Development of Solar-Powered Crop Soil Conditions Monitoring System Using Internet of Things (IoT)

F. F. Fhaizal, S. M. Suboh, R. Ali
Faculty of Electrical Engineering Technology, Universiti Malaysia Perlis, Malaysia
s171090976@studentmail.unimap.edu.my

Abstract. The demand for food and agriculture production is increasing day by day. To cope with this situation, the traditional method used by farmers to monitor their crops needs to be improved. This project proposes a low-cost agriculture monitoring system that is capable of sending real-time crop soil conditions to farmers to help them in making the best decisions such as for planting and watering. The proposed monitoring system is equipped with a DHT11, LDR, and soil moisture sensor to monitor temperature, humidity, and other parameters. The internet of things (IoT) is implemented in this system to send all the information from sensors to the Cloud and display it through the ThingSpeak website. The mobile application named MY_FARM will read all the data from the ThingSpeak website to display and send a push notification to the farmers instantly if the crop soil conditions are out of the acceptable range. Based on the observation, the serial monitor and the ThingSpeak website will be updated with new data for every 20 seconds. Solar PV-based battery is proposed as the main power supply of the system, hence possible to be installed in remote areas. The experimental result demonstrates that the PV-based battery can charge and discharge and supply power to the system for about 11 hours before needs to be recharged.

1. Introduction
In this modern era, series of innovations of technology has been made to improve the agriculture system. Precision agriculture is a combination of new technology and traditional method used by farmers to achieve better productions by applying a control system. One of the approaches is by implementing a monitoring system via the Internet of Things (IoT) to monitor and send real-time information to farmers regarding crop conditions. By utilizing this system, a smart agricultural management approach can be achieved by responding to the needs of the crops appropriately [1]. IoTs bring an innovative solution towards gathering information on agricultural production by involving an intelligent device to monitor the production of their fields [2]. Such technologies could help the farmers to deal with global crisis such as global change and epidemics [3]. Various types of monitoring systems have been developed to enhance the crops’ growth as well as their productivity. For example, it is developed to gain information on the present soil moisture by using a moisture sensor and instantly convey the information to farmers for appropriate actions. Having real-time information on crop soil conditions might provide financial benefits to farmers such as significantly reduce the labor cost, maintenance cost and also water usage. All the information can be monitored through any electronic device such as laptop, smartphone and tablet from anywhere.

This paper will present the development of a solar-powered monitoring system, particularly to inspect the crop soil conditions supported by the IoT. A prototype will be constructed and several
simulation and experimental studies will be carried out. The performances of the entire system will be measured from a few perspectives i.e. solar PV-based battery charging and discharging operations, microcontroller role in receiving data from sensors and sending them to Cloud, its capability as a whole in monitoring and sending accurate information of soil conditions in real-time, etc. The data will be measured by sensors and processed by the microcontroller where the Arduino is used in this work. Meanwhile, the system is supplied by a solar PV-based battery where the battery is charged and discharged within limits that initially have been set to avoid overcharging and over-discharging.

2. Proposed System

Figure 1 illustrates the block diagram of the proposed system that consists of three major subsystems. The first subsystem contains the power supply where a solar PV-based battery is employed. The second subsystem so-called the heart of the whole system is where the microcontroller is placed and connected to a few sensors. Arduino UNO type of microcontroller is used in this work due to its reliable performance and low cost. The last subsystem comprises numerous devices where their specific functions are to transmit and display all the gathered information in real-time.

2.1 Software and hardware components

There is a list of software and hardware components used throughout the design and development stages of the proposed system. Some of the main components will be described in this section.

- **ThingSpeak Website.** It is an Internet of Things (IoT) analytics platform to collect, store, and display cloud data. This website allows instant visualization of data posted through Arduino, by link the API Key and channel ID of the ThingSpeak channel.

- **MIT App Inventor.** It is an online platform to develop and design a mobile application with computational thinking concepts. A mobile application named MY_FARM has been created using this software to read all the data from the ThingSpeak website through the URL and API read key.

- **Arduino UNO.** It is open-source with a single micro-controller board based on ATmega328P. Arduino can interact with hardware and software by upload and burn a program through the Arduino IDE. Arduino will save and load all the data before sending data to the Wi-Fi module or other control operation [4].
- **ESP Wi-Fi Shield.** It acts as a gateway to the Arduino to transfer data to the internet by providing wireless communication to upload and display all measurement data from sensor to the cloud/internet through UART serial communication. The researcher agrees that the Wi-Fi module is a low initial cost compared to the GSM module with higher reliability and ease to program [5].

- **Soil Moisture Sensor.** This sensor is an electronic device capable of measuring the volumetric of water inside the soil and working on electrical resistance or dielectric constant principle [6]. This sensor can be beneficial to the agriculture monitoring system to control the spreading or growth of the bacteria.

- **DHT11.** It is a combination of relative humidity (RH) and temperature sensor. It is a low-cost digital sensor consist of capacitive humidity and a thermistor to measure the temperature and the moisture surrounding the air. It is capable of reading temperature range at 0 to 50 °C±2 °C and relative humidity range at 20 to 80 % ± 5 %.

- **LDR Sensor.** It is a passive electronic that varies with light intensity. The resistance works inversely proportional to the light intensity. This resistance works on the photo-conductivity principle. The resistance will decrease during light and increase when the LDR is exposed in the dark [7].

- **Battery charger.** It is capable of charging and discharging a 3.7 V Lithium Polymer (LiPo) battery. This circuit is designed with an auto cut-off and auto charging circuit to protect the battery from over-discharging and over-charge.

### 2.2 System Description

As aforementioned, a PV-based rechargeable battery is chosen as the main power supply so that the proposed system is also feasible in remote areas which are normally out of electricity connection. As shown in Figure 1, a solar cell will be connected to the battery charger to charge the 3.7 V, 3800 mAh lithium battery. The battery charger circuit is built to automatically cut off and charging when the battery reaches the specific threshold voltages. This is to protect the battery from over-discharging and over-charging. The Arduino UNO's operating voltage is 5 V DC while the output of the battery is 3.7 V DC. In order to generate a 5 V operating voltage from the PV-based battery, a voltage booster will be added to step up the voltage from 3.7 V DC to 5 V DC.

In the controller subsystem, the Arduino UNO will play its role to regulate all the frameworks. All the sensors and devices will be connected to the Arduino UNO. In this work, the DHT 11, soil moisture and LDR sensors will be the system's inputs to monitor the crop soil conditions by measuring the temperature, humidity, soil moisture and light intensity. All sensors will send analog or digital outputs to represent the data. The microcontroller will convert the analog voltage to digital data before sending it to the Cloud. The Arduino UNO will regularly update the data from sensors to Cloud through ESP8266 as the Wi-Fi module by using serial communication. Arduino UNO native serial is built with a UART to obtain serial communication to other modules.

Lastly, the data from Cloud can be accessed via ThingSpeak website. All the data from ThingSpeak can easily be monitored by farmers by using electronic devices such as a laptop, computer by login in to the private channel. Then, an Android app (MY_FARM) will read the data from ThingSpeak website through URL and API read key of the ThingSpeak account and send a push notification to farmers to inform the current status of the crop soil by using a smartphone or tablet.

### 3. Simulation and Experimental Studies

Initially, the proposed system is designed using Proteus Software for simulation study purposes. After the expected results are obtained, the prototype of the system has been developed where the schematic diagram is illustrated in Figure 2. To observe the performances, numerous simulation and experimental studies have been executed.
3.1 Charging and Discharging Operations

The battery charger circuit firstly is designed using Proteus software. The circuit's capability for both charging and discharge operations has been studied. The input voltage source from PV module is 6 V. The charger starts to charge the battery whenever the battery voltage is below 3.7 V. As shown in Figure 3, the green LED (D4) will light up during the charging mode, and COM pin of 5 V relay (RL1) is connected to NC. Figure 4 presents the output voltage that is 4.2 V to charge the 3.7 V battery. It is continuously charging until the battery reaches 4.2 V.

Once the battery's voltage level is below 3.7 V, transistor BC547 triggers the relay to turn the pin COM to NO, thus will light up the red LED (D3) to indicate the battery is fully charged, as demonstrated in Figure 5. While Figure 6 displays the output voltage during the discharging mode which is 3.7 V.
The battery charger circuit then is installed on the breadboard such as displayed in Figures 7 and 8. Charging and discharging operations have been compared between experiments where the charger starts to discharge whenever the battery reaches 4 V but 4.2 V in the simulation. Also, during the charging mode, the charger starts to charge the battery whenever the battery is below 4 V but 3.7 V in the simulation.

3.2 Battery Supply Duration to the System

This experiment has been conducted to observe the supply duration of the selected battery when directly connected to PV module and without PV module. In other words to measure how long that battery could support the system. Figure 9 demonstrates the total supply duration of the battery for both cases (on a sunny day).

According to the experimental result, the battery starting voltage is at 4 V, 3800 mAh, however, drops to 3.95V once connected to the power converter. It seems that the battery connected with PV module can supply the monitoring system for about 11.5 hours with the remaining voltage is 2.80 V. Meanwhile, it is shown that the battery alone only can support the monitoring system for less than 10 hours with 2.83 V of the remaining voltage. It is proved that the presence of PV module could extend the total battery running time. It is worth mentioning that the power converter will stop functioning once the battery is below 3.0 V. This will cause the Arduino fails to update the data on ThingSpeak website, so the battery needs to be recharged immediately. During this period, the system is in idle condition.
3.3 Transferring Real-time Data

It is important to ensure that all communications occur in real-time so that the information received by farmers is valid and accurate to represent the recent status of soil conditions. Figure 10 displays the data that appeared on Serial Monitor at Arduino IDE, while Figure 11 to 13 demonstrates the recorded data on ThingSpeak website measured between 8 to 12 June 2021. It is observed that the data will only be transferred to the server after all the data measured by sensors appeared on the Serial Monitor. It is shown that all the data has been sent to ThingSpeak at 15:19:15 PM and renewed every 20 seconds.

3.4 Notification in Mobile Device

A mobile application named as MY_FARM has been specifically created for users (farmers) to allow them to monitor the crop soil conditions remotely. Figure 14 shows the icon of MY_FARM in the smartphone, while Figure 15 shows the designed layout of MY_FARM. This application will read the data from the ThingSpeak website and display them on the apps. This application has two sections which are the sensor status and ThingSpeak message & alarm. Before that, specific thresholds and messages have been programmed in the application such as shown in Table 1. For instance, when the
soil moisture percentage is below 50%, the ThingSpeak message will display the soil moisture status as dry (red color), as demonstrated in Figure 15. Figure 16 shows the push notification that will pop out on the farmers' mobile device whenever the Thingspeak message displays a red alarm.

**Table 1.** ThingSpeak message & alarm based on its threshold

| Parameter       | Threshold value and message |
|-----------------|----------------------------|
|                 | Blue Alarm                  |
| Temperature     | ≤ 35°C                      |
|                 | Message: Ideal              |
|                 | ≥ 35°C                      |
|                 | Message: Hot                |
| Humidity        | ≥ 50%                       |
|                 | Message: High               |
|                 | ≤ 50%                       |
|                 | Message: Dry                |
| Soil Moisture   | ≥ 50%                       |
|                 | Message: High               |
|                 | ≤ 50%                       |
|                 | Message: Dry                |
| Light Intensity | ≤ 350                       |
|                 | Message: High               |
|                 | ≥ 350                       |
|                 | Message: Low                |

**Figure 14.** Icon in the smartphone  
**Figure 15.** Application layout

**Figure 16.** Push Notification sent by MY_FARM

4. Conclusion

This project proposes a low-cost monitoring system to check the status of crop coil conditions using IoT technologies to collect and transmit data through the network. This system is powered by the solar energy, where a PV module is employed to charge and discharge the battery. Based on the simulation and experimental studies, the battery charger effectively demonstrates its charging and discharging operation with only small differences on the threshold values. One observation has been made to analyze the battery supply duration to support the system when directly connected to PV module and
without PV module. The result proves that the presence of PV module will extend the battery running
time for about 1 hour. The IoT devices’ capability to collect and transmit data through the network in
real-time also has been tested. It is observed that all the data will only be sent to ThingSpeak website
after all data is read from the sensors. Noticeably, ThingSpeak website will refresh the data of the
serial monitor every 20 seconds. Lastly, a mobile application named MY_FARM has successfully read
the data from ThingSpeak website and send push notifications to farmers instantly if the crop soil
conditions are out of the acceptable range. When the battery voltage level is below 3 V, it fails to
activate the Arduino UNO to send information to the network. During this period, the system is in idle
condition.

References
[1] S. Sadowski and P. Spachos, “Solar-Powered Smart Agricultural Monitoring System Using
Internet of Things Devices,” 2018 IEEE 9th Annu. Inf. Technol. Electron. Mob. Commun. Conf.
IEMCON 2018, no. November 2018, pp. 18–23, 2019, doi: 10.1109/IEMCON.2018.8614981.
[2] D. Markovic, R. Koprivica, U. Pesovic, and S. Randic, “Application of IoT in monitoring and
controlling agricultural production,” Acta Agric. Serbica, vol. 20, no. 40, pp. 145–153, 2015, doi:
10.5937/aaser1540145m.
[3] A. Vij, S. Vijendra, A. Jain, S. Bajaj, A. Bassi, and A. Sharma, “IoT and Machine Learning
Approaches for Automation of Farm Irrigation System,” Procedia Comput. Sci., vol. 167, pp.
1250–1257, 2020, doi: 10.1016/j.procs.2020.03.440.
[4] P. V. S. Divya Dhatri, M. Pachiyannan, K. Jyothi Swaroopa Rani, and G. Pravallika, “A Low-Cost
Arduino based Automatic Irrigation System using Soil Moisture Sensor: Design and Analysis,” in
2nd International Conference on Signal Processing and Communication, ICSPC 2019 -
Proceedings, 2019, pp. 104–108, doi: 10.1109/ICSPC46172.2019.8976483.
[5] F. Masi, P. Kamiyabhusain, and K. A. Masi, “Smart automation based on IoT and GSM module
Smart automation based on IoT and GSM module,” no. February, pp. 0–6, 2019
[6] P. Bhadani and V. Vashisht, “Soil moisture, temperature and humidity measurement using
arduino,” Proc. 9th Int. Conf. Cloud Comput. Data Sci. Eng. Conflu. 2019, pp. 567–571, 2019,
doi: 10.1109/CONFLUENCE.2019.8776973.
[7] G. Verma, P. Mittal, and S. Farheen, “Real Time Weather Prediction System Using IOT and
Machine Learning,” 2020 6th Int. Conf. Signal Process. Commun. ICSC 2020, pp. 322–324, 2020,