Wasit Journal of Engineering Sciences

Journal homepage: https://ejuow.uowasit.edu.iq

Enhancing the Efficiency of Solar Cell by using Internet of Things Applications

Mohammed Hassan Majhool[1,a,], Haider Th. Salim AL Rikabi [1,b], and Mansour S. Farhan[1,c]

Affiliations
[1]Electrical Engineering Department, Wasit University, Wasit, Iraq

Correspondence
[a]mhsn32645@gmail.com
[b]hdhiyab@uowasit.edu.iq
[c]mansour@uowasit.edu.iq

Received
28-October-2021
Revised
28-December-2021
Accepted
11-January-2022

Doi: 10.31185/ejuow.Vol10.Iss1.229

Abstract

The IoT is an essential for monitoring and controlling in real-time to reduce human efforts and time. This technique has been used by connecting the devices and sensors with the internet. In this proposed study, the prototype as a sample PV panel was used because it is an active element to produce power of low-cost effect, easy maintenance, easy installation, and encouraging large-scale solar photovoltaic installations. This massive scale of solar photovoltaic deployment requires sophisticated systems to automate the plant monitoring remotely using web-based interfaces. Most of them are installed in inaccessible locations and thus unable to be monitored from a dedicated location. The discussion in this paper is built based on the implementation of a new cost-effective methodology based on IoT to remotely monitor a solar photovoltaic plant for performance evaluation. This method facilitates preventive maintenance, fault detection, historical analysis of the PV panel as well as real-time monitoring. In this paper, two parameters were studied. Firstly, the sensors of dust and LDRs. Secondly, the fault detection for monitoring and controlling. The performance showed an approach of 50% than the dusty panel. The results showed a better response and accurate information which approach 90% using fault detection

Keywords: Solar cell, Detect and Identify Faults, Remote Monitoring, Firebase Platform IoT, ESP8266,ESP32

الخلاصة : يعتبر إنترنت الأشياء عنصر أساسي للمراقبة والتحكم عن بعد نتيجة التطور الحاصل في الهندسة ولغرض تقليل الوقت والجهد استخدمت هذه التقنية بواسطة ربط الأجهزة والمستشعرات عبر الإنترنت. في الدراسة المقترحة، الخلايا الشمسية نموذجا كونها عنصر حيوي وفعال وسد العجز الحاصل بالإنتاج، الخلايا الشمسية رخيصة الكلفة وسهلة الصيانة وسريعة النصب وبالأخص الدول النامية تحتاج لربط هكذا نوع من المنظومات. تتضمن الرسالة عدة محاور بخصوص دراسة اللوح الشمسي ، التطرق الى طريقة لتحسين أنتاجية اللوح الشمسي، نظرا لزيادة الغبار المتراكم في الاجواء العراقية، اقترحنا نظام لزيادة الانتاجية الكهربائية المتولدة من اللوح الشمسي كون الغبار يؤثر سلبا على أداء الخلية الشمسية. بعد اجراء عدة تجارب موقعية اقترحنا نظام يعمل على كشف الغبار المتراكم وطريقة تنظيفة ، تبين الحصول على 50% نسبة أداء أعلى من اللوح المتسخ. نفذنا نموذجين لهذا النظام، أحدهما يعتمد على كمية الغبار (كثافة الغبار الساقط من الجو على اللوح الشمسي) بعد معايرة الانتاجية مع البرنامج المصمم على الحساس المستخدم، بعد تنفيذ عدة تجارب موقعية تبين قدرة الحساس على قياس كثافة الغبار المتراكم والساقط من الجو. النموذج الاخير، يعتمد على المقارنة بين قيم المقاومات الضوئية المثبتة على اللوح الشمسي التي تم استخدامها في عملية التعقب الشمسي ومقارنتها مع الفولتية الناتجة من اللوح الشمسي، أظهرت النتائج بأن الاخير أكثر كفاءة ودقة وسرعة استجابة من أستخدام حساس الغبار. المقترح التصميمي الاخير يعتمد على دراسة كشف الاعطال المحتملة، أظهرت النتائج المختبرية الحصول على أداء أستجابة ودقة المعلومات بحدود 90% لمعرفة نوع العطل وعرض قيم الفولتية والتيار والاشعاع الشمسي ومقارنتها مع القدرة المتولدة من اللوح الشمسي .

1. INTRODUCTION

Electricity stands for high binding energy in human life. The consumption of energy is increasing daily and dramatically, while energy resources are decreasing. To manage the shortage of electricity, many sources are used to produce electricity [1]. There are two methods to generate electricity: the first method is the traditional method, and the other is the unconventional method. Besides, fossil and nuclear fuels generate electrical energy, but they are not unconventional [2]. Sustainable energy sources can be attained by using a solar energy source. Solar energy has been widely employed all over the world. Sunlight has been used to produce energy for billions of years. Sunlight can act as a significant source of electricity produced by transforming it into electrical energy [3, 4]. This application is known as solar thermal energy, and it is conservative. Many ecological sources are presented, such as tides, rain, wind, geothermal energy, natural biofuels, and traditional biomass.

Solar energy has enormous advantages. Nowadays, frequent power outages are very communal in Iraq. So, it is essential to investigate renewable energy. The rapid growth of renewable energy requests has been enabled by the steep reduction in cost over the past decades and produced an effective change in its stable productivity, quality, and life. Photovoltaic cells are used in solar power plants that convert sunlight directly into electrical energy when it falls on them. These solar panels are connected to batteries, store electrical energy, and supply them to homes, manufacturing plants, and educational institutions. Several solar plants are built in direct range and readily available, but others are constructed in sites that individuals cannot regularly visit to monitor plant operation [5]. In [6, 7], researchers proposed a real-time intelligent monitoring system of current and voltages. ZIGBEE technology transfers data upon the application program interface, providing the user with communication between the solar panels and the computer and connected microcontroller type microcontroller center unit MCU18F4620 to connect the sensor nodes. They studied energy efficiency improvement by IOT monitoring. A comparison was made between manual data recording and the embedded systems and displayed on the interface. ESP32 was employed to upload monitoring data to a cloud and display data in the Android application (BLYNK) [8, 9]. In [10], tracking the power plant has been investigated, allowing for easy analysis of the current status of the solar system. The advantage of analysis is that it affects locating or detecting potential system faults while checking the output from different angles. The amount of generated energy is constantly monitored and updated on the server. As the world's renewable resources become scarce, every country is turning to solar systems. Scientists are working to improve their efficiency.

Ponmagal et al.[11], discussed the work of a photovoltaic cell in detail to present the solar system to meet the ever-growing technological advancements. In [12, 13], they suggested a system for monitoring weather changes using IoT to easily access real-time data over a wide range. The system monitors weather, climate changes and transmits data to the web page. Device architecture consists of Arduino UNO, Node MCU, LDR, CO sensor, ML8511, Raspberry pi, and Android application. Arduino UNO is used as the main processing unit for the whole system of Ubidots. The platform design is based on IoT in a solar tracker. The solar cell produced the most power when the sun was as perpendicular to its surface as possible; the platform also uses WiFi to send data to a remote station. The Raspberry Pi3 (RPi3) connects the solar array tracker system [14]. They studied a dust detection system, including a light-dependent resistor (LDR) sensor and a Node Microcontroller Center Unit (MCU). Solar power plants should be checked regularly to ensure maximum output. The parameters in this proposed paper's system are controlled by an AT mega controller. This system continuously monitors solar plant performance and accesses data to the cloud [15]. A mechanism was suggested to show the maximum power generation using a solar tracking system, display its results and monitor using the thing speak platform. The LDR sensor is connected to a Node MCU, which compares the display results and output of the solar panel in dual-axis conditions [16].

The work in [17-19], represented the main motivation for this review to monitor every solar photovoltaic system and understand its current state, as monitoring is critical for performance evaluation. The plant's performance, monitoring, and maintenance will be greatly improved by observing solar photovoltaic plants using IoT-based technology. This will make historical plant analysis, real-time monitoring, and solar panel control easier and assist with power generation by automatically setting the equipment to exploit sunlight as maximum as possible. Solar panels automatically change direction when light intensity decreases, ensuring that solar energy conversion efficiency improve. Consequently, automation and intellectualization of solar power plant monitoring and controlling will enrich future decision-making for a large-scale solar plant and grid integration of such plants. This study proposes effective IoT-based solar power consumption and monitoring system that allows users to screen the activities of these solar plants from afar. Solar plants should be checked regularly to ensure functioning properly. The Node MCU microcontroller is used as the system's mainboard, which consumes electricity throughout the system and then uploads these parameters to the cloud for storing and communicating real-time statistics using Asksensor cloud services. The developed prototype that is much more adapted to remote locations (PV systems installed in Saharian regions) has been reported [20, 21]. The prototype enables its customers to supervise and check the deployment from any place at any time. The recognition method's big problem is that it cannot differentiate among problems with similar problems or characteristics (such as different types of shading, dust accumulation). Using more powerful techniques that can differentiate between problems with the same characteristic and make a clear conclusion, this work may be enhanced and expanded for fault detection of solar systems. Calibration of the technique for large-scale PV modules and positioning problems should be included. The previous works also focus on monitoring systems and collecting the data in a database to store it. In all of the above cases, it is noted that the IoT proves its efficiency day after day. However, this research will focus on another aspect of the IoT when using IoT applications in solar systems.

2. SYSTEM DESIGN AND EXPERIMENRAL SETUP

The method incorporates constant monitoring of all the solar panel's energy generation. The microcontroller type ESP32 & ESP8266 attached to the sensor is sensitive to the environmental conditions and processes. Furthermore, to assist in wireless data transmission, it has a WiFi module. All these parameters are automatically uploaded to the server. A simplified block diagram about this concern is depicted in figure 1, which shows the integrated microcontroller with all required sensors and statistical data. There are four sensors connected with a microcontroller that senses different factors affecting the whole system.

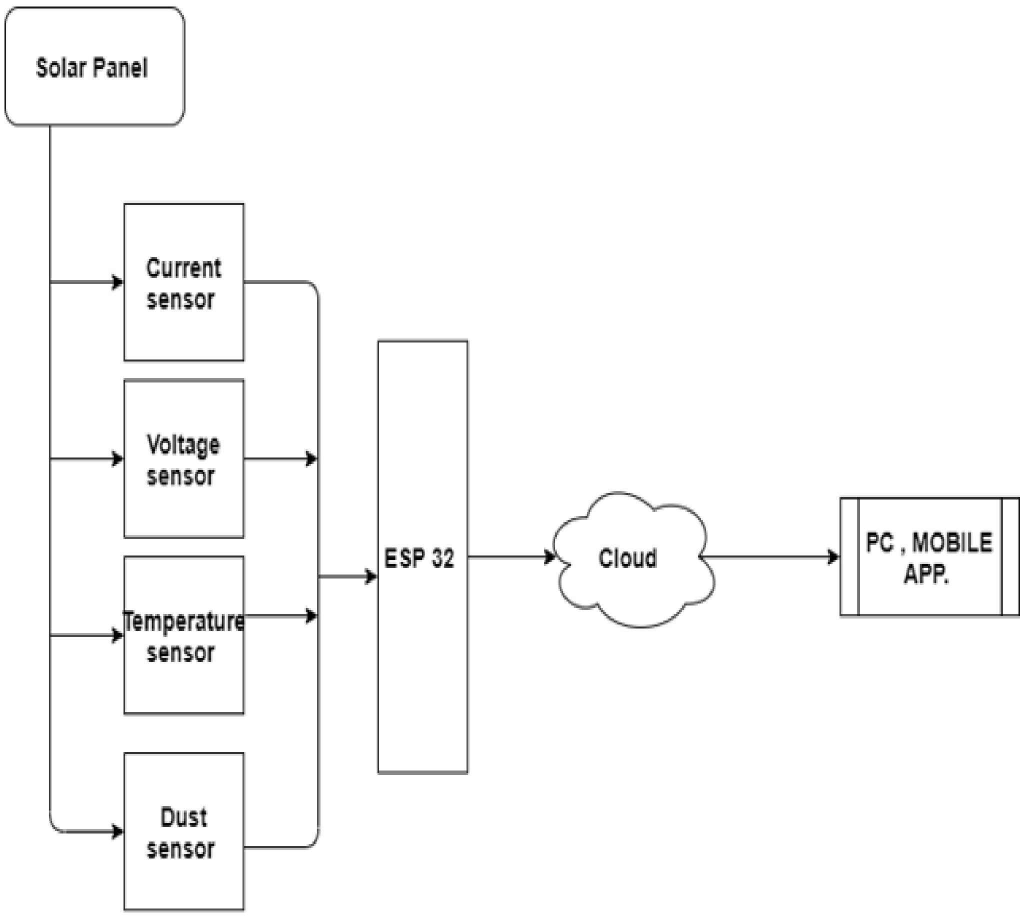

Figure 1. Block diagram of IOT-based solar power consumption and monitoring system

Figure 2 depicts a flowchart describing an entire system's process. First, the ESP32 and ESP8266 are initiated, and then an internet connection is established. If a connection is established successfully, the system will last in operation. Otherwise, the system shows an error message. Next, the input from the solar panel is taken, the sensors attached to the panel access input and pass it to the ESP32 and ESP8266 microcontrollers after a successful internet connection is made. Finally, the primary data is managed by microcontrollers and then transferred to a cloud. These parameters are stored in a cloud, and users can access them through a web browser. The proposed approach circuit diagram shows how the system is integrated as in figure 3. Four sensors are connected to the ESP32, ESP8266 node MCU, including voltage, current, temperature, and humidity.

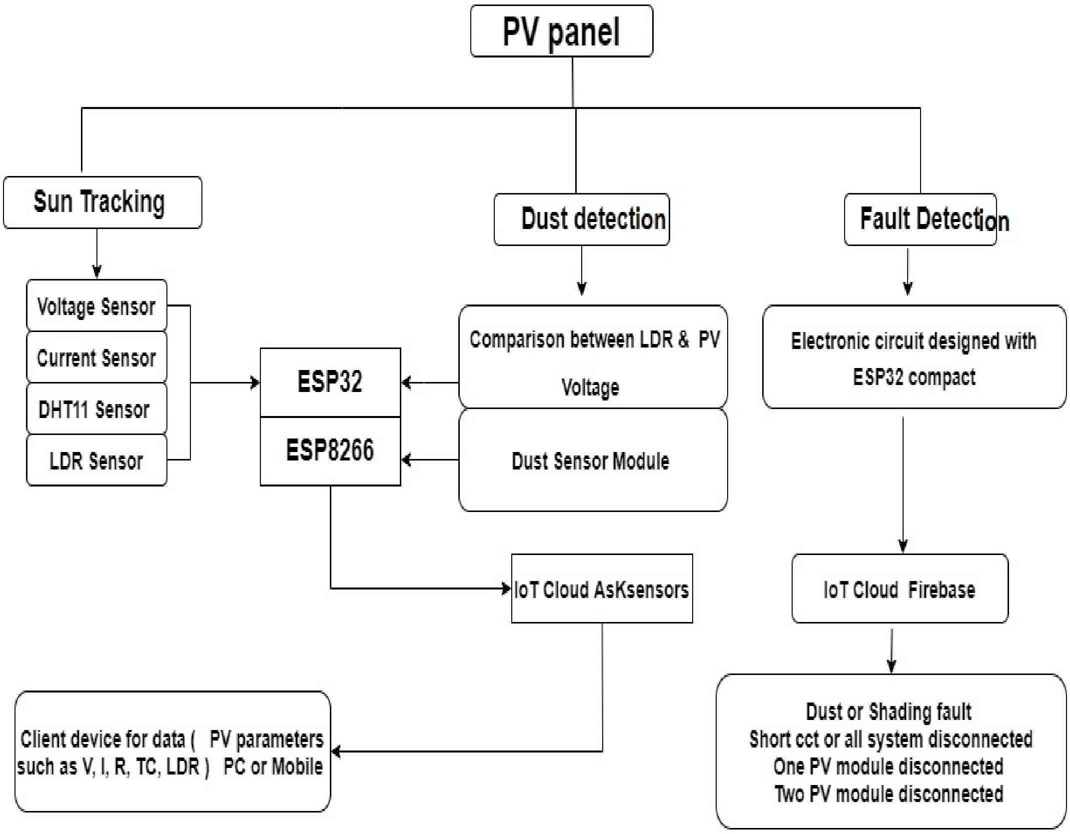

Figure 2. Flowchart describing an entire system's process

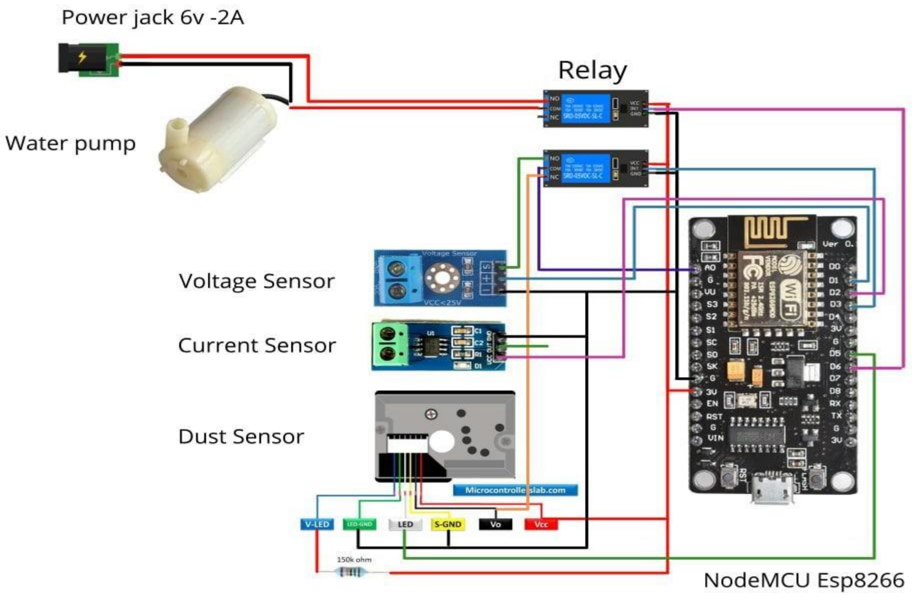

Figure 3. Circuit diagram (voltage, current, and dust sensors)

3. HARDWARE COMPONENTS

For building a prototype of the interconnected system, the following components are used:

3.1.ESP8266 Board

The Shanghai-based Chinese manufacturer Espressif Systems stands for a cost-effective WiFi microchip with a complete TCP/IP stack and Microcontroller. Western manufacturers brought up the first chip in August 2014 using the SP-01 Module produced by Ai-Thinker, a third-party company. The Microcontroller ESP8266EX integrates a 32-bit A reduced instruction set computer RISC processor with TensilicaL106, which delivers extra-low power consumption and a clock speed of a maximum 160MHz. In addition, ROS and WiFi stacks enable consumer programming and development to achieve around 20 percent of the processing capacity [22], as shown in Fig. 4.

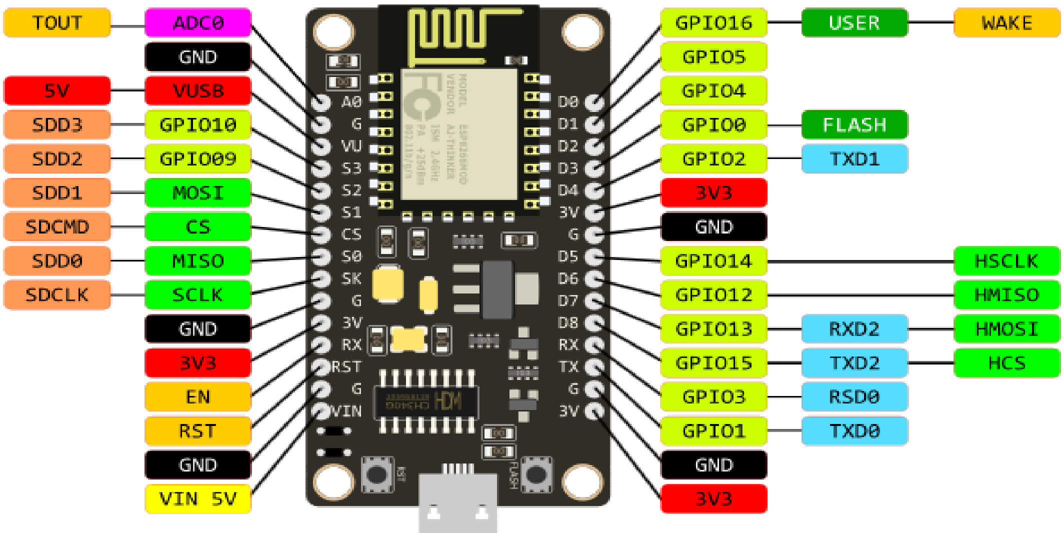

Figure 4. ESP8266 board [22]

3.2.Node MCU

Node MCU stands for open IoT platform source. It consists of firmware on the Espressif Systems ESP8266Wi-Fi module and hardware on the ESP-12 Module. By default, the term "Node MCU" does not refer to dev—kits but the firmware. Node MCU firmware was developed to make it easier for AT commands to be replaced by Lua scripts. Therefore, using AT commands in the MCU node again would be redundant, as shown in Fig. 5[23].

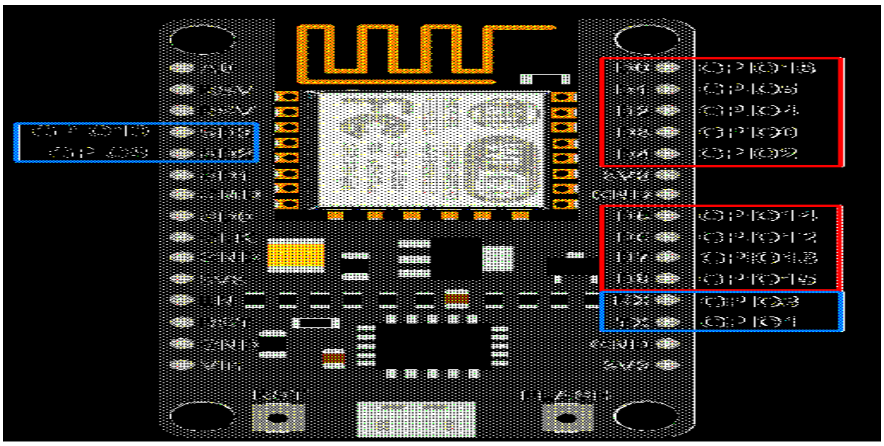

Figure 5. Node MCU GPIO[23]

3.3.Microcontroller ESP32S

The ESP32 is a powerful, integrated WiFi, a full TCP/IP stack, along with Bluetooth 4.2. Due to the low cost, great power, and connectivity, the ESP32 is ideal for IoT development. Furthermore, this chip was chosen because it decreases the charge of the checking system with high treating performances. ESP32 board based on Tensilica 32 - bit LX56 microprocessor, and dual core CPU Xtensa[24].

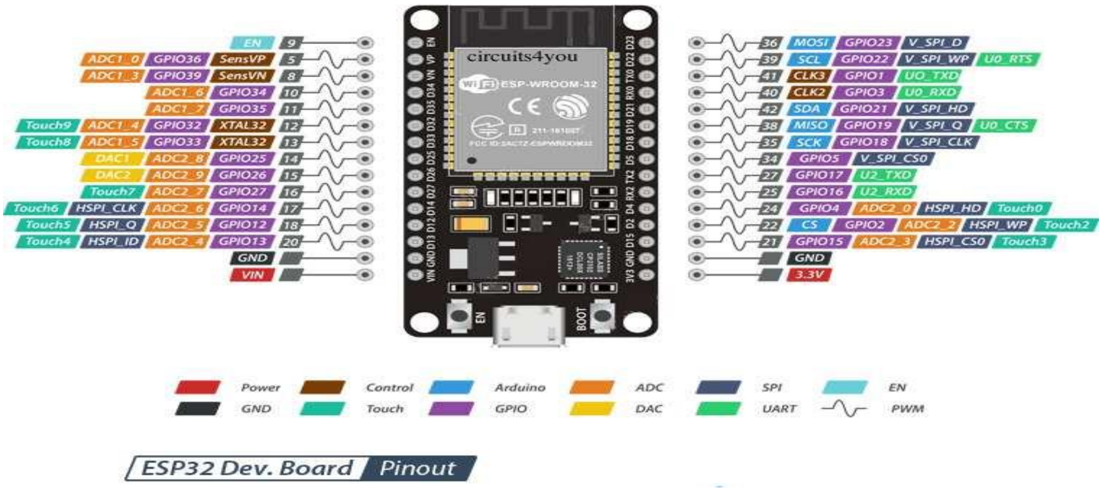

Figure 6. ESP32S board used as a controller[24]

3.4.Current Sensor

It is a device that senses the electrical current that passes through all materials and produces signals that are identical to the electrical current. This can be a digital or an analog signal. For example, an ammeter can measure the current movements, as shown in Fig. 7.

Figure 7. Current Sensor[25]

3.5.Voltage Sensor

This Module converts a circuit's voltage to a physical signal. The voltage diﬀerence of dual points can be evaluated to use this physical signal, as shown in Fig. 8.

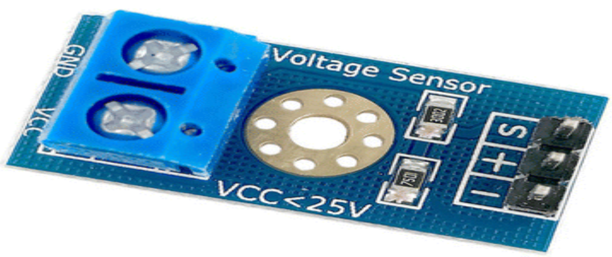

Figure 8. Voltage sensor [26]

3.6.Temperature and Humidity Sensor DHT11

The DHT11 represents a low profile and inexpensive digital sensor, as shown in Fig. 9. Humidity is measured based on a capacitive sensor and a thermistor (no analog input pins required). User libraries are easy to use, but you must be on your toes at all times to acquire data.

Figure 9. DHT11[27]

3.7.Solar Panel

Solar energy is a group of photovoltaic cells that generate electricity from sunlight and convert light into electricity from the sun in an industrial area, domestic, and street lights. They are wide applications of solar panels.

Specifications:

Peak Power (P max	10W
Voltage (V max.)	17.8 V
Current (I max.)	0.56 A
Short circuit current (I sc.)	0.6 A
Open circuit voltage (V oc.)	21.6 V

3.8.Dust sensor (GP2Y1010AU0F module)

Sharp's GP2Y1014AU0F physical air pollution dust sensor has a six-pin analog output and is equipped to detect dust particles in the air. It is widely used in air purifier systems and it operates on the theory of Laser Propagation. It is instrumental in detecting tiny particles such as smoking. An ambient emitting diode and a phototransistor make up this sensor. It needs a nominal 4.5V to 5.5V DC supply voltage to operate. It does, however, operate with a 5.0V DC voltage and a maximum current of 20mA. The detector emits current proportional to the sum of observed light, and the system outputs analog voltage after the amplification circuit amplifies the current from the sensor. The trigger push of the LED on the GP2Y1010AU0F needs a resistor and a capacitor. The analog voltage received as an output from the unit is calculated using the analog pin on the NodeMCU microcontroller and then it is used to calculate the voltage. Any analog pin can distinguish voltages between number qualities ranging from 0 to 1023, which can be traced back to a "real" voltage value. Three equations were used to represent that scenario, as shown in figure 10 [28].

$$Vol\ analoug = voltage\ measure\ A_o \tag{1}$$

$$Claculated.Vol = Vol\ analog(5/1024) \tag{2}$$

$$Density\ of\ dust = 0.17 * Calculated.Vol - 0.1 \tag{3}$$

The analog value from the dust sensor is recorded. The water pump is enabled when the average dust density amount reaches the fixed threshold value.

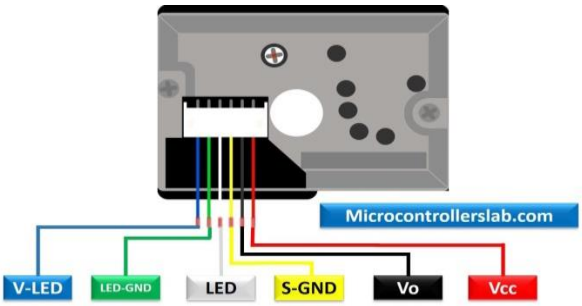

Figure 10. Dust Sensor Module

4. MONITORING AND CONTROLLING FAULT DETECTION AND IDENTIFICATIONIN A SOLAR CELL

In this work, as figures (11) show, a prototype of intelligent monitoring and defect detection device for the solar panel was constructed utilizing the Internet of Things (IoT) technique. An electronic panel linked to the internet was constructed and put in place to check the information acquired from the solar system (current, voltage, temperature, and solar radiation). The circuit has been constructed with several mechanisms to detect various problems, including open circuits and shorts effects. This research discovered that the proposed system could identify faults in real-time using a graphical interface GUI based on the FIREBASE platform to automatically manage the operation of the implemented relays in the executing circuit. The proposed design method, straightforward for adoption, low cost, rapid response, and provides an performance of the PV control up to 90 % throughout real-time.

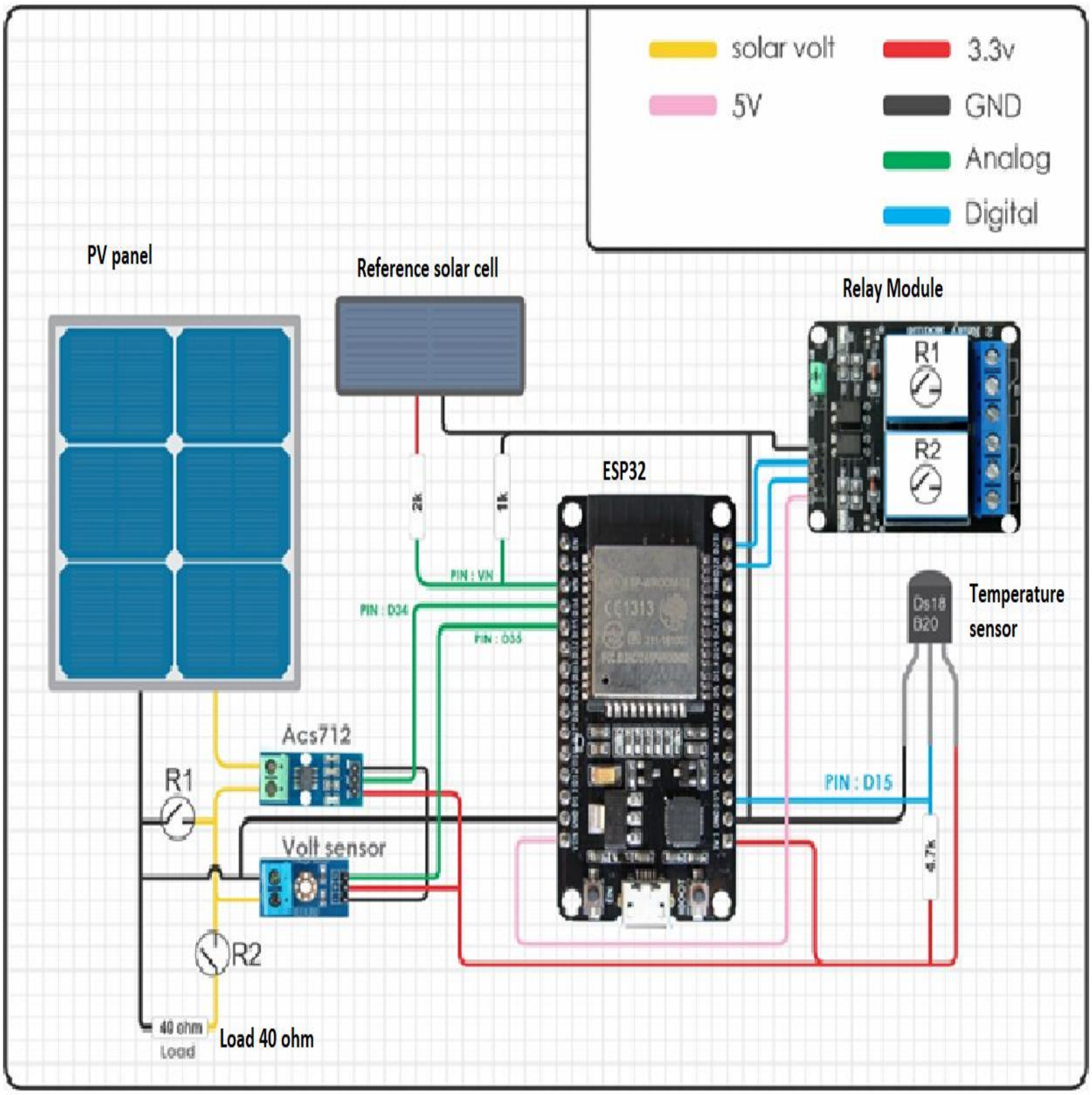

Figure11. Block diagram of fault detection

4.1.Methodology

The method is shown in Figure (12), may be divided into three major sections:

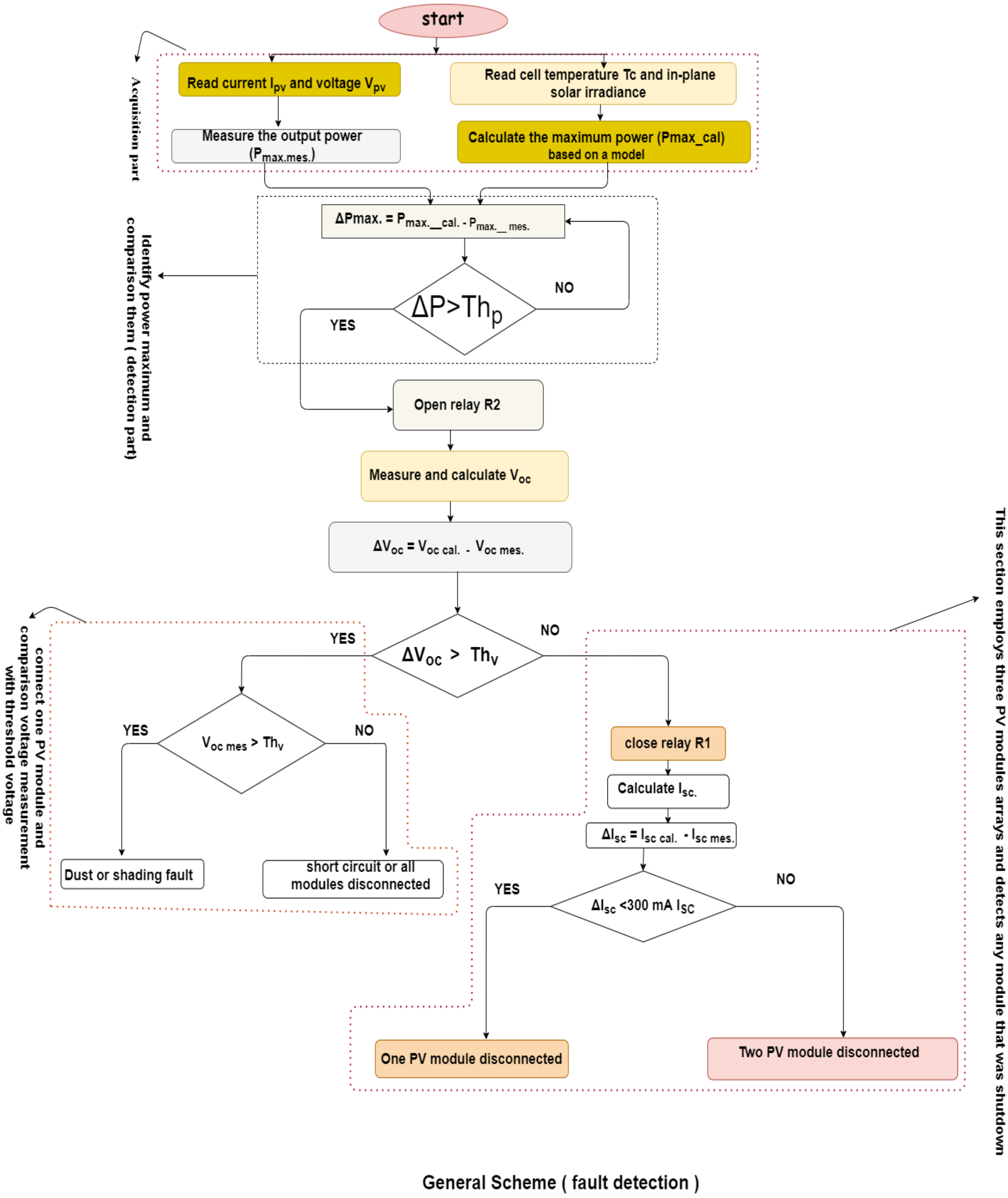

Figure 12. Constructing a flowchart for the process (detection and identification)

4.1.1 Acquisition Part

It entails gathering various physical data, including cell temperature, PV voltage, PV current, and solar irradiation.

4.1.2 Detection Part

The surveillance portion of the system is responsible for detecting any faults in the PV module. $\Delta P_{max}=P_{max-\ cal.} - P_{max-mes}$, which is a straightforward evaluation between recorded (Pmax-mes) and predicted ($P_{max-cal.}$) peak powers under other operating characteristics (figure12), Identification portion), may be used to do this. After many attempts, a criterion, Th_p (threshold power), has already been created: Th_p=3W.

4.1.3 Decision Part

As soon as a risk is discovered, the following step is to identify the nature of the issue discovered. Because of the existence of a malfunction Pmax> Thp (threshold power), a reduction in the measured power is detected, which denotes that the value of voltage (V_{PV}) or current (I_{PV}) has decreased. To determine the kind of fault, one can investigate the fluctuation of the current or the voltage to discover the cause of the problem. In this case, the classification procedure starts with determining the open-circuit voltage (V_{oc-mes}), and the seclusion was obtained by switching the relay R2 (on and off) (figure13). In this token, we can calculate the effects of open-circuit voltage by ($\Delta V_{oc} = V_{oc-cal} - V_{oc-mes}$). The experiment was set up and connected to the server, data was transmitted to the network through IoT, with the information gathered on the visual studio website. As illustrated in figure14 , the steady-state was achieved in the system when the maximum measured values were higher than or equal to the calculated power maximum ($P_{max-mes}>P_{max-cal}$) where the solar panel's environmental conditions are appropriate. Compare $\mathbf{V_{oc\ -mes}}$ with $\mathbf{Th_v}$, which has been accomplished in two stages option. Firstly, the dust or shading effect was achieved in the system when ($V_{oc-mes} > Th_v$), the threshold voltage ($Th_v \approx 3V$). Lack of voltage and current values. Push Button Switch (Test) investigation revealed a problem with dust or shading, as depicted in figure 15.

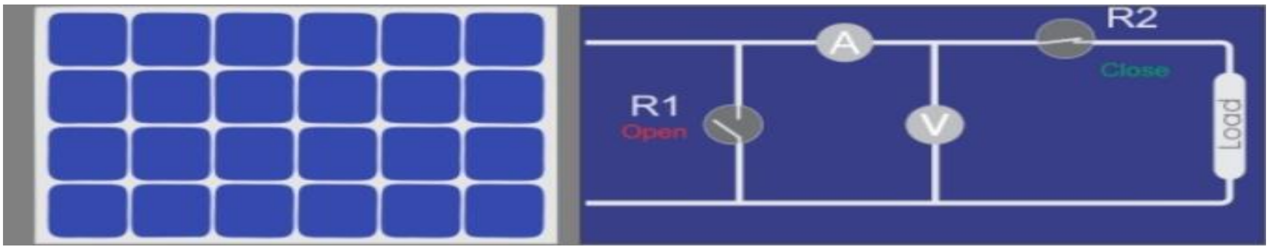

Figure 13. The electrical circuit using two relies upon R1 and R2 (one PV module)

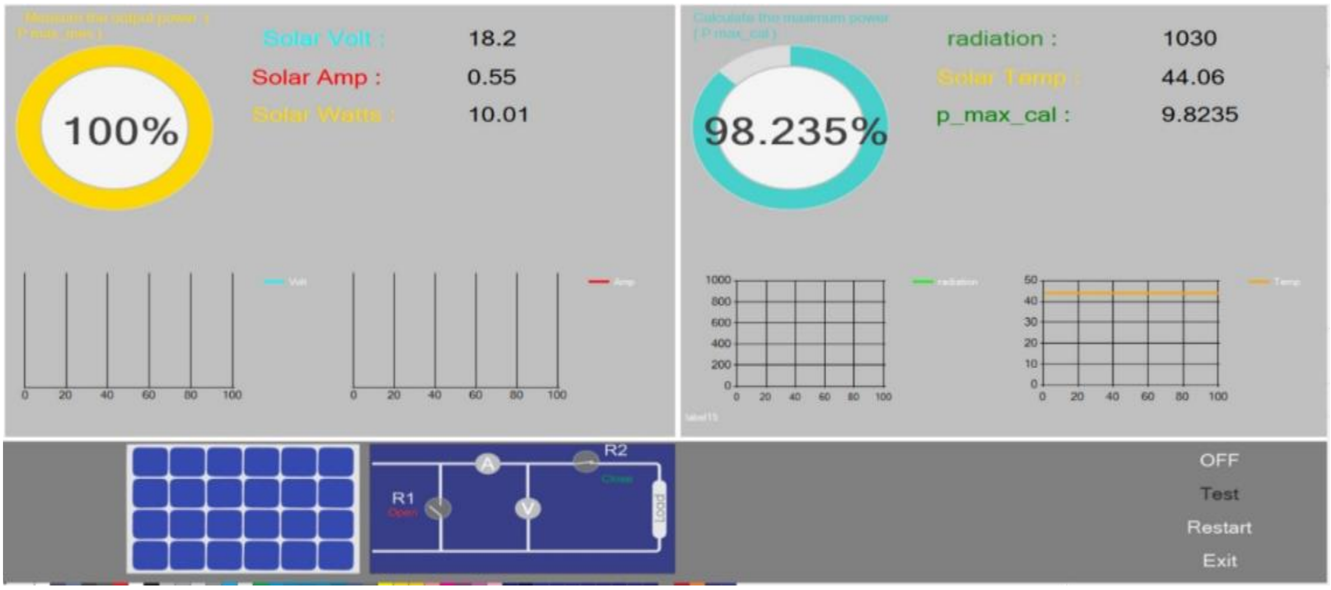

Figure 14. Steady-State Option

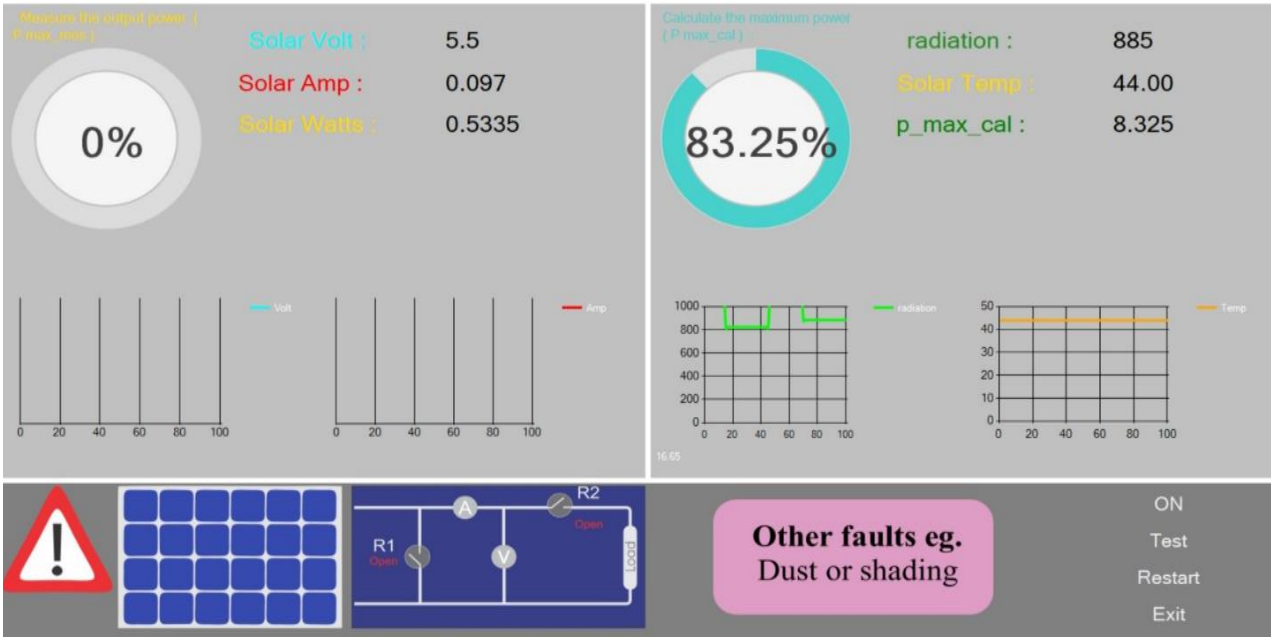

Figure 15. Dust or Shading option

Secondly, $\mathbf{V_{oc\text{-}mes}}$ < Th_v (short circuit or all system disconnect), after the push button switch (Test) has been examined, a short circuit problem has been discovered. That was accomplished at ($V_{oc\text{-}mes}$<Th_v), as shown in figure (16), a short circuit or disconnecting the whole system (isolating the solar cell from the load). System isolated relay R1 and isolated relay R2 (separated load) should be configured as shown on the web page. Otherwise, the PV panel will be removed from the system.

Figure 16. Short circuit or all system network disconnected

5. Monitoring and Controlling Dust accumulated in PV Panel

Dust and air pollution, which accumulate on solar panels, lower panels' performance by 25% in some countries. Consequently, Iraq has some of the most extreme weather, is particularly vulnerable to dust and desertification, and is considered one of the most at-risk countries. Using IoT technology, a framework for dust identification and intelligent solar panel productivity tracking has been proposed. The two detection and monitoring methods are used to detect and monitor the dust accumulation on the solar. Firstly installed GP2Y1010AU0F module at the same surface in PV plane, investigated and measure the dust and pollution in the air. Secondly, compared voltage PV with LDRs values. The previous method used a sensor to detect dust. We are installing electronic equipment in the outdoors. As a result of the changing climate, the dust sensor is affected by heat, humidity, and rainfall, which causes burning and damage. To continue the process of detection and washing, we proposed a more appropriate method, especially in the atmosphere of Iraq, based on the values of LDR and comparing it with the voltages generated by the solar panel, as shown in figures 17, 18.

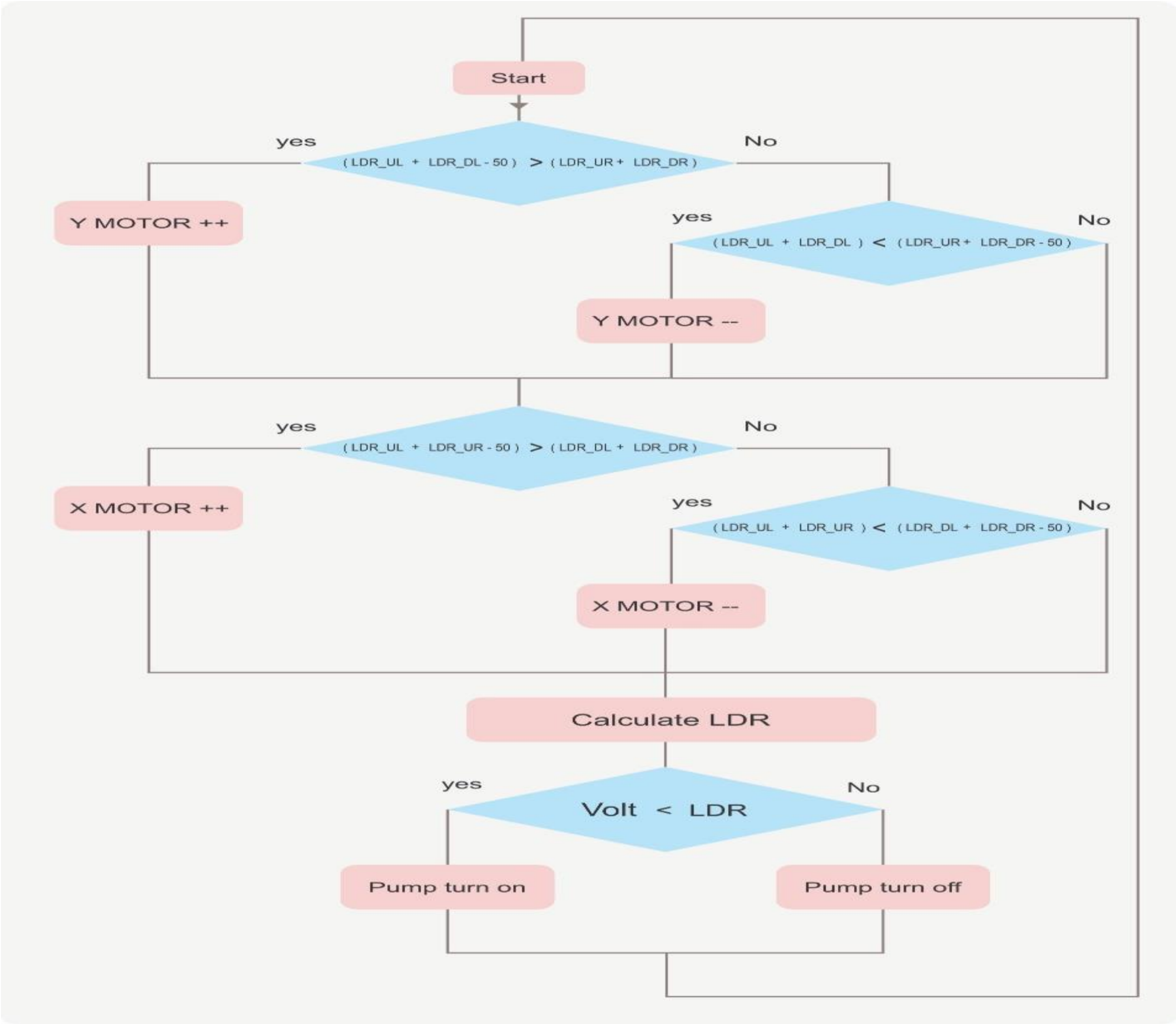

Figure17: Flowchart of the proposed dust detection based on a comparison between LDRs values and PV panel voltage

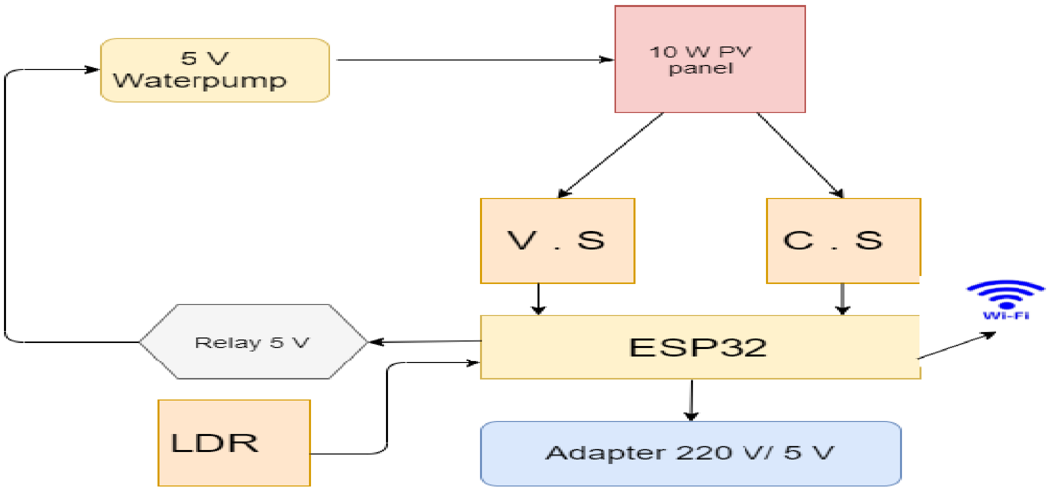

Figure 18: The proposed system based on LDRs values

6. CONCLUSION

Integrating renewable energy into the electricity distribution network is required to find more efficient remote monitoring solutions. The IoT is intended to collect significant solar panel data parameters. It enables the ongoing recording of performance and failure information that can be used to analyze and predict future potential power generation, income generation, etc. It as well eliminates the requirement for frequent maintenance of photovoltaic systems. The IoT has a crucial role in controlling photovoltaic systems installed remotely or away from the control panel. IoT-based monitoring will simplify the information system, improving energy electricity, intervention, and guidance. The recorded data have been transmitted to the internet via IoT technology. The stored data are available to the users with a web-based interface, in which users can browse all recorded data in real-time and check the state of the system. This work could be further improved and extended for fault diagnosis of photovoltaic systems by using more sophisticated algorithms to distinguish between faults with the same signature and make a clear decision. Also, verification of the method for the large size PV array and localization faults.

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