



Design and Construction of a Solar-powered Automatic Irrigation System with IOT support

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ABSTRACT

A solar-powered automatic irrigation system utilizes solar energy to charge a battery which powers the rest of the system. It uses soil moisture sensors to detect soil moisture content and automatically irrigate the soil to meet the optimal moisture requirements. Most contemporary irrigation systems make use of non-renewable energy sources which have high running costs and pose risks to the environment. Also, manual labour is conventionally used for irrigation which can be very stressful and inaccurate because man is naturally error-prone. The system was designed to notify the farmer on the pump state via a web server which is connected to a micro-controller through a Wi-Fi module and an application program interface to communicate with the web server from which the pump could be controlled. Also, a web page was hosted for a more interactive user interface. The results obtained graphically displays pump state, soil moisture content and water level in real time. It collects data from the pump, soil moisture sensor and ultrasonic sensor and then saves it as a csv file for record keeping. It also generates tabular data showing the entry creation time, entry ID, analogue soil moisture sensor readings, digital soil moisture readings, motor state and water level.

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INTRODUCTION

Irrigation can be defined as the art of applying water to land, more specifically to the soil on which planting takes place to achieve a desired objective. When sufficient moisture needed for the healthy development of the plant is naturally not sustainable, irrigation can be applied to ensure development of the plants through their various growth stages, therefore, it needs man to generate means and techniques to ensure plant survival especially for production of food crops [1].

Some irrigation techniques have been applied in the past to deliver water to plants each with their own strengths and setbacks. An example is the Drip Irrigation approach. Drip Irrigation is a method being used by farmers in developed countries. In

this system, water is supplied to the root region of the crops in drips, thus, significant quantity of water is preserved while plants get optimal water content simultaneously. In India, farmers manually irrigate their fields at regular intervals; this process takes up more moisture than the Drip Irrigation system and sometimes crop do not get their required water content resulting in decreased productivity. This problem of deficiency of water can be resolved if we have a drip irrigation system in which the irrigation will take place only when the crops need water.

Due to fossil fuel decline and its enormous contribution to pollution and global warming, scientists are looking out for alternative green energy based on each geographical location's availability because



before the right renewable energy source can be ascertained, tests should be carried out to know the one(s) that will produce the most favourable results at minimal cost. Renewable energy sources such as solar, wind, geothermal and others are being utilized for power generation.

Nigeria being a tropical country is blessed with abundant supply of solar energy. The span of solar radiation in Nigeria is between 7.0kWh/m^2 ($25.2\text{ mJ/m}^2/\text{day}$) in the far north and about $3.5\text{ kWh/m}^2/\text{day}$ ($12.6\text{ mJ/m}^2/\text{day}$) in the coastal latitudes and bright sunshine hours vary from 6 to 9 hours/day [2]. Also as an agrarian-driven economy, the agricultural sector accounts for about 17.8% of its GDP. [3], in his research findings stated that Nigeria has features that support solar-powered irrigation.

Solar energy has been identified as one of the environment friendly way for farmers to save non-renewable energy. An example of its usage is when farmers turn their roofs to photovoltaic systems and therefore avoid burning fossil fuel which is limited in availability in the earth and is also vulnerable to exhaustion. The running and maintenance cost is lower in renewable resources than the non-renewable resources which require continuous supply of fuel for their usage.

The labour cost involved in overseeing an irrigation system could be very costly and therefore, productivity is greatly enhanced when the system is automated.

A solar-powered automatic irrigation system aims at eliminating manual intervention during irrigation by harnessing solar renewable energy, and uses a microcontroller incorporated with a soil moisture sensor which senses soil moisture content thereby helping to effectively conserve water in the soil. This project on "Solar Powered Automatic Irrigation System with IOT support" is intended to create a solar-powered automated irrigation mechanism which turns a pumping motor ON/OFF on detecting the moisture as well as the humidity content of

the soil and makes control possible on an internet-based web app which displays the data on the internet. For continuous agricultural productivity, usage of an effective means of irrigation is crucial.

This project uses a Node MCU which is programmed to detect input signal of variable dampness of the soil via a moisture sensor mechanism. A design for the control of irrigation is facilitated to assist millions of people. This model makes use of a sensing arrangement technology with a microcontroller to make it a smart switching device.

LITERATURE REVIEW

In the past, several attempts have been made to implement an irrigation system powered by a renewable energy source which can be operated autonomously. Each had different methodologies implied in terms of specific benefits and limitations. [4], made use of a soil moisture sensor to sense the soil moisture content and then targeted to sprinkle plants located in pots as controlled by a raspberry pi micro-controller. It used a 9v rated motor to drive water to the plants, soil moisture sensor to detect water level, a buzzer which serves as a notification system, IR sensors and MN925 board. This system helped to save time and manpower. However, it did not utilize a renewable energy power source.

[5], also did not utilize a renewable energy source but was designed to operate autonomously using a submersible low-noise micro-water pump to deliver water to the root of crops from a storage tank. Its peculiarity is that rather than being controlled via a WiFi or GPRS signal, it is controlled based on the results of a test taken to determine the time taken to irrigate different soil types. This system has a limitation of utilizing only one sensor.

[6], used a renewable energy source to power the irrigation system and displays the pump state on a LCD screen. However, it has a limitation of using only one sensor; making it very basic. [7]. made use of embedded systems to increase the

system's functionality. This system incorporates a soil temperature sensor which makes it possible to measure the soil temperature and uses an AT Mega 328 micro-controller. However, this project is not IOT based.

[8], used a GSM module, making it possible to send and receive signals from the microcontroller. It used drip irrigation system which helps to reduce soil and wind erosion; the user interacts with it via a mobile android app built on JAVA. [9], is a system designed to overcome the difficulties realized by the conventional wired watering system. It is a Personal Computer and mobile-controlled system which was developed for facilitating gardening. The system was made possible by enabling Desktop and mobile control for monitoring and controlling watering activities in the farmland thereby reducing wiring mess. The system is divided into two parts; one is the Personal Computer side while the other is the hardware components on the site. The Graphical User Interface was designed with .NET programming language and software instructions were used to transmit messages to the GSM module on site through PC and vice-versa. It involves two modes of operation, the manual mode and automatic mode. In the manual mode, the system was designed to work as a traditional watering system whereby the operator chooses when to start and stop watering. Whereas, in the automatic mode, once the system is started, the user does

not need to stop the system as it would be done automatically and the watering would be decided according to the water level. The user can enable the system by sending a message to the microcontroller via the GSM module in the program. This message after being received by the microcontroller will then trigger moisture sensors and a water level indicator. However, the method of electricity supply used to power the whole system is conventional and therefore not economical.

It can be observed from the methods discussed above that using a renewable energy source for irrigation is more economical because it has lower running costs. Also, it has comparative advantage if the system is able to incorporate more than one sensor so as to increase the scope and efficiency on the system. The constructed system is IOT-based and is not limited to specific kind of devices unlike those that are based on only android or desktop applications.

MATERIALS AND RESEARCH METHODS

The system comprises seven (7) main circuit units namely:

- I. Solar Panel Unit
- II. Power Supply / Regulator Unit
- III. Relay Unit/Switching Circuit
- IV. Micro-controller Unit
- V. Moisture Sensing Unit
- VI. Wi-Fi Module
- VII. DC Water Pump

The pictorial view of the experimental setup is shown in Figure 1.

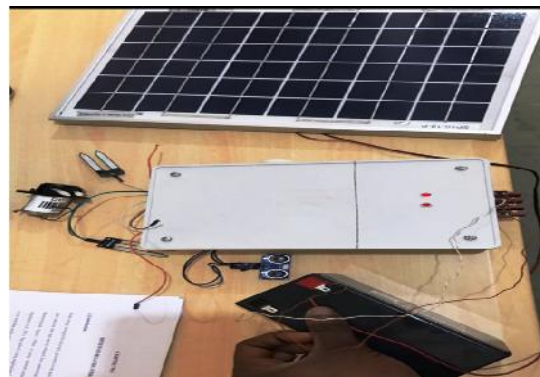


Figure 1: Experimental setup

The block diagram that describes the methodology is shown in Figure 2.

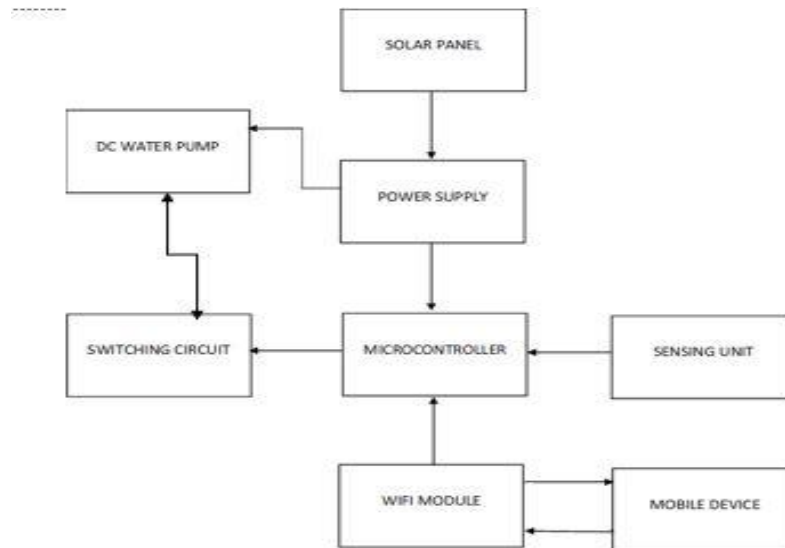


FIGURE 2: SYSTEM BLOCK DIAGRAM

As illustrated in Figure 2, the system works by using a solar panel to charge a battery that is connected to the charging circuit, which then powers the micro-controllers, sensors and pump. A switching circuit is used to vary connections to the Dc water pump. The micro-controller contains the code which helps to control the sensing unit and send signals to the switching circuit. The sensing unit consists of two soil moisture sensors which were used to detect the soil moisture content and transmit the received data to the micro-controller for processing. An ultrasonic sensor is used to measure the water level in a storage tank and then send the signal to the micro-controller from which it can be controlled. A mobile device or any internet-enabled device is used to monitor and control the pump via the web interface.

A Node Micro-controller Unit was configured on the Arduino IDE to

connect to a Wi-Fi network with a pre-defined SSID and key. After the Wi-Fi module receives power, it takes between 2 to 10s to connect to the network while it is within range. Also, the pump's discharge supplies water from a water reservoir on which is mounted an ultrasonic sensor which detects water level.

It is then connected to the soil where soil moisture sensors are used to determine the water content of the soil. In this project, two soil moisture sensors were used to increase the accuracy of the system. A buzzer was also used to notify the farmer when there is low water available in the water reservoir so that it could be refilled. The IOT platform makes use of graphical and mathematical representations to show real-time status of the soil moisture, water level and motor status. The circuit diagram of this design is shown in figure 3.

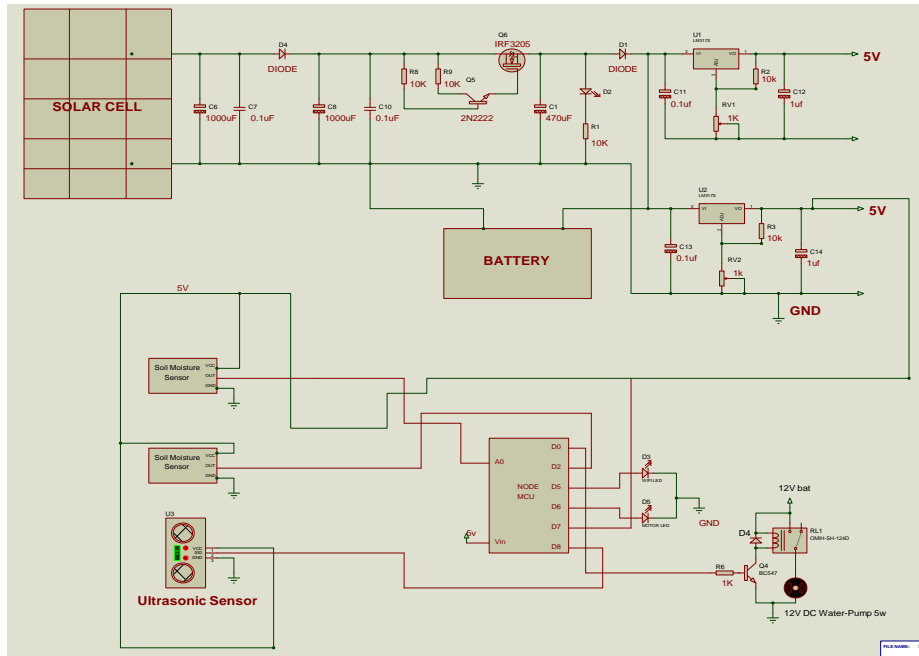


FIGURE 3: SYSTEM CIRCUIT DIAGRAM DESIGNED USING PROTEUS.

A battery of 12V, 7Ah is chosen based on the current requirement. Battery capacity is measured in Amp

$$\text{Battery Ah} \times \text{Battery Voltage} = \text{Battery Power in watt hour} \quad (1)$$

The power is therefore 84Wh. The size of the solar panel depends on the battery's capacity. The battery used is an Absorbed Glass Material type and an AGM battery should be charged at a rate of C/12 or C/8, which means it should be charged at amperage that is 1/8th to 1/12th of the Amp-Hour capacity. So, for our 7Ah, we choose to charge at a rate of 7 Ah/8 which is 0.875 A, approximately 0.9 A.

To estimate the power needed by the solar powered automatic irrigation system, the nominal voltage of the battery and solar panels, presumably 12 V is multiplied by the amperage:

$$\begin{aligned} \text{Power Needed} &= \text{Voltage} \times \text{Current} \quad (2) \\ \text{Power Needed} &= 12V \times 0.9 A \\ \text{Power Needed} &= 10.8 \text{ Watts} \end{aligned}$$

hours. This is converted to Watt hours by multiplying the Amp hours by the battery voltage as shown below:

AGM batteries get damaged easily if they are charged too fast, it would be safe to choose a 10W solar panel, hence the reason for our selection. Therefore, for this project, a 10 W, 12 V Solar Panel was selected for use. The Solar charge time is given as:

$$\text{Solar Charge Time} = \frac{\text{Battery Ah}}{\text{Charging Current}} \quad (3)$$

$$\text{Charging Current} = \frac{\text{Solar Wattage}}{\text{Solar Panel Voltage}} \quad (4)$$

Assuming solar panel charger's efficiency is 85% due to the inability of the solar panel to always deliver its nominal value, thus Solar panel wattage becomes 8.5 W.

$$\begin{aligned} \text{Charging Current} &= 8.5 W \div 12 V = 0.7083 A \\ \text{Solar Charge Time} &= 7 Ah \div 0.7083 A = 9.88 h \approx 10 \text{ hours} \end{aligned}$$

Therefore, the system was designed to charge fully in 10 hours.

RESULT AND DISCUSSION

Figure 4 shows the web interface for switching the water pump as seen on Google Chrome Version 67.0.3396.99 (Official Build) (64-bit).



Figure 4: Screenshot of the Web Interface

This web interface uses an API on www.thingspeak.com and works as illustrated. The button when clicked uses AJAX to send GET requests so as to consume the APIs and yield the same result as directly visiting the API's URL. The API key is at the right of the field area and when copied and pasted on the text area, the motor (pump) can be turned ON and OFF by clicking the buttons.

In Figure 5 the overview showing the four field graphs as were configured on the website is shown. The topmost left corner shows the number of API entries which here is '551'. This shows that the API had been used 551 times as at when this picture was taken. The y-axis has four (4) labels; pump state which shows if the pump is ON (represented by 1) or OFF (represented by 0). It collects the data from the pump which is connected to microcontroller and in turn sends it to the web interface via the Wi-Fi module; Soil Moisture 1 which is the soil moisture sensor connected to the analogue pin's

value and was calibrated to give a maximum value of 1000 and minimum value of 0. Changes in conductivity between the two probes are determinant for values of the analogue sensor, the values are then transmitted to the microcontroller which updates it on a web server via a Wi-Fi module; Water Depth used to show the water level as determined by the ultrasonic sensor. A value of 1000 shows the tank is completely empty while a value of 0 shows the tank is filled up with water. The soil moisture sensor 2 is connected to a digital value which only has values of 0 and 1 per-time. 0 depicts the soil is 'relatively dry' while 1 means the soil is 'relatively wet'. The four y-axis parameters are plotted against Date on the x-axis which represents the date and time. On the web server, the graphs can be zoomed for more details.

It is worthy of note that all y-axis values are dimensionless in this study.

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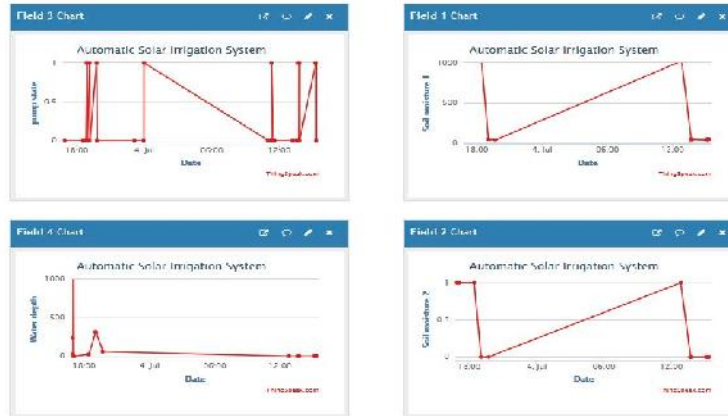


Figure 5: Four Field Graphs

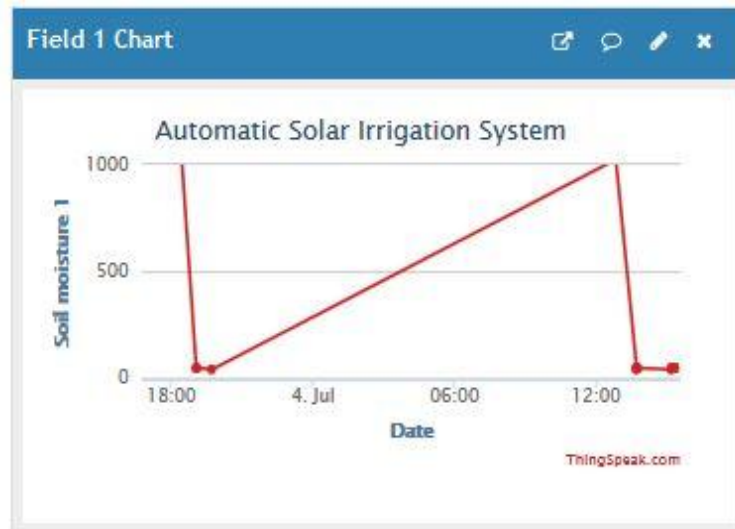


Figure 6: Screenshot of the Real-time graph showing analog moisture sensor readings

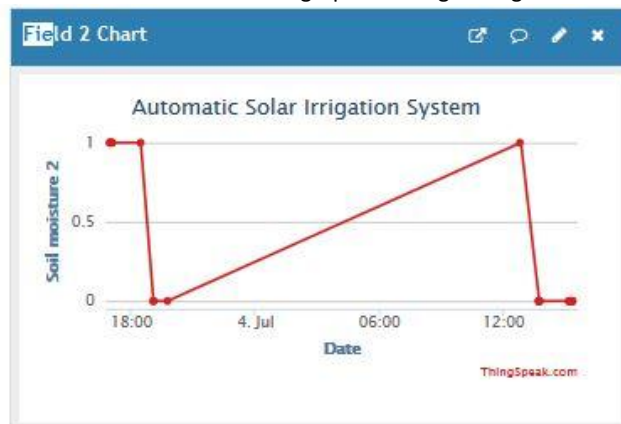


Figure 7: Screenshot of the Real-time graph showing digital moisture sensor readings

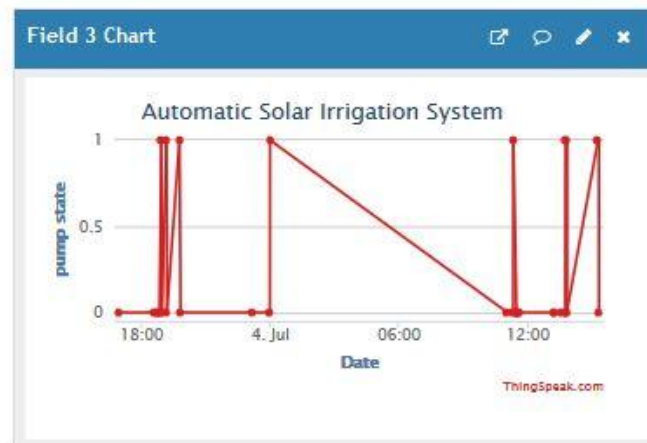


Figure 8: Screenshot of the Real-time graph showing pump state

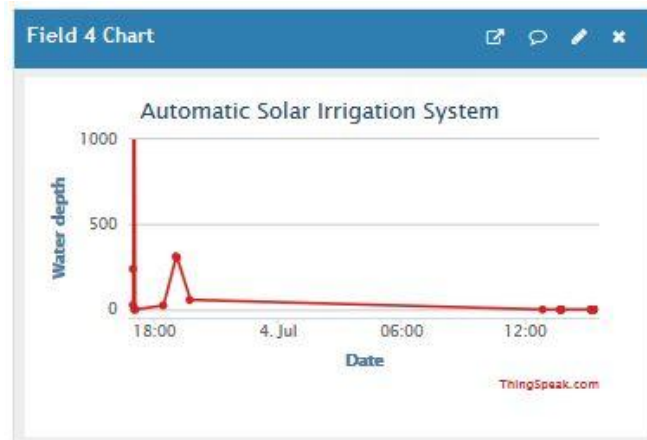


Figure 9: Screenshot of the Real-time graph showing water depth

Aside from graphically, real-time data can be saved as a csv file as shown below:

	created_at	entry_id	Analog Soil Moisture	Digital Soil Moisture	Motor State	Ultrasonic Sensor
1						
2	2019-07-03 11:08:19 UTC	412	44	44	0	0
3	2019-07-03 11:09:10 UTC	411	44	44	0	0
4	2019-07-03 11:09:19 UTC	414	44	44	0	0
5	2019-07-03 11:10:03 UTC	415	44	44	0	0
6	2019-07-03 11:11:02 UTC	416	44	44	0	0
7	2019-07-03 11:20:39 UTC	417	44	44	0	0
8	2019-07-03 11:48:19 UTC	418	44	44	0	0
9	2019-07-03 11:47:31 UTC	419	45	45	0	0
10	2019-07-03 11:48:07 UTC	420	45	45	0	0
11	2019-07-03 11:48:55 UTC	421	45	45	0	0
12	2019-07-03 11:52:24 UTC	422	45	45	0	0
13	2019-07-03 12:17:01 UTC	423	45	45	0	0
14	2019-07-03 12:17:49 UTC	424	45	45	0	0
15	2019-07-03 12:18:25 UTC	425	45	45	0	0
16	2019-07-03 12:22:26 UTC	426	45	45	0	0
17	2019-07-03 12:24:41 UTC	427	44	44	0	0
18	2019-07-03 12:25:09 UTC	428	45	45	0	0
19	2019-07-03 12:27:00 UTC	429	44	44	1	5
20	2019-07-03 12:32:14 UTC	430	44	44	1	5
21	2019-07-03 12:35:07 UTC	431	45	45	1	5
22	2019-07-03 12:40:29 UTC	432	44	44	1	0
23	2019-07-03 12:40:29 UTC	433	44	44	1	0

Figure 10: Screenshot of a sample CSV data generated from the readings.



The csv file format has 7 rows: Serial Number, created_at, entry_id, Analog Soil Moisture, Digital Soil Moisture, Motor State and Ultrasonic Sensor. The Serial Number row is a created by default on Microsoft excel which is not relevant in this data representation. The 'created_at' row shows the date and time in which the specific data was created in UTC time zone using "YYYY-MM-DD HH:MM:SS UTC" format. The 'entry_id' row shows the number of GET request that generated those values on the API. The 'Analog Soil Moisture' row shows the reading generated on the soil moisture sensor connected to the analogue pin. It is usually calibrated to the upper limit and lower limit and values under this column lie between those limits. The 'Digital Soil Moisture' records '1' if the soil moisture sensor value is relatively wet and is expressed as '0' if the soil moisture sensor value is relatively dry. The 'Motor State' records '1' if the D.C pump is ON and '0' if the D.C Pump is OFF. The 'Ultrasonic Sensor' is calibrated to give readings from '0' to '5' depending on the water level in the storage tank.

CONCLUSION

The project has been completed, tested and the expected result; to monitor and control a solar-powered automatic irrigation was achieved. Based on the design, the user would be able to control a water pump via a web interface on any internet-enabled device as real-time readings of the pump, soil moisture level and water level are being generated both graphically and in CSV files. The main intention of the project is to build a system that is flexible and cost effective to control water wastage, encourage use of renewable energy and extend farming from local barriers to global coverage via IOT. The construction is simple thus can be reproduced and maintained locally.

RECOMMENDATIONS

Based on the experience and challenges faced in the course of the

project, it is recommended that the following measures are taken to improve on the quality of the project:

1. To incorporate more sensors so as to detect more soil properties e.g. temperature, pH etc. thereby making the irrigation more extensive
2. To incorporate machine learning to the system so as to detect different soil types from given data-sets and supply their optimal water needs to each soil sample.

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