e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:03/Issue:06/June-2021 Impact Factor- 5.354 www.irjmets.com

A NOVEL ARCHITECTURE FOR SOLAR PLANT MONITORING USING IoT

Mohammad Imran Ali [*1], Maaz Uthman[*2], Salman Javed[*3], Farooq Aziz[*4], Farhan Ali[*5]

[*1] University of Engineering and Technology Peshawar, Department of Computer Systems Engineering, Peshawar, Pakistan.

[*2] University of Engineering and Technology Peshawar, Department of Computer Systems Engineering, Peshawar, Pakistan.

[*3] Preston University Islamabad, Department of Computer Science, Islamabad Pakistan, Pakistan,

[*4] Baluchistan University of Information technology, Engineering and Management Sciences, Department of Computer Engineering, Quetta, Baluchistan Pakistan.

[*5] University of Swat, Department of Physics, KPK, Pakistan.

ABSTRACT

Currently, major sources of conventional energy are fossil fuels which are depleting with each passing day. The modern era demands for renewable and eco-friendly homes of energy of which renewable energy sources (RES) are of greater interest and has the potential to cover the energy demands of the modern the world. Solar energy because of its ubiquitous presence and falling costs is emerging as the optimum solution. However energy output of solar plants are greatly affected by different meteorological parameters such as irradiance, weather, temperature to name a few. Most of solar plants remote location installation makes their physical monitoring expensive. Therefore, a low-cost and real time monitoring system should be in place to supervise the system remotely. In this paper, different techniques and trends in IoT will be explored and analyzed from solar plant monitoring perspective. A comprehensive solution will be proposed by exploring latest development in compute boards, sensors, cloud platforms, fog and edge computing for IoT based solar plant monitoring system.

Keywords: IoT, Monitoring, Cloud based architecture, Solar Plant Monitoring, IoT Architecture, WSN.

I. INTRODUCTION

The modern world is demanding for cheaper, alternate and environmentally friendly resources of energy of which hydroelectric, wind, solar and biomass are of greater interest. The process of converting solar energy is termed as Photovoltaic (PV) effect, discovered by Edmund Becquerel in 1839. The PV cells comprised of P-N junctions which are prepared from layers of semi-conducting material (mostly silicon). These cells produces a direct current (DC) when exposed to sunlight. It is estimated the world be consuming 30 TW of energy by the year 2050 [1] and a recent survey conducted by the International Energy Agency (IEA), it is predicted that by the year 2022, REA will be contributing 28% towards the world's total electricity generation [2]. The number of annual solar installations is expected to exceed by 100 GW at the end of the year 2022 [3]. Solar energy being universally available can provide us adequate amount of energy to meet the energy and power demands of needs of the entire sphere. Solar energy has emerged as the most beneficial form of renewable energy in terms of cost, environment friendliness, and reliability. The has been an increasing interest in getting energy from renewable energy sources over the recent decades due to which the generation cost is reduced with increased life span life span of the solar PV systems as shown in Figure 1. In the last decade, a drop of 60% in cost has been observed with 60% annual growth rate [4]. The PV plants mostly operate in remote and far-flung areas. Therefore, supervising and upholding the systems in such regions will consume plenty of resources both in terms of efforts and manpower. The output of solar PV systems is dependent on several varying environmental factors like solar irradiance, temperature, and direction of sunlight, soiling on the panel, unanticipated errors and other climate conditions. So, it is essential to supervise and maintain the system remotely that will should be able to locate faults and errors by gathering information from the system in real time. IoT based solutions have been used in devising smart cities [14-18]. Solar panels powered street lights will further help in devising intelligent transportation systems [19-23].

II. LITERATURE REVIEW

The data from the sensors are managed by computer boards which are either single computer boards or micro-controller boards [6]. There are different solutions proposed in the literature for solar panel monitoring which can be broadly characterized as Centralized and decentralized systems. A datalogger for data acquisition is presented by M. Fuentes et. al [7] using IEC standards and open source technologies which has enhanced performance as compared to other conventional systems but it has some limitations. Gagliarducci et. al [8] has designed a remote system which has the capability to report the user in case of any undesired situation. The system periodically updates and predict the overall performance of the system.

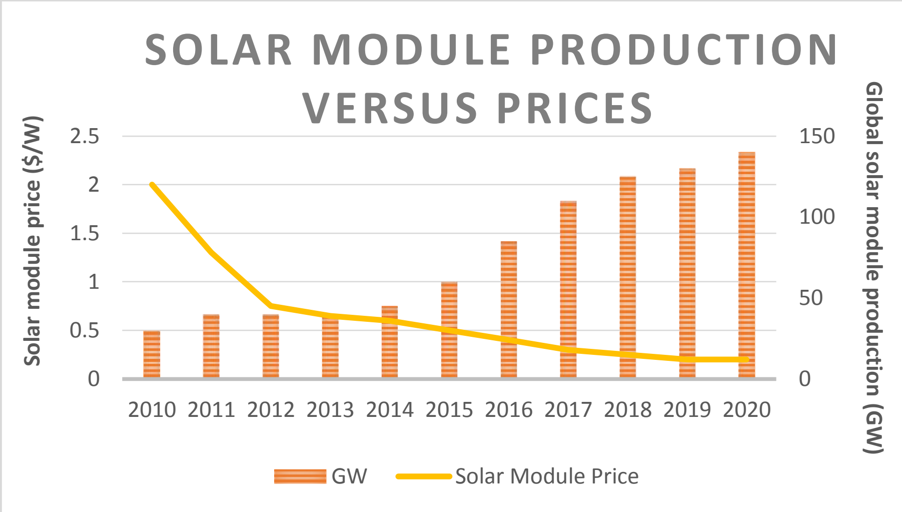

Figure 1: PV module production and prices over the past decade [5].

Andò et. al [9] have proposed a Wireless Sensor Network system at panel level based on the IEEE 802.15.4 protocol. They system is capable of detecting losses in efficiency and predicting performance at panel level. The proposed system claims to offer greater reliability and low-power consumption. A cloud based PV monitoring system is presented in [2] in which a web page is hosted on Raspberrypi (Rpi). The web page is used to access the acquired stored in the cloud. The current and voltage sensors are integrated using Arduino Uno. Another real time remote monitoring system is proposed in [11]. Atmega 2560 arduino is used to integrate the sensed data from current sensors, voltage sensors and temperature sensors. Blynk app is used to send the data to a smartphone via Wi-Fi module. GSM offers greater availability in rural areas and the send data is prone to less errors. A system based on GSM using the GSM voice channel is presented in [12]. Rashidi et. al [12] has proposed a ZigBee based solar PV monitoring system. The system uses a chip USB dongle to send the data from various sensor to a computer and user can interact with the system using a GUI based on LabVIEW. Another such prototype LabVIEW based system is presented in [13]. Dhongade et. al [24] has designed a system using Zig-bee and ThingSpeak cloud which monitors the performance of solar and biogas energy systems (hybrid energy sources). An electronic system is presented in [16] which receives data from inverters using Bluetooth which is further sent to a control machine over the network via Wi-Fi. Papageorga et. al. [25] has designed a system cost efficient using open-source tools and Arduino. The system has wireless connectivity through ZigBee.

The advancement in the remote solar monitoring systems is categorized in the following periods:

From 1994-2001

In this era inverters were the main devices for monitoring.

- From 2002-2006

In this period data logger and communication technologies like GSM, wire and satellite were introduced. The systems in this period made use of sensors and other advance tools such as C#, LabView, Microsoft Access, MySQL and Apache.

- From 2007-2015

This era made use of advanced tools and technologies such as Ethernet, Zigbee, Arduino and other platforms

- From 2016-current,

This area introduced IoT and cloud technologies which enabled the researchers to control such systems remotely with more efficiency and reliability. These system offer support for massive data handling and retrieval along with detailed monitoring reports. Such systems offers real-time control and monitoring to the stockholders.

III. SOLAR PV MONITORING SYSTEMS

Manual monitoring and supervision of Solar PV systems may consume lot of resources and manpower as these plants mostly operates in far-off rural areas. Also, the system output is dependent on various varying environmental parameters and the output fluctuates according to the parameters. Also, according to figures from solaranalytics.com, about 14% of solar power systems experience a major fault within a year of their operation [12]. Undetected faults over longer period of time can affect the efficiency and lead to the overall failure of the system. As discussed earlier there are several architectures in the literature for the monitoring of solar PV systems in an effort to improve the efficiency, output and the life-span of the systems. However, the current methodologies are non-desirable as they use conventional manual methods. Some of the proposed methods have used a proprietary tool. While other proposed system are either slow, hard to implement or may have other operational constraint. Sometimes the systems are suitable for small scale systems but they are not appropriate for larger remote plants. Therefore, it is essential to supervise, troubleshoot, and maintain the system remotely in real-time. The wide progress in the solar area stresses for more precise, remote and performance evaluation systems at reduced maintenance cost, unwanted power disruptions avoidance and with minimal human interaction.

IV. ARCHITECTURE OF IOT SYSTEMS IN PV MONITORING

IoT based Solar PV architectures proposed in the literature comprises of the following layers:

- **Perceptual Layer**

The analog data from the physical world sensed by various sensors is converted to digital data using a Microcontroller [24].

- **Network Layer**

Data acquired by various sensors is sent to either a centralized or decentralized location for further processing. The data is sent via network using various wireless communication technologies. The commonly used technologies in the literature are Ethernet, Bluetooth, ZigBee, Wifi, RF and GSM, Sigfox, LoRA [4].

- **Support Layer**

The data is purified and temporarily stored in the buffer of a terminal (mainly a microcontroller) before it is sent to the application layer. The information can be accessed through the presentation layer either through wireless or wired connection.

- **Presentation Layer**

This layer offers GUI (graphical user interface) and other enhanced tools for data analytics. End user can interact with the system through this layer and can generate reports based on the acquired data.

The overall architecture of the solar PV IoT based monitoring system is presented in Figure 2

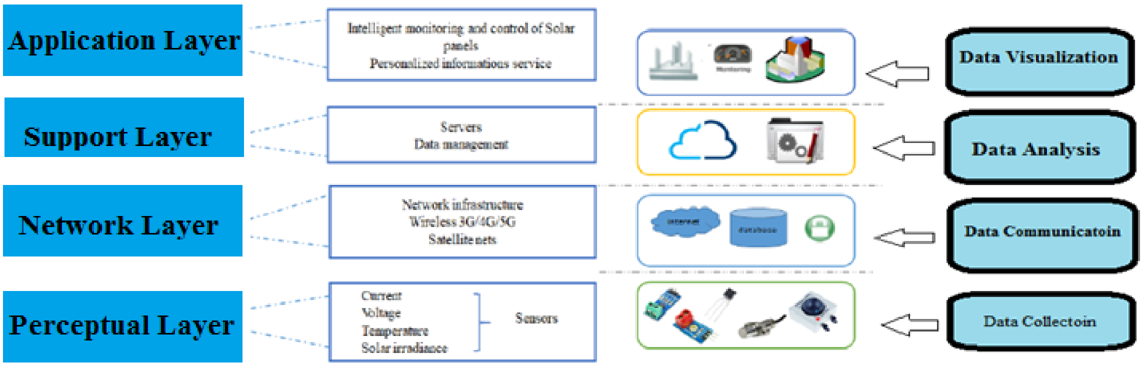

Figure 2: Different Layers of the Solar PV IoT based monitoring systems.

V. COMPONENTS OF SOLAR PV IOT BASED SYSTEMS

The following are the main ingredients IoT based solar PV monitoring systems:

- **Sensor nodes**
  Comprises of the sensors and the processing unit.
- **Communication technology/ Protocol.**
  The sensed data is transmitted through the network via a communication technology. The communication technology may be wired or wireless such as Wi-Fi, Bluetooth, GSM, Zigbee or LoRA.
- **Base station**
  It can be either a centralized or a decentralized entity.
- **Managing node**
  It offers a GUI to the end user. It can be a host computer or a laptop.

VI. CONCLUSION

Out of the various proposed methodologies in the literature, cloud based solutions are the most desired when it comes to remote monitoring. We have proposed a solution based on AWS that offers enormous support for IoT systems along with other features like security, scalability and alarm notification service. The system is desirable for both small scale and large scale systems with improved security and supervision tools.

VII. REFERENCES

[1] T.M. Razykov, T.M, C.S. Ferekides, D. Morel, E. Stefanakos, H.S. Ullal, H.M.Upadhyaya “Solar photovoltaic electricity: current status and future prospects.” In Solar Energy 85, pp. 1580–1608, ELSEVIER, 2011

[2] Patil, S. M., M. Vijayalashmi, and R. Tapaskar, “Iot based solar energy monitoring system,” in 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), pp. 1574–1579, IEEE, 2017.

[3] Bikrat, Youssef, Khalid Salmi, Ahmad Benlghazi, Abdelhamid Benali, and Driss Moussaid. "A Photovoltaic Wireless Monitoring System." In 2018 International Symposium on Advanced Electrical and Communication Technologies (ISAECT), 00978-1-5386-7328-7 IEEE, 2018

[4] Shuda, J. E., A. J. Rix, and M. J. Booysen. "Module-Level Monitoring Of Solar PV Plants Using Wireless Sensor Networks." In 26th Southern African Universities Power and Engineering Conference, pp. 1-7. 2018.

[5] https://www.greentechmedia.com/articles/read/solar-pv-has-become-cheaper-and-better-in-the-2010s-now-what

[6] Mokrani, H, R. Lounas, M. T. Bennai, S. D. Eddine and R. Djerbi, "Air quality monitoring using iot: A survey." SmartIoT 2019, pp. 127-134, IEEE, 2019.

[7] Fuentes, M, M. Vivar, J.M. Burgos, J. Aguilera, J.A. Vacas, “Design of an accurate, low-cost autonomous data logger for PV system monitoring using Arduino (TM) that complies with IEC standards.” Solar Energy Materials and Solar Cells m130, pp. 529-543, ELSEVIER, 2014

[8] Gagliarducci, M, D. A. Lampasi, and L. Podestà, “GSM-based monitoring and control of photovoltaic power generation,” Measurement, vol. 40, no. 3, pp. 314–321, 2007

[9] Andò, B, S. Baglio, A. Pistorio, G.M Tina, Ventura, C. Sentinella, “Smart Monitoring of Photovoltaic Systems at Panel Level,” IEEE Trans. Instrum. Meas.2015

[10] Gusa, R. F., W. Sunanda, I. Dinata, and T. P. Handayani. "Monitoring system for solar panel using smartphone based on microcontroller." In 2018 2nd International Conference on Green Energy and Applications (ICGEA), pp. 79-82. IEEE, 2018.

[11] Tejwani, R, G. Kumar, and C. Solanki, “Remote monitoring for solar photovoltaic systems in rural application using gsm voice channel,” Energy Procedia, vol. 57, pp. 1526–1535, 2014

[12] Rashidi, M. Moallem, and S. Vojdani, “Wireless Zigbee system for performance monitoring of photovoltaic panels,” in IEEE 37th Photovoltaic Specialists Conference (PVSC), Seattle, WA, pp. 003205–003207, 2011

[13] Haider-e-Karar, A. A. Khuwaja, and A. Sattar, “Solar power remote monitoring and controlling using Arduino, LabVIEW and web browser,” in IEEE 2nd International Conference on Power Generation

System and Renewable Energy Technologies (PGSRET), Islamabad, Pakistan, pp. 1–4, 10–11, 2015.

[14] Khan A, Khurram S. Khattak, Khan ZH, Khan MA, Minallah N. "Cyber physical system for vehicle counting and emission monitoring." International Journal of Advanced Computer Research. 2020; 10 (50): 181-193.

[15] Malik, Haroon, Khurram S. Khattak, T. Wiqar, Z. H. Khan, and A. B. Altamimi. "Low Cost Internet of Things Platform for Structural Health Monitoring." In 2019 22nd International Multitopic Conference (INMIC), pp. 1-7. IEEE, 2019.

[16] Sohail, A. Mehmood, Khurram S. Khattak, Adil Iqbal, Z. H. Khan, and Aakash Ahmad. "Cloud-based Detection of Road Bottlenecks Using OBD-II Telematics." In 2019 22nd International Multitopic Conference (INMIC), pp. 1-7. IEEE, 2019.

[17] Hussain, Sayed Shahid, Khurram S. Khattak, Ali Khan, and Zawar H. Khan. "Cyber Physical System for Solar Energy Monitoring." In 2019 International Conference on Frontiers of Information Technology (FIT), pp. 185-1855. IEEE, 2019.

[18] Khan, Nauman, Khurram S. Khattak, Shaukat Ullah, and Zawar Khan. "A Low-Cost IoT Based System for Environmental Monitoring." In 2019 International Conference on Frontiers of Information Technology (FIT), pp. 173-1735. IEEE, 2019.

[19] Iftikhar, Amir, Zawar H. Khan, T. Aaron Gulliver, Khurram S. Khattak, Mushtaq A. Khan, Murtaza Ali, and Nasru Minallah. "Macroscopic Traffic Flow Characterization at Bottlenecks." Civil Engineering Journal 6, no. 7 (2020): 1227-1242.

[20] Khan, Zawar H., Waheed Imran, T. Aaron Gulliver, Khurram S. Khattak, Zahid Wadud, and Akhtar Nawaz Khan. "An Anisotropic Traffic Model Based on Driver Interaction." IEEE Access 8 (2020): 66799-66812.

[21] Khan, Zawar H., T. Aaron Gulliver, Khizar Azam, and Khurram S. Khattak. "Macroscopic Model on Driver Physiological and Psychological Behavior at changes in Traffic." Journal of Engineering & Applied Sciences 38, no. 2 (2019).

[22] M. Rehmat Ullah, Khurram S. Khattak, Zawar H. Khan, Mushtaq A. Khan, Nasru Minallah and Akhtar N. Khan, "Vehicular Traffic Simulation Software: A Systematic Comparative Analysis", Pakistan Journal of Engineering and Technology, 2021 4(1): 66-78.

[23] Waheed Imran, Zawar H. Khan, T. A. Gulliver, Khurram S. Khattak, Salman Saeed, Sagheer Aslam, "Macroscopic Traffic Flow Characterization for Stimuli based on Driver Reaction", Civil Engineering Journal 2021 7(1): 1-13.

[24] Dhongade, V and A. Shaligram, "Cloud service based monitoring system for hybrid renewable energy sources using internet of things platform," in AIP Conference Proceedings, vol. 1989, no. 1. AIP Publishing, p. 020012, 2018

[25] Papageorgas, P.; Piromalis, D.; Antonakoglou, K.; Vokas, G.; Tseles, D.; Arvanitis, K. Smart Solar Panels:In-situ Monitoring of Photovoltaic Panels based on Wired and Wireless Sensor Networks, Energy Procedia, 36, 535–545, 2013.