



## Build and Implement Radiation Control using IoT in Parabolic Trough Solar Collector (PTSC)

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### HIGHLIGHTS

- The radiation intensity was controlled via the Internet of Things.
- The Internet of Things was used to overcome the limitation of distance.
- The Internet of Things was used to reduce efforts of long-time monitoring.

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### ABSTRACT

Connecting the devices to the internet based on the internet of things IoT increases the capability of monitoring and measuring, and controlling essential variables. In this study, the radiation intensity was controlled via the internet of things IoT for PTSC to study the collector's behavior. The light control circuit was designed, built, and implemented. The circuit mainly consists of a power supply, Arduino, relay, and potentiometer. Radiation was successfully monitored using a sensor and displayed through a smartphone via Wi-Fi, and the intensity of radiation light controls the PCM status. A data logging system was applied using a micro SD in a smartphone card and Arduino Node-MCU as a microcontroller. The experimental results show the relationship between solar radiation and resistance change. Inversely, the maximum radiation found from this work was 780 W/m<sup>2</sup> with 74 k  $\Omega$  resistance, and the minimum radiation was 300 W/m<sup>2</sup> with 170 k  $\Omega$  resistance. The output power changes directly through solar radiation, which means the power output with maximum solar radiation will be 3018 W. Using IoT Technology reduces efforts of long-time monitoring during the experiment (many hours)

## 1. Introduction

The Internet of Things (IoT) is related to the exchange of data between devices on available network infrastructure for monitoring and controlling the devices [1, 2]. The main idea of the parabolic trough collector (PTC) system is to polarize the sunlight and convert it into heat which can be directly utilized in many applications such as solar cookers, water pumping, and water heating [3]. Some researchers in IoT and PTCS systems were summarized in this section: Ranhotigamage et al. [4]. IoT is related to the exchange of data between devices on available network infrastructure for monitoring and controlling the devices. IoT is playing a crucial role in the daily life of humans by enabling the connectivity of many physical devices where the devices are intelligently linked together, enabling new kinds of communication between things and people and between things themselves to exchange the data. Mutlak [5]. Parabolic solar concentrators consist of a surface with high reflectivity of solar radiation. Günther [6]. The parabola collector takes the shape of a parabola to reflect solar radiation, which is parallel to the axis of the parabola trough collector and reflected about a set of points located on a single line called line focus. In the past few years, IoT has taken a vital key in the industrial field [7-9]. Al-Fuqaha et al. [10] An effective methodology and new cost based on IoT for remotely monitoring a solar photovoltaic plant to evaluate the performance. That would easy preventive maintenance, fault detection, historical analysis of the plant, and real-time monitoring. Adhya [11]. Four ways are used to control the change of solar radiation intensity (a light dimmer) device; it has the key to adjusting the solar radiation at the required value. Turn on external lights automatically by motion sensors when these sensors detect movement and switch off them later. Occupancy sensors detect internal movement within a particular region and timers. Rath.[12]. Designed an intelligent control photovoltaic system, while the third one to control the halogen lamp was an established control system. Primiceri et al. [13]. The system is implemented on an embedded platform & is equipped with a photosensitive detector (LDR) which provides the required input for operation. The working of our light control system is based on the amount of luminous energy in the environment at that moment in time. Depending upon the light intensity at that instant, the lighting of the lighting system is adjusted. The embedded mainboard, including the Microcontroller chip, memory (flash), and communication port, is used as a processing module for the

input from peripheral devices (LDR). Vargas [14] Once the device has been thoroughly reviewed, is up and running, and uploaded to the IoT cloud, it has become a repository of research results [15,19]. The authors used a Wireless Sensor Network (WSN) and the Message Queuing Telemetry Transport (MQTT) protocol to communicate between home appliances and track home devices. Haxhibeqiri et al. [16] The idea behind the IoT principle is to connect the sensors and devices of a unique system on a common network through wired or wireless nodes [17-19]. Developed an intelligent control system based on two Arduinos, other components, and a smartphone to adjust the strength of radiation using two methods: a potentiometer and Bluetooth on an Android-based smartphone [20]. The presented experiment is to record the temperature output from the Parabolic Solar Thermal Collector (indoor). It takes all day (sunshine until sunset) which is a long-time monitor. The aim is to simulate sunlight projected to Parabolic Solar Thermal Collector (PSTC) and adopt an intelligent radiation monitoring and controlling system based on IoT. Record and control the system's data by sending data wirelessly to the smartphone and computer at certain intervals to change radiation intensity.

## 2. Experimental Set-Up

The parabolic trough solar collector was designed with a double pass evacuated tube and was tested indoors. Two rows of halogen lamps were experimented with; each contains 6 lamps, so 12 halogen lamps were used, each of which has 500 W of rated capacity. The distance between one lamp to another is 13 cm, and the distance between the two rows is 25 cm. Thus, the height between the parabolic trough collector and halogen lamps is 150 cm to ensure direct and uniform solar radiation distribution across the device. The parabolic trough solar collector system consists of the reflector structure, the reflector, and the double pass evacuated tube. Water was used as a working fluid, as shown in Figure 1.

## 3. Monitor and Control System

The implantation components used in the proposed system to monitor and control are classified as hardware and software. The hardware items are a power supply, Node Mcu 8266, single-phase solid-state relay, Relays 5v, five variable resistors, jumper wires, and an assembly box. The software items are Android or IOS phone, Blynk application, and Wi-Fi network.

### 3.1 Hardware specifications and features

The main component used to implement the control circuit is as follows:

#### 3.1.1 Power supply

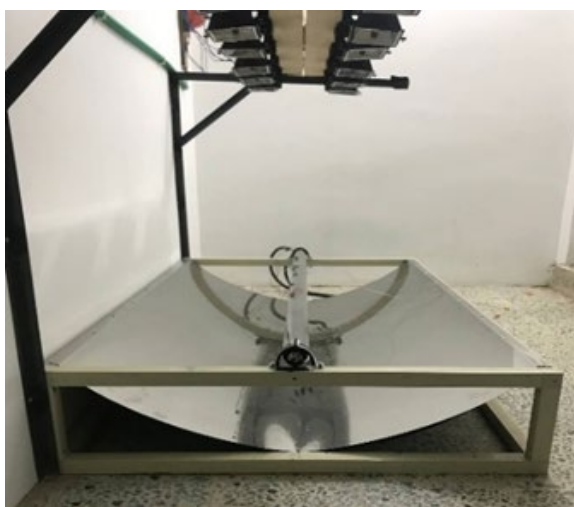
Power supply is an electrical device used to provide power to the loads, as shown in Figure 2.

#### 3.1.2 Node-MCU

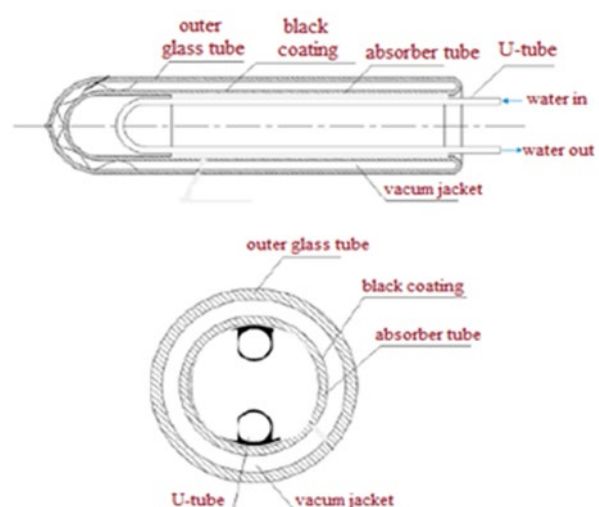
This item is an open-source-based firmware and development board particularly targeted for IOT-based Applications, as shown in Figure 3. Its specifications are listed in Table 1.

#### 3.1.3 Solid-state relay

MGR-R (Single Phase Potentiometer Type Voltage Regulator, Standard Package), A Solid-State Relay, is a relay with no moving contact. SSRs are not much different from mechanical relays with moving contacts in terms of functioning. However, SSRs use halving components like thyristors, triacs, diodes, and transistors. SSRs simply need a minimal quantity of electricity. That is why electric noise must be turned down as far as possible from the input terminals. Input terminals may be malfunctioned by noise. SSR is relays using the switching elements of the semi-conductor. The photocouplers are termed optical semi-conductors to separate the input and output signals [21], shown in Figure 4-a and the specification shown in Table 2. The module needs a heat sink. For cooling, the heat generated by the relay has to dissipate to improve its reliability and prevent the component from failing prematurely. Figure 4-b displays the used heat sink.



(a)



(b)

**Figure 1:** (a) Parabolic trough solar collector. (b)The schematic diagram of the tube used in the solar collector



Figure 2: Power supply

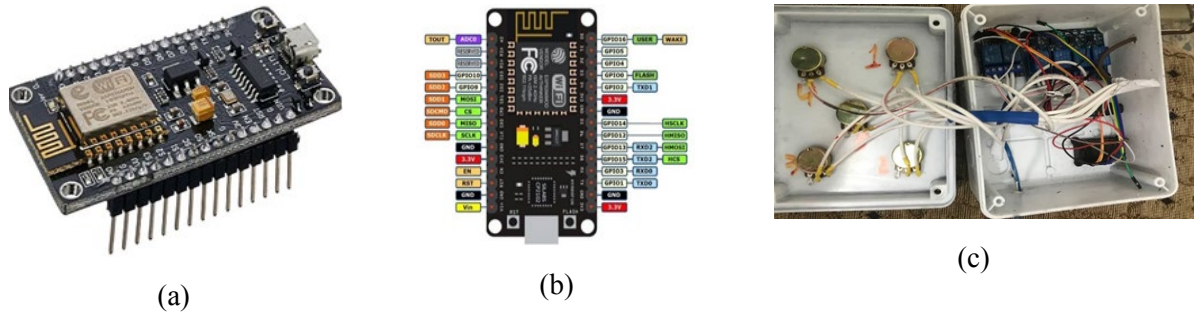


Figure 3: (a),(b) Circuit of Node-MCU ESP8266, (c)Arduino Node- MCU ESP8266

Table 1: Specification of Node-MCU ESP8266

Parameter	Specification
microcontroller	Tensilica 32-bit RISC CPU Xtensa LX 106
Input voltage	7-12V
Analog Input	1
Pins(ADS)	
SPIs	1
Flash memory	4MB
Clock Speed	80MHz
Antenna	PCB Antenna
Operating Voltage	3.3v
Digital I/O	16
Pins(DIO)	
UARTs	1
I2Cs	1
Size	Small-sized module to fit smartly inside your IoT projects

Table 2: Specification of Solid-state relay

Parameter	Specification
Control Method	Adjustable potentiometer
Current	60A
Frequency range	47-63
Operating voltage	0~220V AC

Table 3: Specification of Variable resistance

Parameter	Specification
Resistance selection	KΩ
Resistance	500 KΩ
Power rating	2 W

Table 4: Specification of Relay 6 Channel

Parameter	Specification
Relay Maximum Output	30V/10A, AC 250V/10A
Low-level Trigger expansion board	5 V
Module board	138 56 mm

### 3.1.4 Variable resistance

The variable resistor potentiometer contains three sides, shown in Figure 5 and the specification in Table 3.

### 3.1.5 Relay

This item consists of 6 channels, as shown in Figure 6. Its specifications are listed in Table 4.

## 3.2 Radiation control method

The intensity of the bulb's radiation is controlled using the dimmer (variable resistance). Since we have to obtain five values of the intensity of the radiation, five variable resistances are adjusted. The basic idea is to move from one resistance to another. We used the AC relay type 6 Channels, for each time to connect a resistance and separate the other four, the signal is taken from the Arduino micro-control. Set an hour between every intensity. After each moving from one intensity to another, the data is sent to an application on the mobile for system monitoring. First, the data was sent via the Wi-Fi network to the Android application. The node microcontroller contains a built-in Wi-Fi chip. When the system starts up, the connection is made to the local Wi-Fi network that enters it into the code. Then the data is sent to the Blynk platform, which will send it to the mobile application through the authorization code.

## 3.2 Experimental control procedure

1. Connect relay pins to Arduino pins
2. Connect the potentiometers mid pin to AC relay on COM
3. Connect the Normally Open AC relay to the solid-state relay
4. Connect the other side of potentiometers to the solid-state relay
5. Connect the line of the AC power supply to the load side of the solid-state relay
6. Connect the other pin of the solid-state (@load side) relay to the load
7. Connect the neutral from the AC power supply to the load
8. The power supply for each part is 3.3V for Node Mcu and 5v for AC Relay, as shown in Figure 7.
9. An Arduino code was written for the specific control circuit.

## 3.3 Software specifications and features

### 3.3.1 Node-MCU Software:

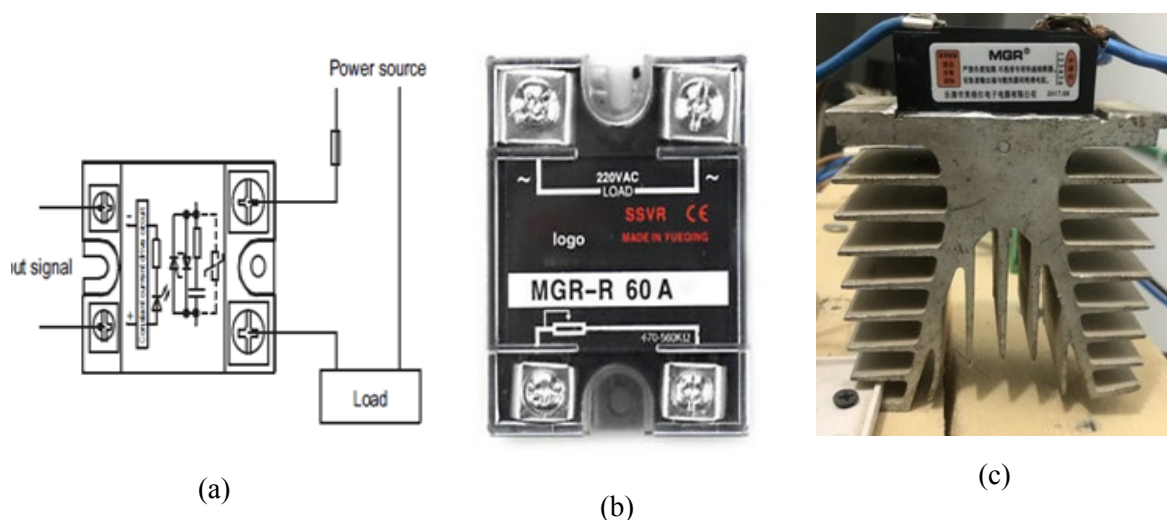
To program the microcontroller and enable it to connect to the internet for monitoring the light intensity, Figure 8 presents the developed code flowchart for the microcontroller.

After uploading the code to the Node-MCU (Arduino), the following procedure takes place:

1. The system started with the first intensity, and after one hour, it moved to another, and so on.
2. At the same time, we receive the intensity data on the mobile app, as shown in Figure 9-a.
3. If the system has a defect, we notice the alarm mark on the screen, as shown in Figure 9-b.

### 3.3.2 The Queuing Telemetry Transport protocol diagram (MQTT)

This protocol is designed for usage in restricted settings because of its simplicity and minimal overhead [22]. Figure 10 shows the Queuing Telemetry Transport protocol diagram (MQTT), and Figure 11 shows the schematic diagram of the system.



**Figure 4:** (a) Description circuit of Solid state relay,(b) Solid state relay,(c) Solid state relay with heat sink

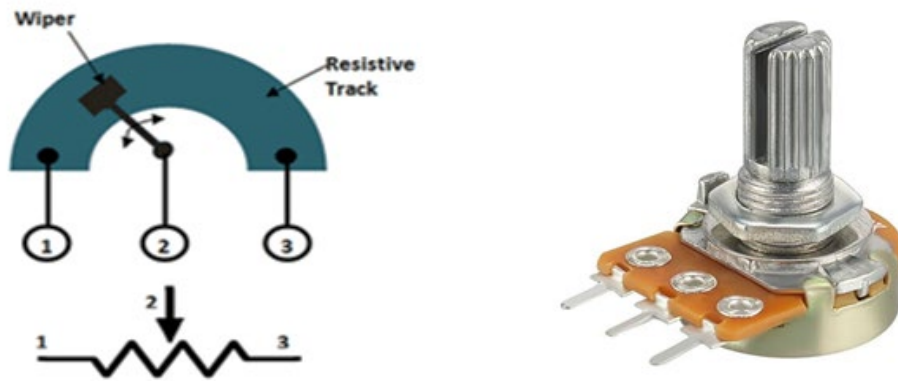


Figure 5: Variable resistance

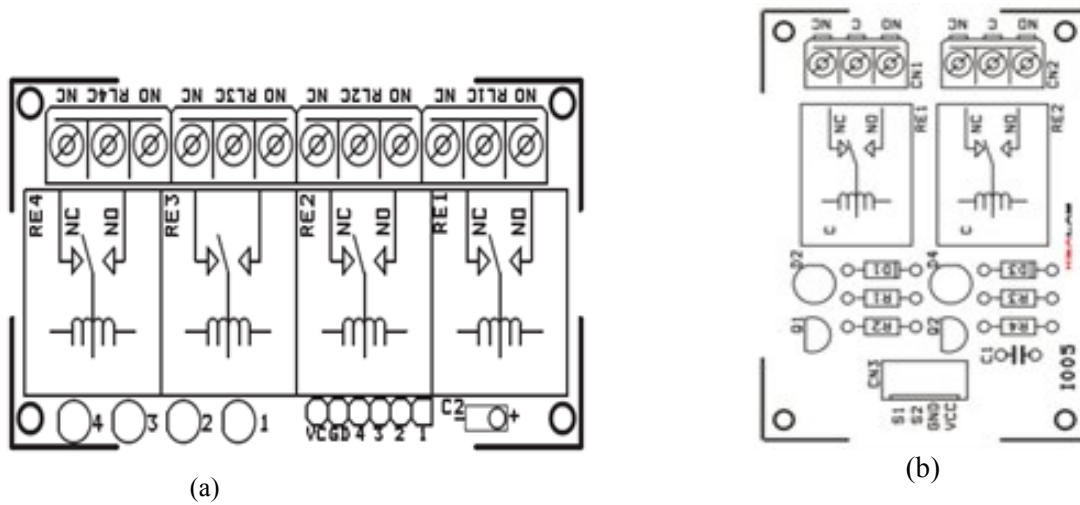


Figure 6: (a),(b) Description circuit of Relay 6 channels

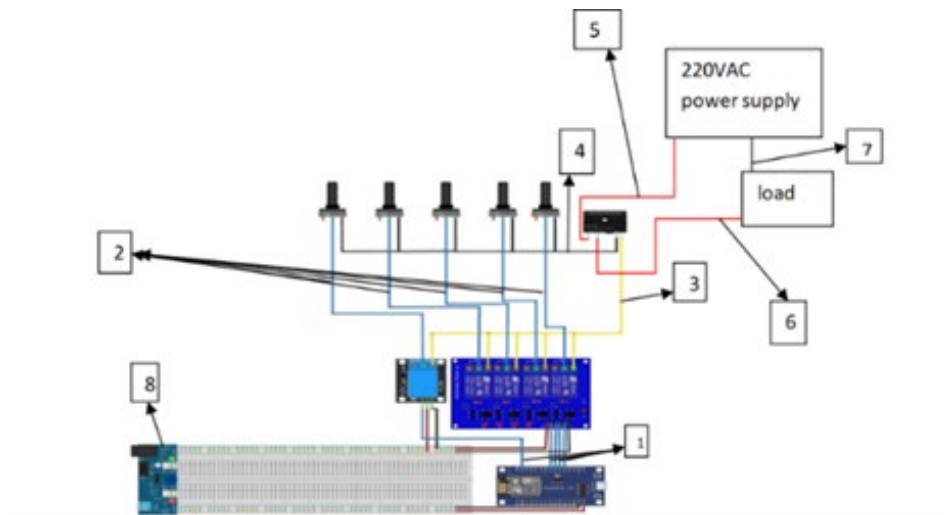


Figure 7: Control circuit connection

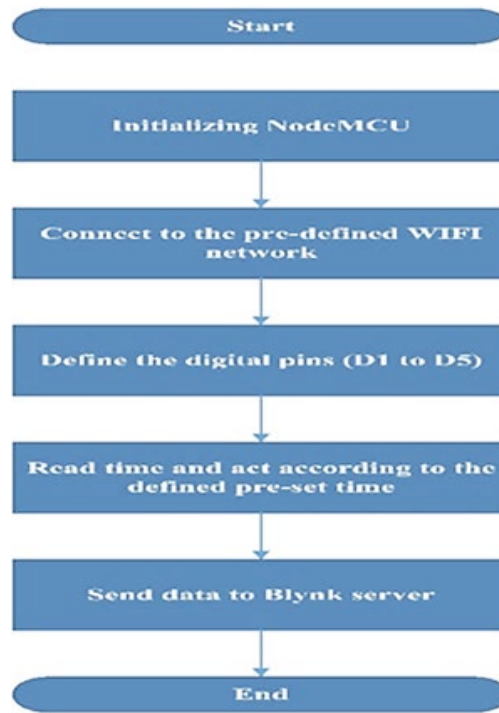


Figure 8: Node-MCU program flowchart

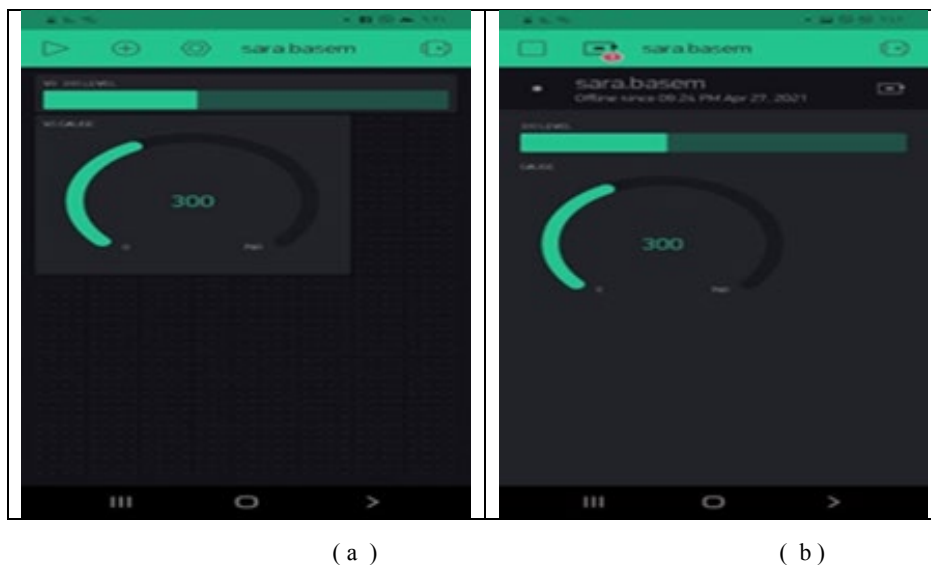


Figure 9: a: Data on the mobile app b: Alarm mark on the screen

## 4. Measurement Devices

### 4.1 Solar power meter

Solar power meter is used to measure the amount of light that enters the curved surface through a solar collector from lights. The device has a one-second reaction time and measures radiation strength from 0 to 2000 W/m<sup>2</sup>, as shown in Figure 12-a.

### 4.2 Digital power clamp meter

Digital power clamp meter multi-purpose electronic device used to measure voltage, current, and resistance, as shown in Figure 12-b.

## 5. Calculation of the Output Power

The output power is calculated for each time radiation intensity changes using Eq. (1):

$$P_o = I * V \quad (1)$$

Where: P<sub>o</sub>: is output power in (W), I is the current (A), and V is the voltage (V).

### 6. Results and Discussion

The process of recording the measured data was remotely sent to the connected devices (mobile , computer ) base on the circuit in Figure (11) automatically. The elapsed time to record these data was approximately 15 hours/day last for 30 days (the intensity of light was changing every hour during the day). That would be a long time to monitor the experiment, and this control circuit abbreviate hours of sitting and monitoring manually. The data were measured (current, voltage, resistance, heat flux) and plotted in the Figures below, considering that radiation control was based on wireless connection. Figure (13) illustrates the variation of the resistance with heat flux, when resistance decreased, heat flux increases. Figure (14) display the voltage increased, the heat flux increases. As long as the voltage is directly proportional to the current, the current increase cause increasing in the heat flux, as shown in Figure (15). Because of the power results from multiplying voltage with current, when the power is increased, this increases radiation, as seen in Figure (16). When increasing the resistance, that led to decrease the current and voltage as seen in Figure (17).

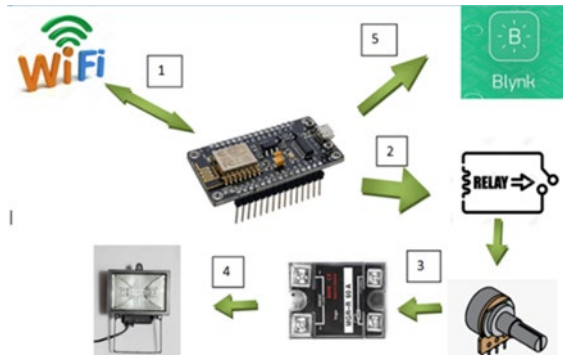


Figure 10: MQTT diagram

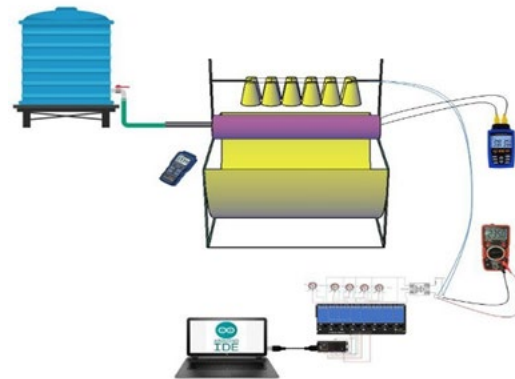


Figure 11: Schematic diagram of the system



(a)



(b)

Figure 12: (a) Solar power meter (b) Digital power clamp meter

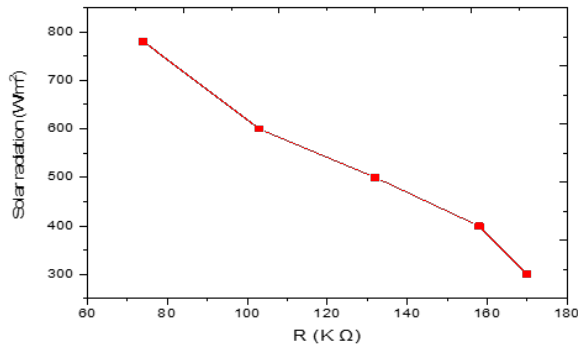


Figure 13: The variation of resistance and solar radiation

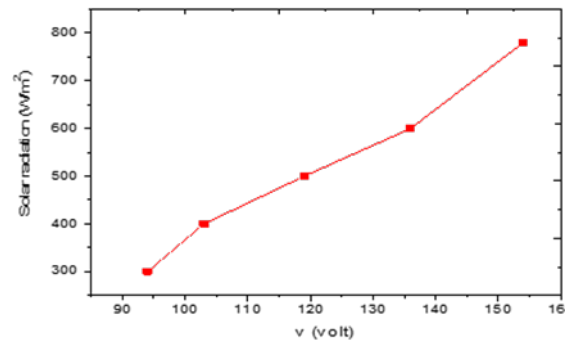


Figure 14: The variation of the voltage and solar radiation

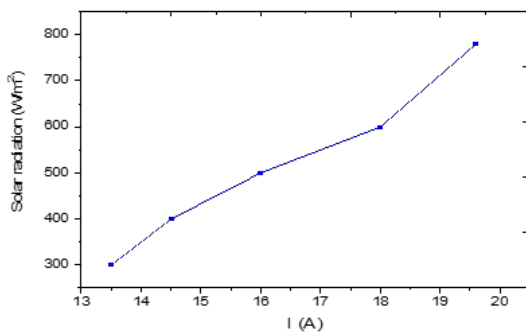


Figure 15: Variation between current and solar radiation

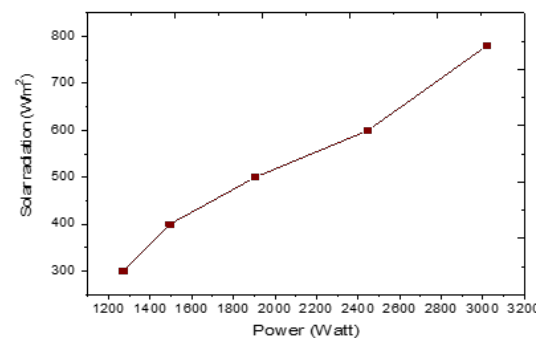


Figure 16: The behaviour of the resistance and current

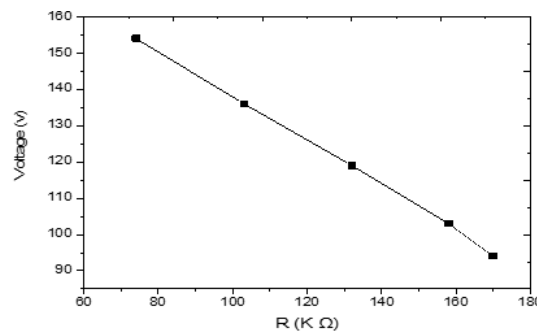


Figure 17: Variation between the voltage and resistance

## 7. Conclusion

The proposed control circuit is used to control circuit was built and implemented based on IoT to overcome the limitation of distance and record data (only display). The radiation was controlled during the experiment for parabolic trough solar collectors with double pass water passage tube based on IoT. Using IoT Technology reduces efforts of long-time monitoring during the experiment (many hours), where the control circuit adjusts the radiation and automatically recoded the data sent to the application in the smartphone. These data were used to obtain suitable radiation for the work. The solar radiation decreased resistance, while the power output increased with solar radiation increasing. The maximum solar radiation obtained from this work reached 780 W/m<sup>2</sup> with 74 k Ω resistance, while the minimum solar radiation was 300 W/m<sup>2</sup> with 170 k Ω resistance

### Future Work

This work would be more reliable if the data collected from the control circuit is stored in a Google cloud so that the data will be reachable and available on any smart device.

### Author contribution

All authors contributed equally to this work.

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### Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

### Conflicts of interest

The authors declare that there is no conflict of interest.



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