

# Development of Wireless Photovoltaic (PV) Monitoring System

Ahmad Syafiq Ahmad Shaukhi<sup>1</sup> & Mohd Izhar A Bakar<sup>2</sup>

<sup>1,2</sup>Section of Electrical Technology  
Universiti Kuala Lumpur British Malaysian Institute

Corresponding email: [mizhar@unikl.edu.my](mailto:mizhar@unikl.edu.my)

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**Abstract:** Solar monitoring system is getting demand all over the world due to many companies use solar energy in daily operation. The main objective of this project is to apply a wireless system to monitor the performance of solar panels and get accurate real-time data. However, lack of technology and inaccurate real-time data caused monitoring inconsistent and difficult. Therefore, the wireless system used to monitor the performance of solar panels is very effective anywhere and anytime. The sensor connected to Wi-Fi using Arduino help to get solar parameter more efficient. It is easy to configure because it has a built-in Wi-Fi network. It also uses the Ubidots platform to read and stored all the data. Voltage, current, temperature, and light intensity sensors obtain and recorded all the data accurately from time to time. As a result, the parameter reading is easier and accurate. The data can be read wirelessly regardless of time and place.

**Keywords:** Wireless Solar Monitoring, Arduino, Solar Parameter, Sensor

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## 1.0 INTRODUCTION

The electricity demand has increased over the past decade as Malaysia's economy develops. According to data from Malaysia Energy Information Hub (MEIH), it reached 134 billion kWh in 2012 [1]. The amount of energy generated from the photovoltaic cell depends on solar radiation. The higher the radiation, the higher power of PV panel can generate. Currently, the solar system is very popular as it has many advantages such as it gives no pollution, simplicity of allocation, infinite resource, has a great return of investment when it can save utility bills and maintenance costs and it has no noise. Furthermore, Malaysia is now the top 3 largest manufacturer of photovoltaic (PV) cells and modules in the world. Malaysia comes in third place after China and Taiwan [2].

In addition, the advantage of the wireless system is low-cost to install because extensive wiring is no longer necessary between sensors and data acquisition. There are many proposed and developed monitoring systems to ensure the stability and reliability of a PV system. The main function of this system is to monitor and gather data on the performance of the PV in real-time. The status of the monitoring system will be displayed on Arduino software. The data can be recorded directly to the application whenever and wherever you are. Developing this project which is a wireless photovoltaic (PV) monitoring system can help especially the company that uses a solar panel to convert the sunlight energy to electrical energy for their daily operation. It helps the company in managing the

operation to monitor the solar panel parameter consistently.

## 2.0 LITERATURE REVIEW

There are several existing projects of the solar monitoring system that has been done for the past few years. It has the same aim which is to monitor solar performance with the various sensor but for some projects, it is used in a different types of places which are on land and underwater.

### 2.1 Wireless ZigBee system for performance monitoring photovoltaic panels

This project uses a wireless ZigBee microcontroller to monitor the performance of solar. It contains a back-end embedded program and also a front-end graphical user interface (GUI) to enable remote monitoring of current, power, and voltage. It also provides a low-cost and reliable performance monitoring system for large and small-scale PV [3].

### 2.2 Data Monitoring System For Solar Panels With Bluetooth

Monitoring and analyzing the changes collected from the panel can help to detect errors easily. An online software system has been developed to send data such as current, voltage, temperature, humidity, and radiation. All of them is gained from an installed 1000W PV system via Bluetooth. Software compatible

with Bluetooth 2.1 and 4.0 standards collects measurement data that was placed at different locations [4].

### ***2.3 Underwater Characterization and Monitoring of Amorphous and Monocrystalline Solar Cells in Diverse Water Settings***

This system allows for an exploration of the performance of PV cells underwater environment. An underwater has the potential to use in defense applications such as sensors, underwater vehicles, autonomous power systems, and many more. It can overcome the way of cooling and cleaning PV cells. Suitable solar cells were encapsulated with polydimethylsiloxane (PDMS) and various characteristics were performed to sense the actions of amorphous and monocrystalline cells with different types of water [5].

### ***2.4 Monitoring System for Solar Panel Using Smartphone-Based on Microcontroller***

Nowadays, the real-time photovoltaic (PV) control device is still having a strong demand in the industry. Anyway, this real-time monitoring system uses Arduino Atmega 2560. It is connected to three sensors which are a current sensor, a temperature sensor, and a voltage sensor. In addition, Arduino Atmega 2560 also connects to a smartphone with a Wi-Fi module. It is designed to display the voltage, power, and current data of the solar panel as well as the ambient temperature data through the Blynk app. Next, it has a good degree of accuracy that the average output rate of error is less than 10%. Monitoring using smartphone-based microcontrollers can be done in real-time and can be developed for large PV systems [6].

### ***2.5 Time-Series Energy Prediction Using Hidden Markov Model for Smart Solar System***

Photovoltaic solar energy has been identified as the third-largest source of renewable energy. The management of the photovoltaic system is therefore very important to increase and maintain efficiency. The system has two phases: a panel-level monitoring system and a solar power system. To enhance efficiency, IoT has been used to control and track solar farms. Essentially, this device gathers a few data that are analyzed by panel level feedback measurement sensors. It keeps track of the generation of solar power at a certain location, such as temperature and humidity. In addition, it also predicts the faults as well as the dead state of the panel with time parameters. In addition, the second phase is working on solar power prediction with the help of the Hidden Markov Model. This helps to provide correct estimation given the similarity of the first value to the next value in the time series. The performance would then be linked to the current prediction module [7].

### ***2.6 Iot Application For Real-Time Monitoring Of Solar Home Systems Based On Arduino™ With 3G Connectivity***

A data logger has been developed, configured, and implemented as an experimental project on a variety of sites focused on free software and hardware. Remote monitoring is carried out to ensure the efficiency of data loggers in areas deprived of electrical grids and traditional wired telecommunications networks. The IoT device enables centralized control of a tiny stand-alone PV network. It also improves system performance and maintenance. In addition, the function of the data logger is to measure the electrical and climatic parameters with the required accuracy laid down in the IEC61724 standard, including 3 G technology. It enables remote monitoring of the PV system via the web or mobile applications at a low cost. This system has been tested with an outdoor campaign for over 12 months in harsh environmental situations at several locations to demonstrate the robustness and reliability of the system [8].

### ***2.7 Experiment-Based Supervised Learning Approach Toward Condition Monitoring Of Pv Array Mismatch***

Unprecedented mismatch occurs regularly in the PV array system. The analysis of artificial intelligence technologies requires any well-designed experiments for rigorous testing since the mismatch is determined by different factors such as the PV collection, the DC-DC converter, the DC-AC inverter, loads, and environmental variables. There are two aims which are, firstly, the creation of certain similar apparatuses to replicate the same real-world solar power station which has operated under a range of uncertainties for controllable, repeatable, and comparable experimental studies and secondly, the suggestion for a novel situation monitoring techniques based on the backward propagation of the neural network and a decision-making algorithm. Controllable indoor and uncontrollable outdoor tests have been carried out to test theories. As a result, the derived monitoring systems identify and precisely classify dissimilar indoor and outdoor unevenness. The findings of real-time experiments conclude that the data-driven approach of self-learning skills adapts to changes in the environment [9].

### ***2.8 Low-Cost Data Logger Intended for Remote Monitoring of Solar Photovoltaic Standalone Systems Based On Arduino***

This project involves low-cost data loggers for stand-alone PV systems that have been developed using open-source software and hardware. It can calculate electrical and meteorological parameters that meet the precision specifications defined by the International Electro-Technical Commission (IES), which is the standard for the photovoltaic monitoring system. In addition, it requires the implementation of a control device in areas such as lack of telephone

networks, handling of SD card data, and minimal maintenance requirements. A true stand-alone photovoltaic system has been installed at the IMDEA Water Institute in Madrid, Spain. Testing and validation of the new low-cost data logger were carried out under actual conditions. Finally, the finding was demonstrated in compliance with the IEC standard by measuring all parameters with high precision and low power consumption [10].

### 2.9 A Condition Change Detection Method For Solar Conversion Efficiency In Solar Cell Manufacturing Processes

Typically, there are multiple serial steps in the manufacture of solar cells. There is also a limitation of the quality inspection and control points along a few manufacturing stages which result in uneven product quality at the finishing level. Present studies concentrate on offline output control after completion for all stages of development. It is also important to provide an efficient method of detecting changes to reduce the effects of price variability. In addition, the project suggests an in-process strategy to identify improvements by studying multichannel sensing signals obtained at the epitaxy level. In addition, this stage is significant for the formation of material layers and significantly affects the efficiency of the product's solar conversion. Interpretable geometric structures are acquired by considering the knowledge of the process for each sensing data channel. The system of decision-level data fusion is further suggested to incorporate the identification of improvements for each sensing signal and is illustrated by the actual case of solar cell manufacturing processes [11].

## 3.0 MATERIALS AND METHODOLOGY

The development of this project is divided into two parts which are hardware and software development will be explained in this section.

### 3.1 Materials

#### a) Photovoltaic Module

The PV module in Figure 1 is shown on the material of the solar panel from Monocrystalline 50W Power IP65 Water-resistance.

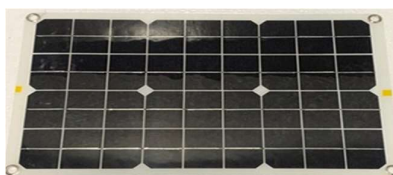


Figure 1: PV module of Solar Panel IP65

#### b) Voltage Sensor

The voltage sensor in Figure 2 is used to determine the voltage supply. The analog signal from a solar panel is converted to a digital signal built-in 10-bit ADC. It required programming coding to convert ADC value to real voltage. Then, the voltage will be displayed on the monitor.

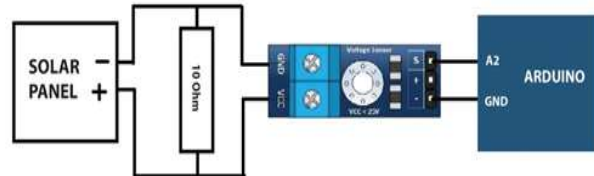


Figure 2: Voltage Sensor Circuit

#### c) Temperature Sensor

DS18B20 in Figure 3 is used to gain temperature reading on the solar panel. The DS18B20 communicates over a 1-Wire bus which requires one data and ground for communication with Arduino.

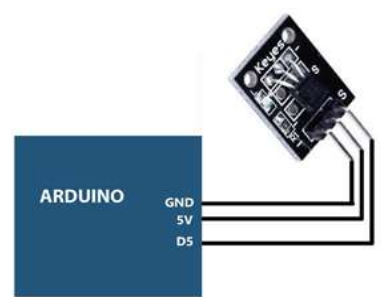


Figure 3: Temperature Sensor Circuit

#### d) Current Sensor

The current sensor in Figure 4 is a device that detects electric current and converts its output voltage. The current sensor circuit ACS712 is used to get the current reading from the solar panel. An external 12V supply is needed for ACS712 to operate. 10Ω resistor is used as the load to get maximum current from the PV module

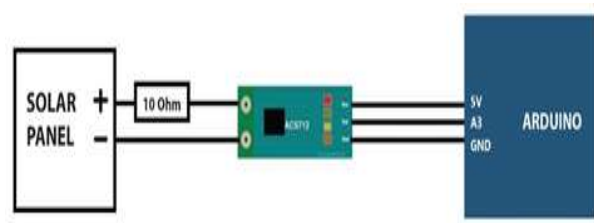


Figure 4: Current Sensor Circuit

#### e) Light Intensity Sensor

A pyrometer is needed to measure solar radiation. It is highly cost to purchase. Therefore, the light intensity is being compared with the value from the irradiance meter to get an approximate value of solar irradiance. Figure 5 shows the sensor of solar irradiance.

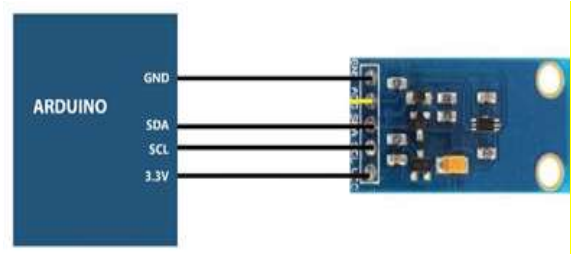


Figure 5: Light Intensity Sensor Circuit

**f) Arduino Yun**

The Arduino Yun in Figure 6 is a microcontroller board based on the ATmega32u4 and the Atheros AR9331. It manages all the components such as analog sensor, digital sensor, and memory installed in the node. The Arduino Yun is used in this project because of its simplicity to transmit and receive data wirelessly via Wi-Fi

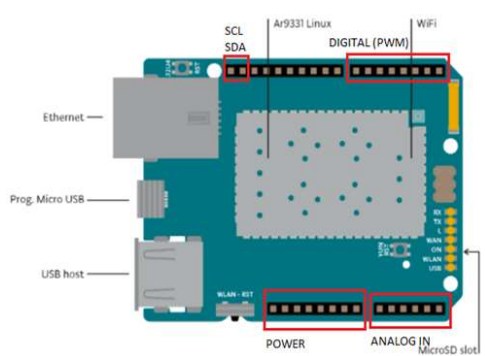


Figure 6: Connection used of Arduino Yun board

**g) Arduino IDE 1.8.7**

Arduino is open-source software that allows writing code more easily and can upload into the board. It is written in C and after that will be uploaded to Arduino Yun using IDE 1.8.7. The heading source code is shown in Figure 7.

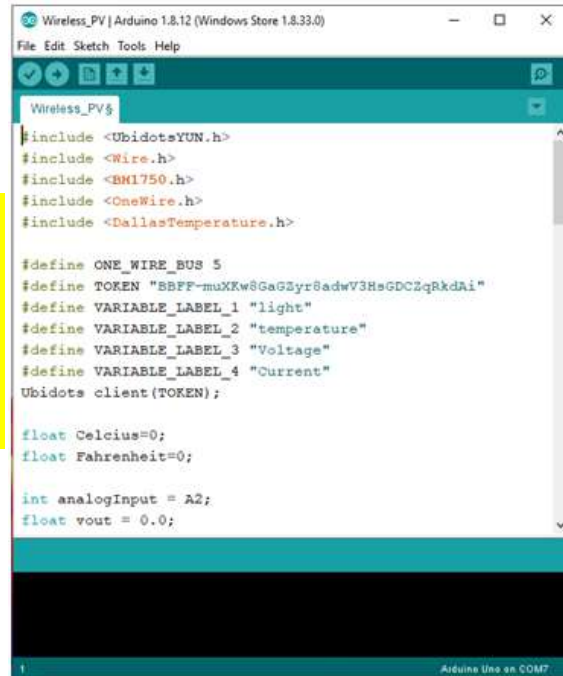


Figure 7: Interface of Arduino IDE 1.8.7

**h) Ubidots**

Ubidots in Figure 8 is an IoT platform that automates the process of IoT application creation that captures real data. It is connected hardware and software to control, monitor, and automate processes. The Ubidots Arduino Yun library is installed in Arduino IDE 1.8.7



Figure 8: Yun connected with Ubidots

**3.2 Methodology**

The development of the methodology for the solar monitoring system as follows.

**a) Block diagram**

The hardware part consists of a PV module, sensors, and Arduino Yun to implement the wireless PV monitoring system shown in Figure 9.

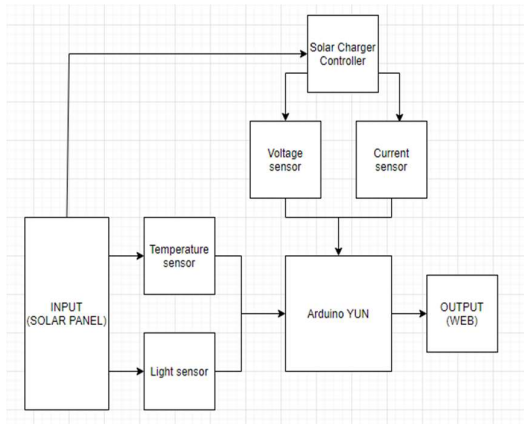


Figure 9: Block diagram of Wireless PV Monitoring System

b) Flowchart

Figure 10 shows the flowchart for this project.

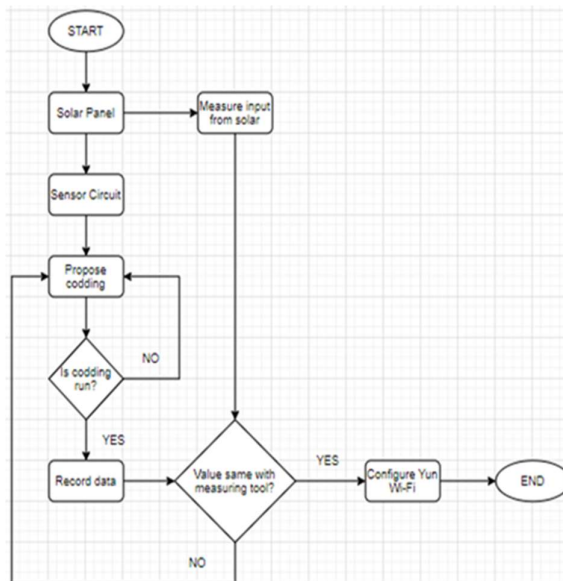


Figure 10: Flowchart of the Workflow

4.0 RESULTS AND DISCUSSION

Following are the results of the wireless photovoltaic monitoring system.

4.1 Results

The results for irradiance, temperature, current, and voltage produce by Photovoltaic are tabulated in Table 1.

Table 1: Result Monitoring of Four Parameters

No.	Irradiance (W/m <sup>2</sup> )	Temp. (°C)	Current (Output) (A)	Voltage (Output) (V)
1	42348.33	36.88	1.35	10.52
2	18718.33	36.88	1.49	10.45
3	14802.5	36.75	1.49	10.11
4	13895	36.5	1.42	10.45
5	12900	36.0	1.49	10.06
6	11384.17	36.0	1.42	10.13
7	9845.83	35.88	1.35	10.23
8	9800.83	35.75	1.21	10.18
9	8545	35.56	1.21	10.18
10	9543.33	35.38	1.42	10.13
11	10304.17	35.25	1.02	10.08
12	10441.67	35.19	1.21	10.18
13	10069.17	35.13	1.35	10.23
14	9580.83	34.69	1.02	10.11
15	8285.83	34.69	1.21	10.18
16	7257.5	34.13	1.35	10.23
17	6616.67	33.81	1.07	10.12
18	6095.83	33.88	1.28	10.25
19	5830	33.44	1.35	10.23
20	5776.67	33.38	1.21	10.18
21	5658.33	33.44	1.21	10.18
22	5380.83	33.5	1.28	10.25
23	4964.17	33.19	1.14	10.21

Figure 11 and 12 shows the graph for output current and voltage.

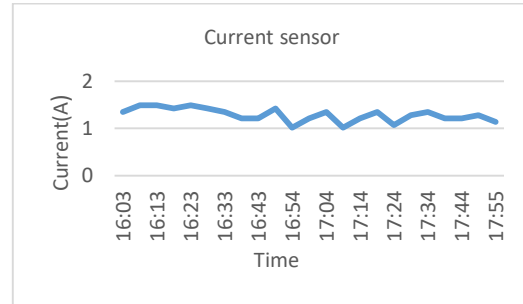


Figure 11: Current Sensor

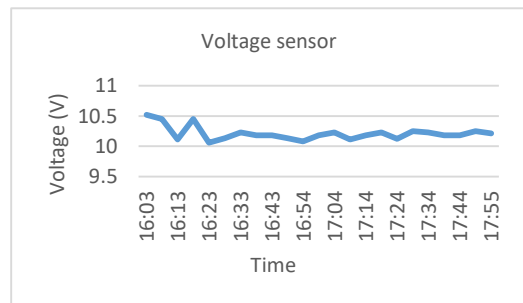


Figure 12: Voltage Sensor

Figures 13 and 14 show the results for light and temperature of the sunlight.

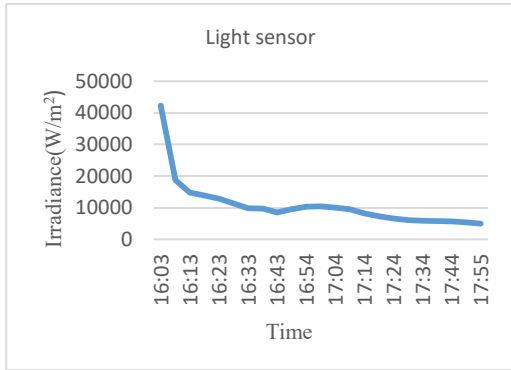


Figure 13: Light Sensor

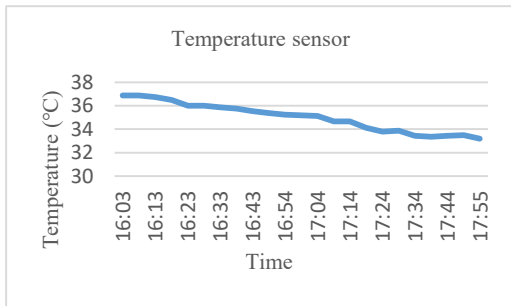


Figure 14: Temperature Sensor

The dashboard interfaces display to show the performance of monitoring PV system on the Smartphone is shown in Figure 15.

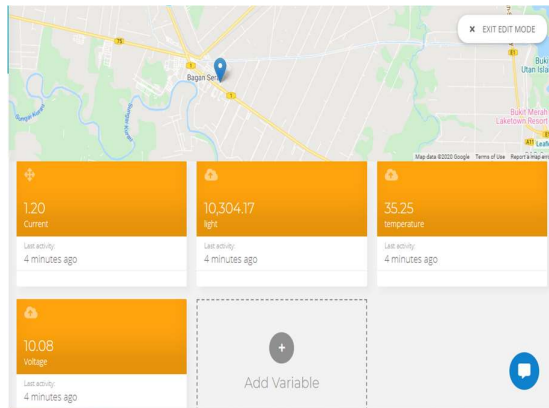


Figure 15: Dashboard Interface

#### 4.2 Discussion

The measurement readings for every five minutes for each parameter are recorded in Table 1. These results show the maximum output voltage is 10.45V, current 1.49A at a 10ohm load. Also, found that the output voltage is slightly decreased at certain times which was due to many clouds cover the sunlight was

facing in front of the PV panel. The PV panel output voltage is also used to charge the PV battery system to 12V.

Figures 13 and 14 show that the relationship between radiation and temperature is directly proportional. If the sun's rays decrease then the temperature also decreases because the clouds have covered the sunlight. Therefore, PV cannot receive radiation from sunlight and causes the output voltage to drop.

Figure 15 shows the dashboard interface of Ubidots where it can autoing the current location of the photovoltaic system is located on the smartphone. Also, this dashboard will show the current results of four parameters such as current, voltage, light, and temperature. Therefore, from this system, the user can know the exact condition of radiation and output voltage, and current from the PV system. Furthermore, all the data from this system monitoring can be downloaded through personal email using the Ubidots platform. It means that the user can analyze the performance of the PV system in real-time.

#### 4.3 Prototype

The whole prototype of the Wireless Photovoltaic Monitoring System is shown in Figure 16.



Figure 16: Prototype Stand-alone Wireless PV Monitoring System

#### 5.0 CONCLUSION

Arduino Yun is a microcontroller that has been used in this project which is an advanced technology. The Arduino Yun is relatively easy to configure because it has a Wi-Fi network. The project also uses the Ubidots platform to read and store all data. There are four sensors have been used, namely voltage, current, temperature, and light intensity sensors. All of these sensors will accurately detect and record data from the Ubidots platform. It is found that the energy produced by PV panels is constantly changing due to weather changes such as cloudy and sunny. Also, the results show sunlight affects the PV output voltage. Therefore, using a wireless monitoring system with the

Arduino Yun platform and Ubidots succeeded in monitoring solar panel performance in real-time.

## 6.0 RECOMMENDATION

There are several recommendations for this project that were proposed to improve the system in the future.

1. Arduino Yun is still a bit expensive, uses cheaper technology options but has high-quality outcomes.
2. Using other IoT systems so that the dashboard has no limit time and less delay to transfer data from hardware to software.
3. Add additional parameters to monitor the solar panel surface such as dust.
4. To improve the continuity circuit for sensitive components such as sensors.

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