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IoT Enabled Environmental Data Monitoring System to Forecast Solar Generation

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Abstract: The ability to accurately forecast the energy generated by Photovoltaic (PV) systems is critical, and it has been described as one of the main challenges for wide PV implementation. PV power generation is entirely dependent on uncontrollable meteorological factors including solar irradiance, ambient temperature, module temperature, wind pressure and direction, and humidity. So, the main concern for this project was to design and develop an Internet of Things (IoT) enabled weather station using sensing technology that can measure ambient temperature, humidity, wind speed, and light intensity. Other than that, to analyze environmental parameters with PV output power collected with the rate of 4 samples/min over a period of four consecutive days. With the help of an IoT system, it can make users easier to monitor and analyze data collected by using a cloud platform which is ThingSpeak. The location for experimental set-up has been done near the Enviro Lab and behind the Kolej Kediaman Tun Fatimah. The duration for data collection was four consecutive days. Based on the result and analysis that has been done, it was proved that environmental parameters can affect the PV power. Besides that, based on the regression analysis, the PV power can be forecasted even though the reading of actual PV power and the forecasted PV power has big differences. This project can be beneficial to people that want to implement a PV system for forecasting PV output purposes and want to analyze the weather parameters.

Keywords: Photovoltaic, Internet of Things (IoT), Weather Station, Forecast

1. Introduction

Weather tracking and forecasting are useful in one way or another in our everyday activities [1]. PV systems have gained widespread acceptance and are now playing an important role in supplying clean and renewable energy. As a result, PV power installation has exploded in popularity in recent years [2]- [6].

PV output is primarily determined by the amount of solar global irradiation incident on the panels, which is not constant over time [3], [4]. The ability to accurately forecast the energy generated by PV

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systems is critical, and it has been described as one of the main challenges for wide PV implementation. An accurate forecast benefits not only system operators but it also benefits PV plant managers by avoiding potential penalties incurred due to differences between forecasted and generated electricity [5].

So, the main concern for this project was to design and develop an IoT enabled weather station using sensing technology that can measure ambient temperature, humidity, wind speed, and light intensity. Other than that, to analyze environmental parameters with PV output power collected with the rate of 4 samples/min over a period of four consecutive days. This project was installed at behind the Kolej Kediaman Tun Fatimah. With the regression that has been done, it can forecast the PV power based on the current environmental parameters.

2. Methodology

This section will present the methodology used to develop the weather station system. The first subsection present overall block diagram of the system, followed by the circuit design of this project and finally the example of data display on ThingSpeak.

2.1 Block diagram

Figure 1 shows the overall block diagram working process of this weather station. This weather station using three sensors which are DHT11 to measure ambient temperature and humidity, TSL2561 to measure light intensity and anemometer to measure speed of wind. Arduino Mega which the heart of the system will control the entire system. ESP8266 will transmit all the data to the cloud by using Wi-Fi. Cloud platform that used by this project is ThingSpeak. This platform enable user to monitor live data stream and store in the cloud. This weather station powered by 9V supply.

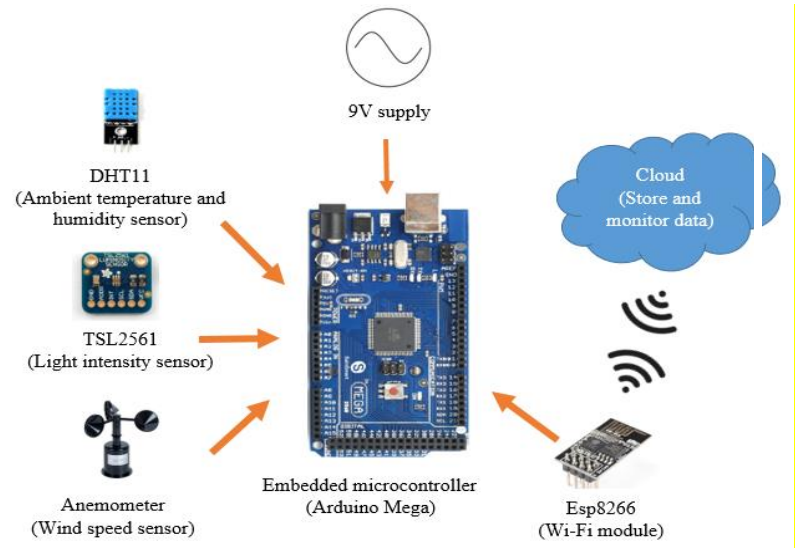


Figure 1: Block diagram of the weather station

2.2 Circuit design

This circuit consist of three sensors which DHT11, TSL2561 and anemometer. ESP8266 will transmit all the data collected by the sensors to the clouds by using the internet. The power supply of the Arduino Mega can be supplied by using DC voltage supply ranging from 7V to 12V that can be plugged in either two input sources port. The DHT11 sensor is powered by the 5V pin of the Arduino and its data pin is connected to digital pin 8 for one-wire communication. The TSL2561 sensor is powered by the 3.3V pin of Arduino and its data pins SCL (Serial Clock) and SDA (Serial Data) are connected to the communication pin 21 and 20 pin of Arduino for I2C communication. Anemometer is also powered by 5V of Arduino and its data pin is connected to interrupt pin 18 of Arduino. For ESP8266 module is also powered by the 3.3V pin of the Arduino and its Tx and Rx pins are connected to interrupt pins 10 and 9 of Arduino for serial communication. All the connection for the sensors circuit as shown in Figure 2.

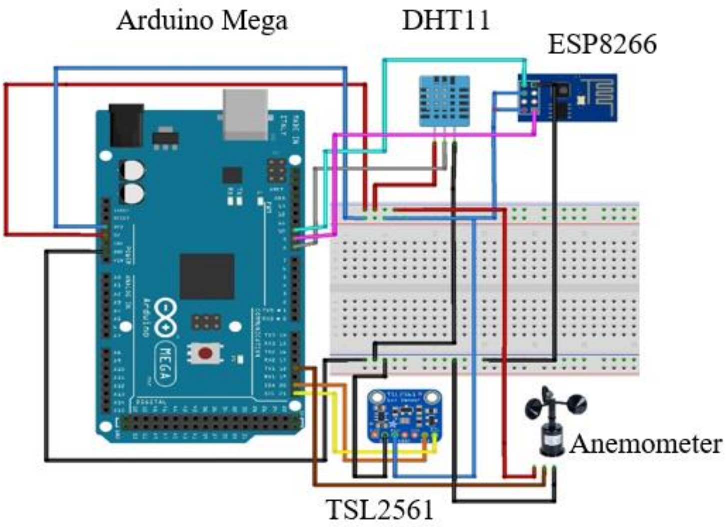
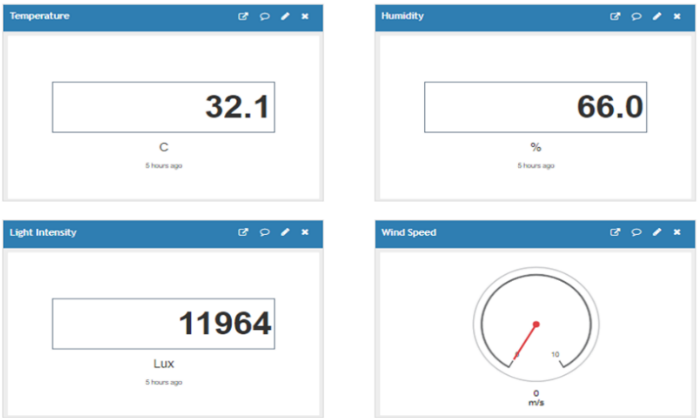


Figure 2: Sensors circuit

2.3 Data display on ThingSpeak

Figure 3 shows the example of the ThingSpeak interface where data display the parameter that has been collected by all the sensors. We have to create an account first for able to use the ThingSpeak. The graph shows the current environmental parameters against time. On ThingSpeak, it also allows user to add widget. This widget display the current value of parameter collected by the sensors.

(a) Graphical display



(b) Widget display

Figure 3: Data display on ThingSpeak

3. Results and Discussion

This section is discussing the result obtained from the experiment on the condition of the project. The test was performed in a total of 4 consecutive days for 10 hours. The site location is near at Enviro Lab.

3.1 Weather data analysis

The temperature and humidity have a relation, as shown in Figure 4. The humidity will decrease as the temperature rises. At 8.15 a.m., when the temperature is 23.98˚C, the highest humidity measured is 93.53%. The highest temperature recorded was at 3.00 p.m. with 33.58˚C when the humidity is 50.08%. Even if the temperature is nearly identical at 9 a.m. and 6 p.m., the humidity value is vastly different, with 70.67% at 9 a.m. and 64.20% at 6.00 p.m. This is due to the early dew, which raises the humidity level.

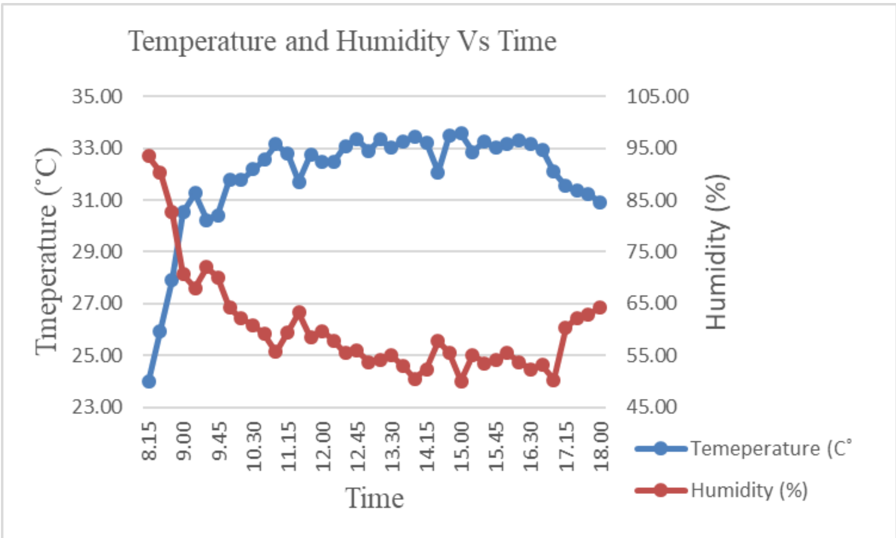


Figure 4: Average of temperature and humidity against time for 4 days

Based on Figure 5, the graph is quite difficult to interpret. This is because the light intensity sensor TSL2561 can only detect 40 000 Lux. If the sensor detects more than that, it will show the constant value which is 65 5536 Lux. However, it still can show the difference amount of light intensity when in the morning and in the evening. Between 10:00 a.m. and 5:00 p.m., the light intensity reaches its highest value. The lowest of light intensity is in the morning due to the position of the sunlight and the cloud pattern is plenty. The decreasing amount of light intensity is starting from 5.00p.m.

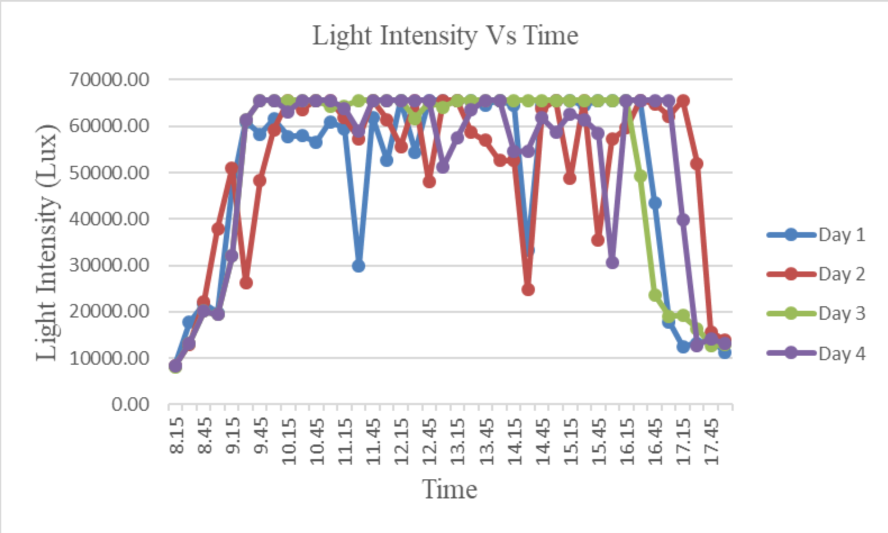


Figure 5: Light intensity against time for 4 days

Based on Figure 6, it can interpret that sometime wind speed can effect temperature and light intensity. For instance, when the wind speed is at 3.24m/s the temperature and light intensity is drop from 32.78˚C to 31.7˚C and from 62380.58 Lux to 52950.56 Lux respectively. However, when the fastest wind speed recorded was 4.08m/s, the value of temperature and light intensity were increased to 33.44˚C and 62289.20 Lux respectively. This prove that the wind speed is irrelevant to temperature and light intensity.

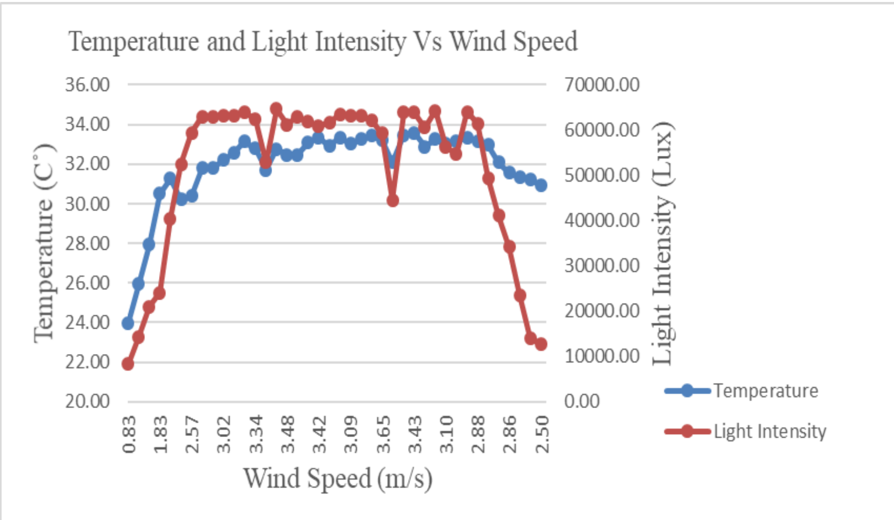


Figure 6: Average of temperature and light intensity against time for 4 days

3.2 Regression analysis of PV power against weather parameter

It can be observed from Figure 7 that the temperature has positive exponential relationship with PV Power. The highest PV power occurred when the temperature at 32.86˚C which is 59.62W. However, mostly the high value of PV power recorded when the temperature at around 33˚C. Moreover, the formula for PV power can be obtained in Eq 1.

$$PV_{avg} = 0.000001605e^{0.5164102743Tem_{avg}} \quad \textit{Eq. 1}$$

Where, PV_{avg} is the average PV power and Tem_{avg} is the average Temperature. The coefficient determination (R^2) is equal to 0.8041, which is close to 1. It has strong positive exponential relationship between temperature and PV Power where 80.41% of total variation in PV power can be explained by the exponential relationship with temperature.

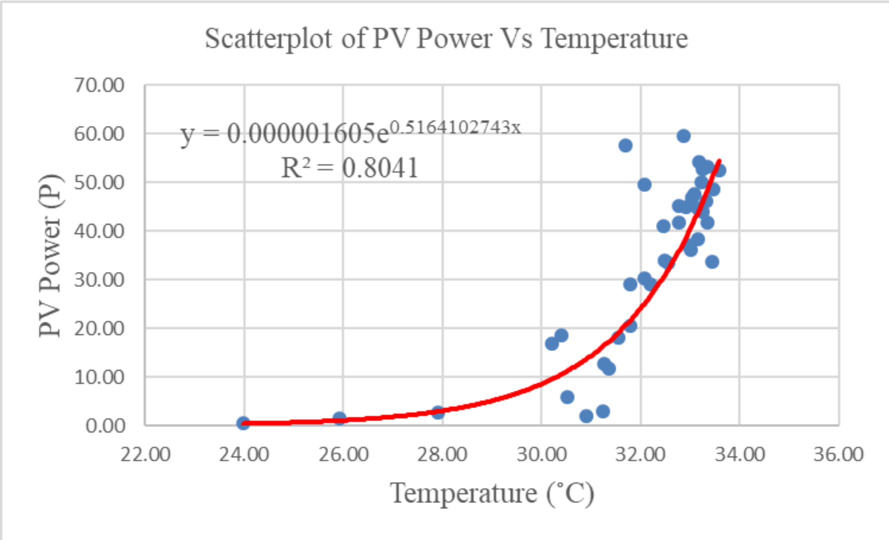


Figure 7: Scatterplot of average PV power vs temperature in 4 day

Based on Figure 8, it can be interpreting that when the humidity is low the PV power will increase. The highest PV power recorded was 59.62W, when the humidity at 55.09% and the lowest was 0.49W, when the humidity at 93.53%. PV power formula also can be calculated based on Eq 2.

$$PV_{avg} = 9676.98e^{-0.10H_{avg}} \qquad Eq. 2$$

Where H_{avg} is the average humidity. The $e^{-0.10H_{avg}}$ indicates negative correlation between PV power and humidity. The R^2 is equal to 0.74 which is not near to 1. It has nearly strong negative exponential relationship between humidity and PV power where 74% of total variation in PV power can be explained by the exponential relationship between humidity.

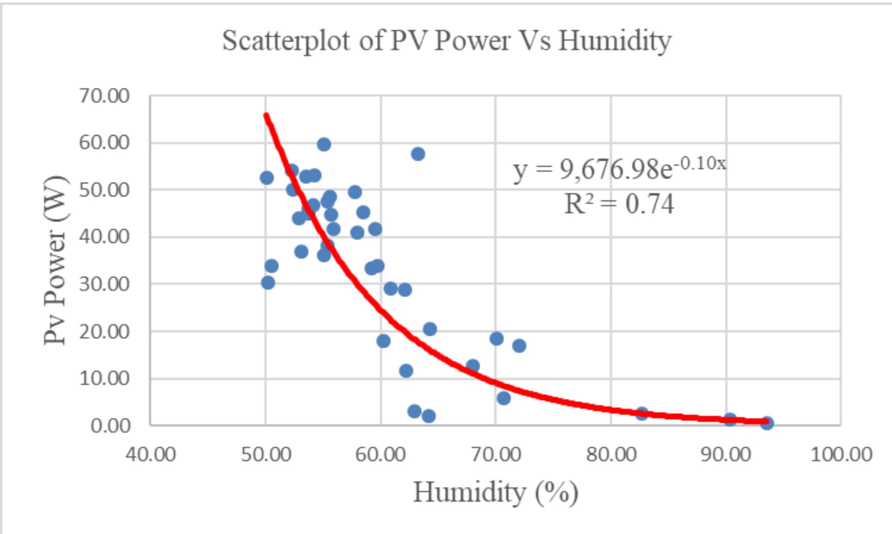


Figure 8: Scatterplot of average PV power vs humidity in 4 days

3.3 Forecast analysis

Based on Figure 9, the highest PV power recorded was 75.82W when the light intensity at 655536 Lux while, the lowest was 0.24W when the light intensity at 8173.37 Lux. The R^2 is equal to 0.58 and it indicates that PV power has weak correlation with light intensity. This is due to the error by light intensity sensor, TSL2561 that have been mention earlier. If the sensor can detect more light intensity, it surely can change the value of R^2. However, the equation of PV power can be obtained by Eq 3.

$$PV = 1.36348808e^{0.00005264Lux} \quad Eq. 3$$

Where the PV is the PV power and lux is the light intensity

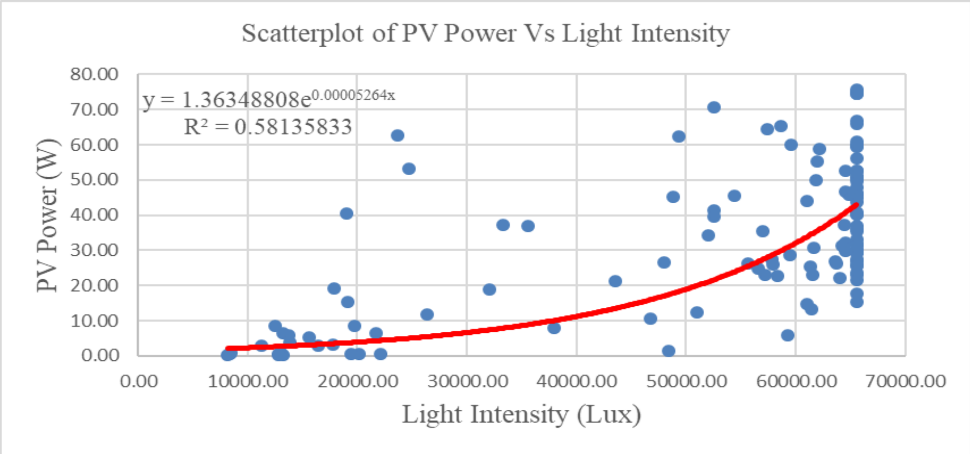


Figure 9: Scatterplot of PV power vs humidity in 3 day

Based on Eq 3, we want to forecast the value of the PV power on day 4 based on the light intensity that have been collected.

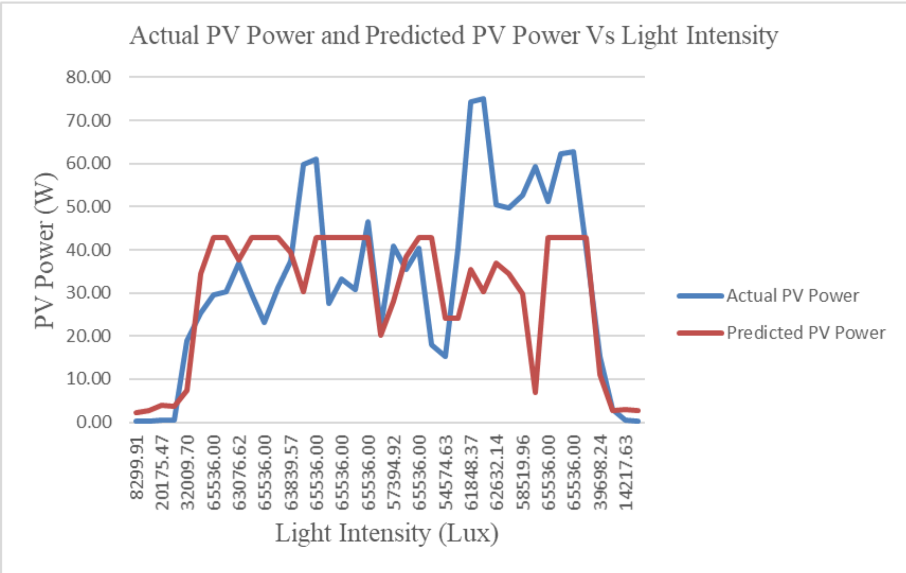


Figure 10: The actual PV power and predicted PV Power against light intensity

Figure 10 shows that the reading different is big between the two of it. This is because of the predicted PV power value is fix based on the equation while the actual PV power is depending on the current light intensity value and other environmental parameters as well.

4. Conclusion

In conclusion, we able to design and develop the an IoT enabled weather station using sensing technology. Moreover, we also able to analyze environmental parameters with PV output power. There are several graphical methods to analyze the data that have been collected such as using regression analysis to forecast the PV power. Every result and analysis obtained to prove that the environmental parameters can affect the PV Power (W). With regards to some limitations of the project, several improvements need to be considered for the future works which are use high-quality sensors to enhance the performance of the system and insert an SD card into the system. In the scenario of an internet problem, this can be used as a backup for the data collected by the sensors

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