTAIC (PV) SYSTEM

Photovoltaic (PV) systems figure 2, in which convert solar irradiation directly to electricity, can be used for small systems AC and DC load or wide range of applications. The PV array itself, a heart of system, addition of PV modules shows the totaling of power capacity of the system. The system includes equipment for mounting, support of the PV panels, power conditioning, energy storage, measurement of system performance and safety. The operating conditions govern on the basis of system location for the solar irradiation, the ambient temperature and other climate aspects which directly influence the system performance. Photovoltaic systems categories in two types Grid connected which connected to the local grid. Stand-alone PV systems design to supply the specified load in remote areas [8].

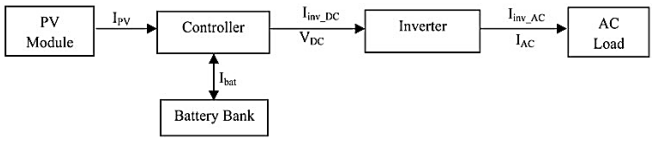


Fig. 2. Block diagram of PV system

V. OVERVIEW OF IOT TOOLS USED IN PV SYSTEM

A. ThingsBoard

ThingsBoard is known as an open-source IoT platform that can be used for visualization, data collection, processing and device management. ThingsBoard, it required an account where device is added in result access token is generated. This generated token needed in order for ThingsBoard to collect the telemetry data from the device under a common IoT protocols, which includes Message Queuing Telemetry Transport (MQTT), Constrained Application Protocol (CoAP), and Hypertext Transfer Protocol (HTTP). Our proposed system in figure 3 utilizes. User can design customize IoT dashboards on ThingsBoard. Dashboards contain widgets where telemetry data can be visualized in form of cards, tables, charts, alarms and digital gauges of various IoT devices [13].

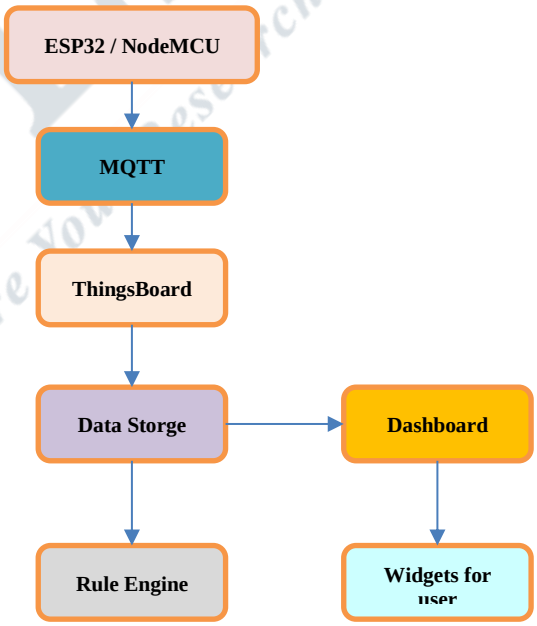


Fig. 3. Concept of ThingsBoard

B. Blynk

Blynk is an IoT platform for smartphones that is used to control microcontroller or local controller (NodeMCU and Raspberry pi) using internet, this is used to create a human machine interface (HMI) or graphical interface by compiling and provides address on the available widgets. It helps to control hardware remotely, display sensor data, store data, visualize data in so many ways. It has three components for creating amazing interfacing for widgets, communication

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between hardware and smart phone and process all incoming outgoing commands are known as Blynk App, Blynk Server and Blynk library [14] figure () relate these three.

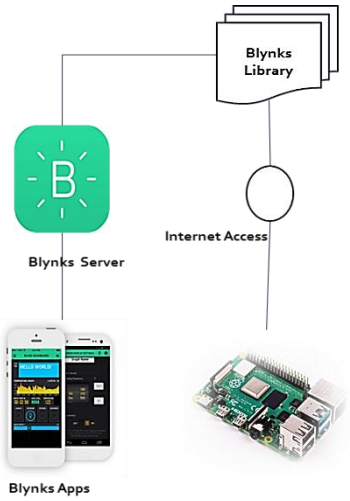


Fig. 4. Blynks

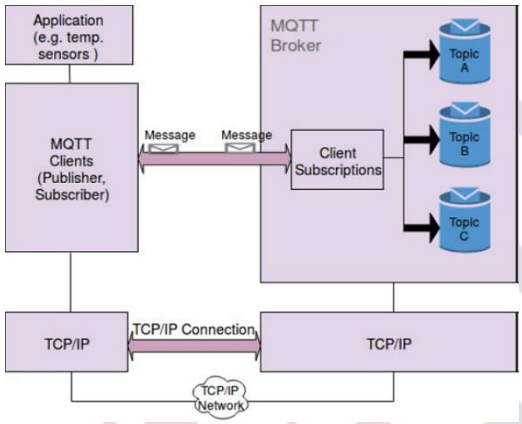


Fig. 5 MOTT architecture [15]

C. Message Queuing Telemetry Transport (MQTT)

Figure 5 present the architecture of MQTT divided into two main parts Client and Broker as shown in figure 2. Each part briefly described below.

1. Client*:* Client could be a Publisher or Subscriber and it always establishes the network connection to the Server (Broker). It can do Publish messages, receiving messages, unsubscribe to extract from the subscribed subjects and detach from the Broker [15].
2. Broker*:* Broker controls the distribution of information and mainly responsible for receiving all messages from publisher, filtering them, decide who is interested in it and then sending the messages to all subscribed clients. It can do accept Client requests, receives Published messages by Users, processes different requests like Subscribe, unsubscribe from Users and after receiving messages from publisher sends it to the interested Users [15].

D. Raspberry Pi

The Raspberry Pi is a versatile, flexible, robust features and computing platform mostly used in research. educational, and project development. The Raspberry Pi is a Single Board Computer with multi pins called General Purpose Input/Output (GPIO), which are allow the Raspberry Pi to communicate with the outside world. This device is able to controlling devices, data, information, and communicating with other devices effectively. The Raspberry Pi can be downloading and installing the operating system (OS) from the official Raspberry Pi website, the OS is installed on a microSD card, using Raspberry Pi OS (Desktop) make easier to use its graphical interface. After installing the OS, it is necessary to update the system by using basic commands available on the official Raspberry Pi website. After the Raspberry Pi installation Node-RED can be deployed on the dashboard. The details of procedure to installation are available on the official Node-RED website. Whenever both platforms are successfully installed, an IP address will be allotted, which allowing Node-RED to be accessed and executed via any internet browser [16]. Node-RED main objective is to develop IoT systems. Where, each node provided input output data flow for specific function. It is well-suited for this work because it incorporates the MQTT protocol, which enables stable communication between the ESP32 and Raspberry Pi [16]. System is set up to collect data of the PV voltage, current, the stored battery voltage and power for remote monitoring and control [17].

E. NodeMCU

NodeMCU is use to assist IoT application, it is an open-source kit. NodeMCU use for Application Program Interface (API) for Input output hardware. APIs make faster to manage and configuring hardware devices. The NodeMCU can be programmable for various programming languages with help of an IDF open source. It is allowed to directly uploaded of code using Arduino IDE. Where is ESP8266 provide Wi-Fi integrated chip in small size [18].

F. ESP32

The ESP32 is small size microcontroller widely used in the world of electronics and programming. It is design with key tools for IoT project having low power consumption. The ESP32 has multi pin that help it to send, receive digital signals, allow to interaction with other devices via sensors to actuators. ESP3 used in projects involving Red Node and MQTT [16].

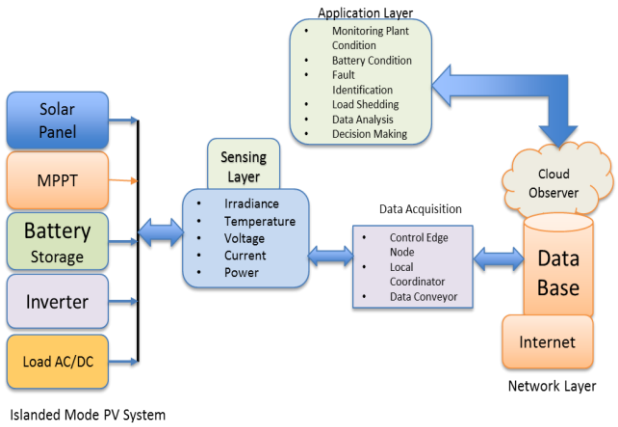
VI. SYSTEM ARCHITECTURE

An architecture of PV system with integration of IoT tools ESP32 nodes capturing PV metrics, communicating through MQTT to a Raspberry Pi gateway given in figure 6. The gateway send data to ThingsBoard or Blynk dashboards. Decision logic at the edge enables real-time load shedding, MPPT tuning, and battery protection.

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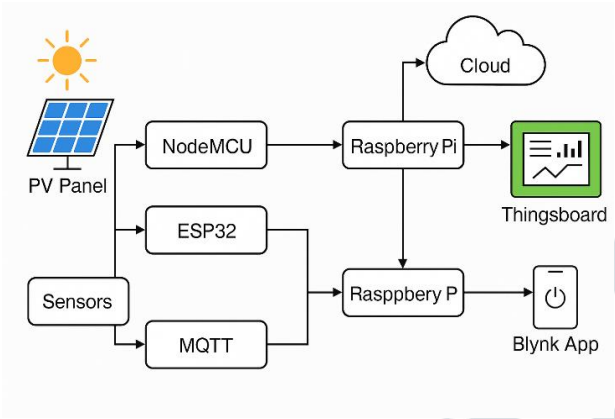


Fig. 6. Proposed IoT tools-based system architecture

VII. CASE STUDIES AND RESULTS

Suggest the load shedding, source management (Overcurrent mode and normal conditions), performing data acquisition, control and load forecasting on the designed standalone PV system to predict their performance and efficiency [9].

Load energy management can be done by An Intelligent Smart Energy Management Systems (ISEMS) considering Solar Energy source, data collection for prediction models, smart energy management system for load scheduling and IoT integration for the user to access the energy details and management, predict accurate energy for the day ahead and monthly basis and control strategy depending on the consumer assigned priority of load [10].

Micro Grid (MG) System prototype was developed for testing of control approaches, integration of the IoT for Big-data platform for real-time data collection, processing, and analysis. Collected data used for real-time MG control by balancing the power demand and load [11].

An IoT platform is adapted to visualize the data acquisition and calculate the energy generated for a given generation system, this made continuous remote monitoring and improved efficiency of the source. The remote monitoring made easy to identifying various anomalies that may affect the operation of solar panels and PV system [12].

VIII. CONCLUSION

IoT tools such as NodeMCU, ESP32, Raspberry Pi, MQTT, ThingsBoard, and Blynk play a pivotal role in modernizing off-grid PV systems. They enable smart control, real-time monitoring, and efficient energy management. This paper provides a foundation for implementing scalable, cost-effective IoT solutions in future solar energy applications.

REFERENCES

[1]. K. Rose, S. Eldridge, and L. Chapin, "The internet of things: An overview," The Internet Society (ISOC), vol. 80, no. 15, pp. 1–53, 2015.

[2]. S. Li, L. D. Xu, and S. Zhao, "The internet of things: a survey," Information Systems Frontiers, vol. 17, pp. 243–259, 2015.

[3]. R. A. R. Ait Mouha, "Internet of things (IoT)," Journal of Data Analysis and Information Processing, vol. 9, no. 2, p. 77, 2021.

[4]. L. O. Aghenta and T. Iqbal, "Design and implementation of a low-cost, open source IoT-based SCADA system using ESP32 with OLED, ThingsBoard and MQTT protocol," AIMS Electronics and Electrical Engineering, vol. 4, no. 1, pp. 57–86, 2019.

[5]. T. M. F. B. Abd Razak, "Real Time Monitoring Small Scale Off Grid Solar System with Blynk App," Progress in Engineering Application and Technology, vol. 4, no. 2, pp. 385–393, 2023.

[6]. H. Prasetyo, "On-grid photovoltaic system power monitoring based on open source and low-cost internet of things platform," 2021.

[7]. Krishna, A. Murali, K. Prabhakara Rao, M. Bhanu Prakash, and N. Ramchander. "Data acquisition system for performance monitoring of solar photovoltaic (PV) power generation." *International Journal of Engineering Research & Technology (IJERT)* 1, no. 7 (2012): 1-6.

[8]. Pearsall, N. M. "Introduction to photovoltaic system performance." In *The performance of photovoltaic (PV) systems*, pp. 1-19. Woodhead publishing, 2017.

[9]. Swathika, OV Gnana, and K. T. M. U. Hemapala. "IOT based energy management system for standalone PV systems." Journal of Electrical Engineering & Technology 14, no. 5 (2019): 1811-1821.

[10]. Pawar, Prakash, and Mudige TarunKumar. "An IoT based Intelligent Smart Energy Management System with accurate forecasting and load strategy for renewable generation." *Measurement* 152 (2020): 107187.

[11]. Elmouatamid, Abdellatif, Youssef NaitMalek, Mohamed Bakhouya, Radouane Ouladsine, Najib Elkamoun, Khalid Zine-Dine, and Mohammed Khaidar. "An energy management platform for micro-grid systems using Internet of Things and Big-data technologies." Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering 233, no. 7 (2019): 904-917.

[12]. Khan, Mohd Sajid, Himanshu Sharma, and Ahteshamul Haque. "IoT enabled real-time energy monitoring for photovoltaic systems." In 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon), pp. 323-327. IEEE, 2019.

[13]. Henschke, Matthew, Xinzhou Wei, and Xiaowen Zhang. "Data visualization for wireless sensor networks using ThingsBoard." In *2020 29th Wireless and Optical Communications Conference (WOCC)*, pp. 1-6. IEEE, 2020.

[14]. Rif'an, Muhammad. "Internet of things (iot): Blynk framework for smart home." KnE social sciences (2019): 579-586.

[15]. Soni, Dipa, and Ashwin Makwana. "A survey on mqtt: a protocol of internet of things (iot)." In *International conference on telecommunication, power analysis and computing techniques (ICTPACT-2017)*, vol. 20, pp. 173-177. 2017.

[16]. Navarrete-Sanchez, M. A., Re Olivera-Reyna, Ro Olivera-Reyna, R. J. Perez-Chimal, and J. U. Munoz-Minjares. "IoT-Based Classroom Temperature Monitoring and Missing Data Prediction Using Raspberry Pi and ESP32." *Journal of Robotics and Control (JRC)* 6, no. 1 (2025): 234-245.

[17]. Aghenta, Lawrence O., and M. Tariq Iqbal. "Development of an IoT based open source SCADA system for PV system monitoring." In 2019 IEEE Canadian Conference of Electrical and Computer Engineering (CCECE), pp. 1-4. IEEE, 2019.

[18]. Sutikno, Tole, Hendril Satrian Purnama, Anggit Pamungkas, Abdul Fadlil, Ibrahim Mohd Alsofyani, and Mohd Hatta Jopri. "Internet of things-based photovoltaics parameter monitoring system using NodeMCU ESP8266." *International Journal of Electrical & Computer Engineering (2088-8708)* 11, no. 6 (2021).

[19]. Kashyap, Monika, Vidushi Sharma, and Neeti Gupta. "Taking MQTT and NodeMcu to IOT: communication in Internet of Things." Procedia computer science 132 (2018): 1611-1618.