Real-Time Monitoring System Using IoT for Photovoltaic Parameters

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***Abstract* – The monitoring performance of the photovoltaic system in real time is required for estimation and optimization purposes. This monitoring system has been the subject of extensive research, but in general it employs costly commercial software and as well as other license-based software. This paper discusses the design of a photovoltaic parameter monitoring system that uses Internet of Things technology to monitor in real time. This software is intended to be as interactive as possible in order to display all measurement data in the form of graphical according to a user-specified time interval. The constructed system is tested to display the measurement parameters of the fixed and dual axis solar tracker. The test results indicate that the system can display data in real time. Every data shown is accessible from any location and at any time, so long as the device being used is connected to the Internet. This system obviously can be applied and developed for an internet of thing-based photovoltaic parameter monitoring system to facilitate system estimation and optimization.**

***Keywords* – Photovoltaic monitoring, Internet of thing, Thinger.io, photovoltaic parameters, solar radiation.**

DOI: 10.18421/TEM123-11
https://doi.org/10.18421/TEM123-11

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Received: 16 May 2023.
Revised: 07 July 2023.
Accepted: 08 August 2023.
Published: 28 August 2023.

1. Introduction

Environmental pollution in the form of CO_2 emissions, rising fossil fuel prices, climate change, and the energy crisis caused by limited fossil energy resources have made the use of renewable energy sources a top priority [1], [2], [3]. Solar energy using photovoltaic (PV) technology is one of the most widely used renewable energy sources in an effort to overcome this problem [4]. Solar energy is free and abundant when compared to other energy sources. Aside from that, by utilizing modern monitoring and control systems, solar energy using PV technology can be the most efficient and dependable source of renewable energy [5], [6]. System monitoring is critical for ensuring the performance of the PV system [7], [8]. The monitoring system is useful for collecting data and sending it to the control center, which allows users to conduct assessments and evaluations and control systems with the goal of lowering maintenance costs, viewing system performance, and detecting errors in the PV system [9] Monitoring the PV system has several goals, including providing information about energy potential, fault detection, extracted energy, and energy losses [6], [10]. It is important to understand not only the description of system performance, but also how long a PV can work effectively in one day and other issues that can reduce energy production [11]. This monitoring is also necessary because the level of solar radiation is always changing according to location, time of day and climatic conditions [12]. All of the monitoring data can be used as a guide for maintenance and preventative measures, as well as a warning for early detection and evaluation of changes in environmental conditions [7], [13]

One method for performing real-time monitoring is to use Internet of Things (IoT) technology [12], [14]. IoT is a revolution in the electronic development that uses sensor technology connected to the Internet network either via cable or wireless with the goal of allowing users to access data and control the system from anywhere and at any time over the Internet [15], [16].

For the purpose of evaluating and optimizing system performance, it is necessary to monitor all parameters in real time. The IoT technology allows users to monitor Photovoltaic performance in terms of voltage, current, produced energy, and ambient temperature (2). Aside from that, the use of IoT technology makes it feasible for machines and devices to communicate without human intervention [17].

Many studies have been published recently that present data acquisition systems that use a combination of microcontrollers and licensed software such as LABVIEW [18], [19], [20], MATLAB [21], [22], [23], and VISUAL BASIC [24], [25]. However, the licenses are expensive and necessitate a substantial initial investment. Some systems include wires, but can only be accessed in close proximity to the PV system, are manually operated, and employ a wireless system that is dependent on licensed software [26]. Very few wireless data gathering systems employ open-source software. Using the proposed IoT-based data collecting system can reduce the occurrence of such issues.

This paper proposes a data acquisition system for a photovoltaic system. Arduino Mega 2560, Node MCU ESP8266, DHT11 temperature and humidity sensor, ACS712 current sensor, F031-06 voltage sensor, BH1750 digital light sensor, relay module, and Thinger.io platforms comprise the system. The measurement results from the BH1750 light sensor are translated to solar radiation data.

The process of data recording is carried out with the aid of sensors and processed by an Arduino Mega 2560. The information is then transmitted to the Thinger.io cloud through Node MCU 8266 using the Wi-Fi-network. The data can then be viewed on the Thinger.io platform from any location and at any time using a computer or smartphone that is connected to the Internet. Depending on the user's preferences, data on the Thinger.io platform can be shown in graphical or tabular format.

In this study, the data monitored by the proposed system is a comparison of the two PV system models' parameters such as current, voltage, temperature, and humidity, as well as solar radiation. The first system is a PV system with fixed tracking, whereas the second system is a PV system with dual-axis solar tracking. The suggested monitoring system is utilized to view and compare parameter values of solar radiation, current, voltage, temperature, and humidity. The objective is to determine which system produces electricity most efficiently.

2. Proposes System Design

The system proposed in this study is used to monitor current, voltage, temperature, humidity, and solar radiation in two PV system models. The first system is a PV system that is tested in an unchanged state (Fixed tracking system), whereas the second system operates by applying the concept of dual axis solar tracking. The block diagram of a monitoring system using IoT is depicted in Figure 1.

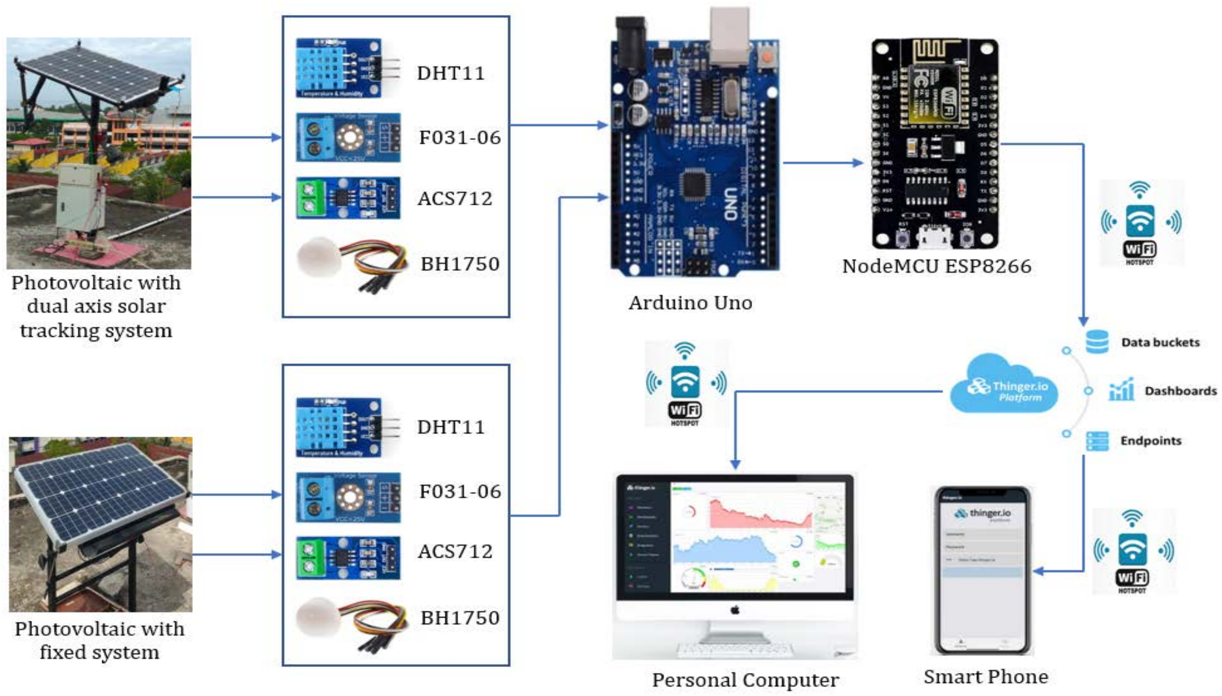

Figure 1. The block diagram of monitoring system using IoT for PV including the dual axis solar tracker and fixed system

Using sensors from both photovoltaic systems, all data is collected in real-time and delivered to the Arduino Mega 2560 for processing before being forwarded to the Node MCU ESP 8266. The data is then transmitted via Wi-Fi to the Thinger.io platform.

This data is displayed in graphical form. Data that has been processed on the Thinger.io platform can be accessed from anywhere and at any time using a computer or smartphone connected to the Internet.

Table 1. Electrical specification of PV Greentek MSP-100W

No	Parameter	Variable	Value
1	Maximum power	P_{max}	100 W
2	Voltage at P_{max}	Vmp	18.1 V
3	Voltage at P_{max}	Imp	5,54 A
4	Open Circuit voltage	Voc	22,2 V
5	Short-circuit voltage	Isc	6.00 A
6	Temperature coefficient of V_{oc}	Kv	-(0.40 ± 0,05) % / ^{0}C
7	Temperature coefficient of I_{sc}	Ki	-(0.065 ± 0,01) % / ^{0}C
8	No. of cells and connection	n_s	72 (4 x 18)

Furthermore, the PV systems either with tracking systems or fixed systems have the same specifications as shown in Table 1. The ACS712, F031-06, DHT 11, and BH1750 sensors are used to measure current, voltage, temperature, humidity, and solar radiation.

Arduino Mega 2560 is used as the system's control center, including issuing commands to operate the relay module for measuring the current and voltage on each solar panel.

This type of microcontroller is chosen based on the number of parameters being measured, as it requires a large number of data input pins. Node MCU ESP8266 is useful for transmitting measurement data from Arduino Mega 2560 to Thinger.io cloud via Node MCU ESP8266. Thinger.io is an open-source IoT application platform. On this platform, there is a menu of data buckets that serve as virtual storage for data to be displayed, such as current, voltage, temperature, humidity, and solar radiation.

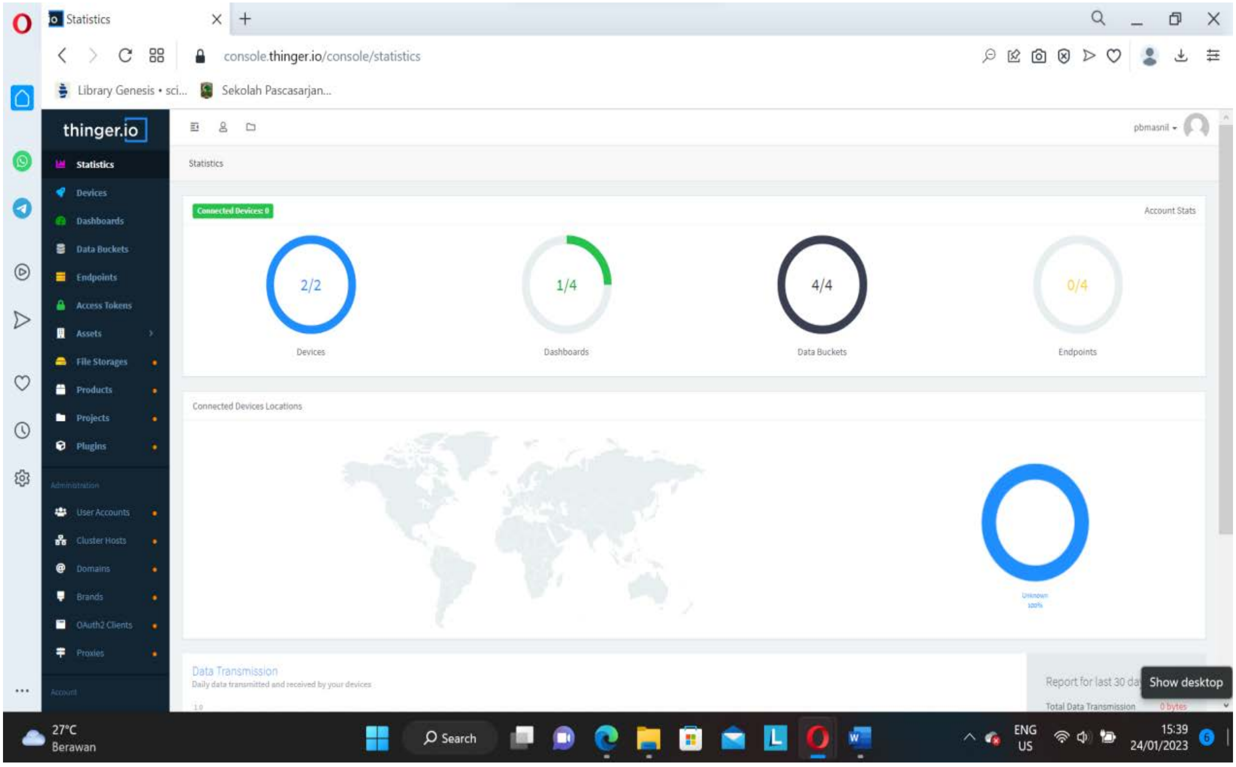

Figure 2. The graphical user interface of the Thinger.io platform's statistics menu

As for the design of the existing data's presentation format, this is accomplished on the data buckets page of the dashboard menu. Figure 2 depicts the general display format of the Thinger.io platform. The Thinger.io platform's graphical user interface can be viewed anywhere and at any time on a computer, laptop, or smartphone. This application is used as an interface to show and monitor the desired parameter measurement data. Figure 3 depicts the work process until data can be monitored and displayed using the Thinger.io application.

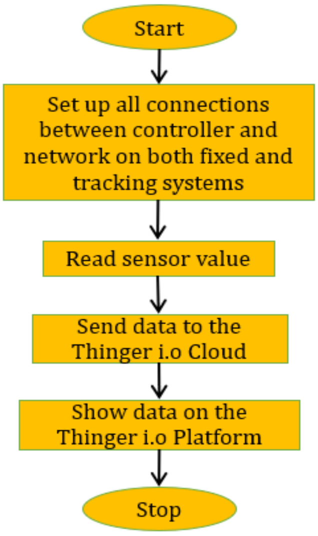

Figure 3. The procedure for displaying data on the Thinger.io platform

3. Results and Discussion

This study measures the characteristics of voltage, current, temperature, relative humidity, and solar radiation. The measurement results are transmitted to the Thinger.io platform through a wireless network. The measured data is a comparison of daily characteristic data from two PV systems, a fixed PV system and a tracking PV system. Figure 4 depicts the physical appearance of the device used to measure the values of voltage, current, temperature, humidity, and solar radiation.

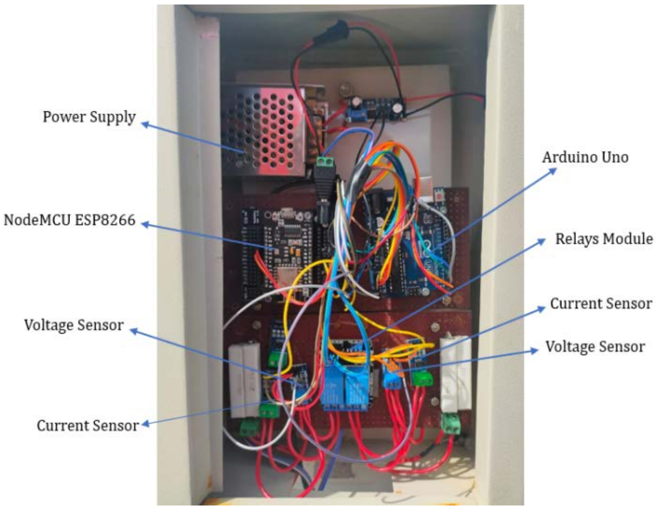

Figure 4. The measuring instruments used to monitor the parameters

In Figure 5, an overall view of the Thinger.io platform displaying the results of the required parameter measurements is shown with all parameters represented graphically. The results can be accessed from anywhere and at any time using a computer or smartphone. Figures 6 and 7 depict a comparison of the voltage and current measurement results for both the PV system with the tracking system and the fixed system, respectively. The measurement is conducted from 07:30 AM to 07:30 PM. It can be seen that the voltage measurement results of the tracking PV system are greater than that of the fixed solar panel system where the average voltage value acquired from the tracking PV system is above 19.75 Volts. Moreover, the monitoring also indicates that the current from the tracking PV system is also greater than that of the fixed PV system. This monitoring reveals that the movement of the sun and the capacity of the tracking system to align the solar panel's surface perpendicular to the path of sunlight have a significant impact on the amount of energy produced.

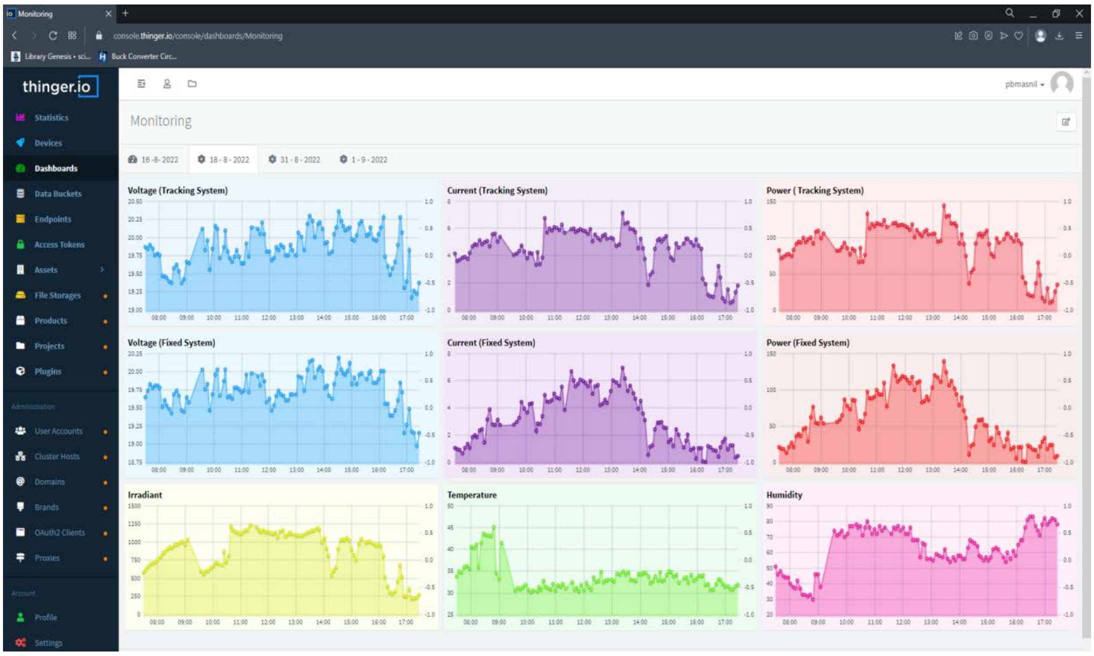

Figure 5: The Thinger.io application's display of monitoring results for voltage, current, temperature, humidity, and solar radiation

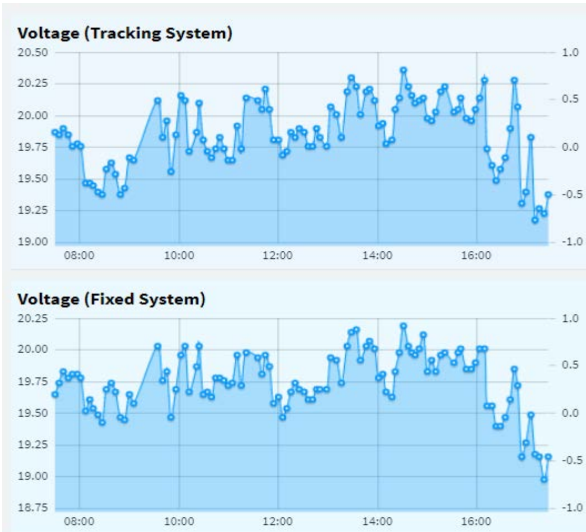

Figure 6. The display of photovoltaic voltage measurement monitoring results

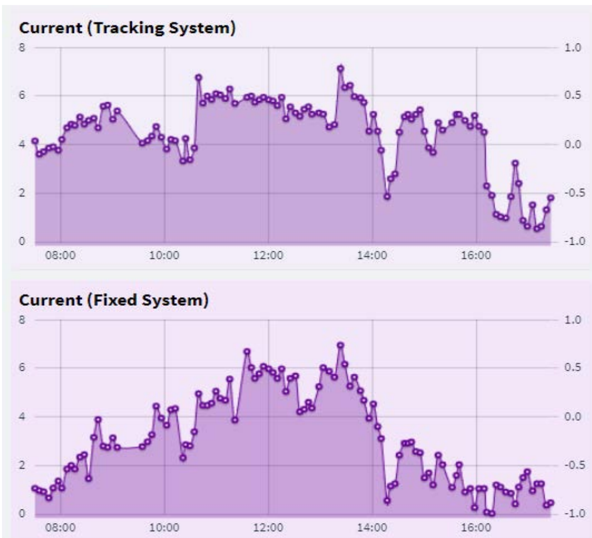

Figure 7. The display of photovoltaic current measurement monitoring results

In addition, the measurement results of temperature, humidity, and irradiance are presented in Figure 8. As seen in that figure, the temperature value is the inverse of the humidity value. If the temperature is high, the relative humidity will be low, and vice versa. In the meantime, the irradiance varies according to the sun's movement and the shadows that prevent sunlight from reaching the solar panel's surface. The value of solar radiation drops between 9:00 AM and 11:00 AM due to the existence of cloud shadows that prevent sunlight from reaching the surface of the solar panel. Similarly, the radiation value will fall if there are shadows preventing the sun rays from the surface of the PV and will return to its maximum if there are no shadows blocking the sun rays.

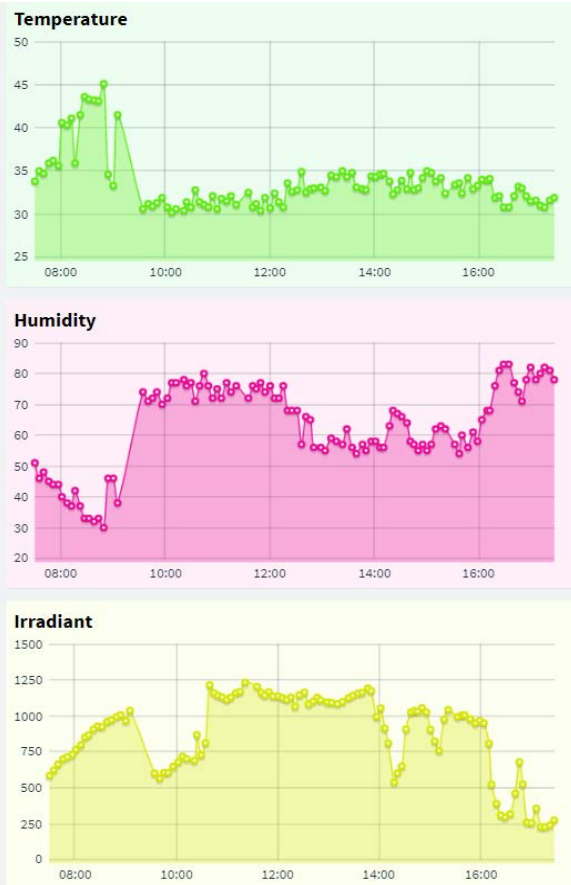

Figure 8. The display of photovoltaic temperature, humidity, and irradiance measurement monitoring results

4. Conclusion

A real-time monitoring system based on the Internet of Things concept has successfully measured voltage, current, temperature, humidity, and solar radiation values in this study. Using the IoT concept allows user to monitor from anywhere and any time as long as the device is connected to the Internet network. The developed system can assist related parties or users in predicting and evaluating the performance of the photovoltaic system.

It can also help users with preventive and maintenance actions, as well as provide a warning for early detection and evaluation of changes in environmental conditions. In addition to interactively displaying data, the Thinger.io-based monitoring system utilized in this work provides an open source platform at low cost. The objective is to lessen reliance on expensive commercial software, license-based software, and other cloud services. According to the test results, the system employed in this study can be applied and extended o a larger system for simpler, open-source, and real-time monitoring of solar system parameters.

Acknowledgements

Authors gratefully acknowledge the support of the Institute for Research and Community Services Universitas Negeri Padang under Penelitian Dasar Scheme Project No: 1033/UN35.13/LT/2022.

References

[1]. Çelik, Ö., Tan, A., Inci, M., & Teke, A. (2020). Improvement of energy harvesting capability in grid-connected photovoltaic micro-inverters. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 1-25. Doi: 10.1080/15567036.2020.1755389.

[2]. Al-Majidi, S. D., Abbod, M. F., & Al-Raweshidy, H. S. (2019). Design of an efficient maximum power point tracker based on ANFIS using an experimental photovoltaic system data. *Electronics*, *8*(8), 858. Doi: 10.3390/electronics8080858.

[3]. Jha, R. R., Srivastava, S. C., & Kumar, M. (2017). Development of control schemes for a cluster of PV-integrated houses in islanded mode. *IET Renewable Power Generation*, *11*(7), 903-911. Doi: 10.1049/iet-rpg.2016.0048.

[4]. Ranjit, S. S. S., & Abbod, M. (2018). Research and integration of IoT based solar photovoltaic panel health monitoring system. *Indian Journal of Public Health Research and Development*, *9*(12). Doi: 10.5958/0976-5506.2018.02232.5.

[5]. Sutikno, T., Purnama, H. S., Pamungkas, A., Fadlil, A., Alsofyani, I. M., & Jopri, M. H. (2021). Internet of things-based photovoltaics parameter monitoring system using NodeMCU ESP8266. *International Journal of Electrical and Computer Engineering*, *11*(6), 5578–5587. Doi: 10.11591/ijece.v11i6.pp5578-5587.

[6]. Rahman, M. M., Selvaraj, J., Rahim, N. A., & Hasanuzzaman, M. (2018). Global modern monitoring systems for PV based power generation: A review. *Renewable and Sustainable Energy Reviews*, *82*, 4142–4158. Doi: 10.1016/j.rser.2017.10.111.

[7]. Madeti, S. R., & Singh, S. N. (2017). Monitoring system for photovoltaic plants: A review. *Renewable and Sustainable Energy Reviews*, *67*, 1180–1207. Doi: 10.1016/j.rser.2016.09.088

[8]. Njoka, F., Thimo, L., & Agarwal, A. (2022). Evaluation of IoT-based remote monitoring systems for stand-alone solar PV installations in Kenya. *Journal of Reliable Intelligent Environments*. Doi: 10.1007/s40860-022-00190-5.

[9]. Gorjian, S., & Shukla, A. (2020). *Photovoltaic Solar Energy Conversion Technologies, Applications and Environmental Impacts*. Elsevier.

[10]. Cheddadi, Y., Cheddadi, H., Cheddadi, F., Errahimi, F., & Es-sbai, N. (2020). Design and implementation of an intelligent low-cost IoT solution for energy monitoring of photovoltaic stations. *SN Applied Sciences*, *2*(7), 1165. Doi: 10.1007/s42452-020-2997-4.

[11]. Madadi, S. (2021). A Study of Solar Power Monitoring System Using Internet of Things (IOT). In *International Journal of Innovative Science and Research Technology*, *6*(5).

[12]. Gopal, M., Chandra Prakash, T., Venkata Ramakrishna, N., & Yadav, B. P. (2020). IoT Based Solar Power Monitoring System. *IOP Conference Series: Materials Science and Engineering*, *981*(3), 1–8. Doi: 10.1088/1757-899X/981/3/032037.

[13]. Adhya, S., Saha, D., Das, A., Jana, J., & Saha Hiranmay. (2016). An IoT Based Smart Solar Photovoltaic Remote Monitoring and Control unit. *2016 2nd International Conference on Control, Instrumentation, Energy & Communication (CIEC*, 432–436.

[14]. Sarswat, S., Yadav, I., & Maurya, S. K. (2019). Real Time Monitoring of Solar PV Parameter Using IoT. *International Journal of Innovative Technology and Exploring Engineering*, *9*, 267–271. Doi: 10.35940/ijitee.a1054.1191s19.

[15]. Kang, B., Park, S., Lee, T., & Park, S. (2015). IoT-based monitoring system using tri-level context making model for smart home services. *2015 IEEE International Conference on Consumer Electronics, ICCE 2015*. Doi: 10.1109/ICCE.2015.7066379.

[16]. Kekre, A., & Gawre, S. K. (2017, October). Solar photovoltaic remote monitoring system using IOT. In *2017 International conference on recent innovations in signal processing and embedded systems (RISE)*, 619-623. IEEE. Doi: 10.1109/RISE.2017.8378227.

[17]. Badave, P. M., Karthikeyan, B., Badave, S. M., Mahajan, S. B., Sanjeevikumar, P., & Gill, G. S. (2018). Health monitoring system of solar photovoltaic panel: An internet of things application. In *Lecture Notes in Electrical Engineering*, 435, 347–355). Springer. Doi: 10.1007/978-981-10-4286-7_34.

[18]. Jumaat, S. A., Anuar, A. S. B. M., Abdullah, M. N., Radzi, N. H., Hamdan, R., Salimin, S., & Bin Ismail, M. N. (2018). Monitoring of PV performance using labVIEW. *Indonesian Journal of Electrical Engineering and Computer Science*, *12*(2), 461–467. Doi: 10.11591/ijeecs.v12.i2.pp461-467.

[19]. Samkria, R., Abd-Elnaby, M., Singh, R., Gehlot, A., Rashid, M., Aly, M. H., & El-Shafai, W. (2021). Automatic PV Grid Fault Detection System with IoT and LabVIEW as Data Logger. *Computers, Materials and Continua*, *69*(2), 1709–1723. Doi: 10.32604/cmc.2021.018525.

[20]. Farooq, A., & Aftab, R. (2019). Performance study and evaluation of a solar PV testbed system using labview. *International Review of Applied Sciences and Engineering*, *10*(1), 113–123. Doi: 10.1556/1848.2018.0012.

[21]. Rouibah, N., Barazane, L., Benghanem, M., & Mellit, A. (2021). IoT-based low-cost prototype for online monitoring of maximum output power of domestic photovoltaic systems. *ETRI Journal*, *43*(3), 459–470. Doi: 10.4218/etrij.2019-0537.

[22]. Le, P. T., Tsai, H. L., & Lam, T. H. (2016). A wireless visualization monitoring, evaluation system for commercial photovoltaic modules solely in MATLAB/Simulink environment. *Solar Energy*, *140*, 1–11. Doi: 10.1016/j.solener.2016.10.043.

[23]. Sabry, A. H., Hasan, W. Z. W., Ab. Kadir, M. Z. A., Radzi, M. A. M., & Shafie, S. (2018). Wireless monitoring prototype for photovoltaic parameters. *Indonesian Journal of Electrical Engineering and Computer Science*, *11*(1), 9–17. Doi: 10.11591/ijeecs.v11.i1.pp9-17.

[24]. Ahmad, T., Hasan, Q. U., Malik, A., & Awan, N. S. (2015). Remote Monitoring for Solar Photovoltaic Systems in Rural Application Using GSM Network. *International Journal of Emerging Electric Power Systems*, *16*(5), 413–419. Doi: 10.1515/ijeeps-2015-0017

[25]. Harmini, H., & Nurhayati, T. (2017). Monitoring system of stand alone solar photovoltaic data. *Proceedings of the ICECOS*.

[26]. Gupta, V., Sharma, M., Pachauri, R. K., & Babu, K. N. D. (2021). A Low-Cost Real-Time IOT Enabled Data Acquisition System for Monitoring of PV System. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *43*(20), 2529–2543. Doi: 10.1080/15567036.2020.1844351.