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Internet of things (IOT) for smart solar energy: A case study of the smart farm at Maejo University

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***Abstract*—This research aims to prototype a small smart off-grid solar cell system. o provide an alternative electrical supply for a smart Lingzhi mushroom farm. This research applied the use of IOT with voltage and current sensors to measure and monitor the voltage of solar cell charging, amp (ampere) of current charging from the solar panel into a battery and (ampere) of current loading from a battery to the irrigation systems (fog and sprinkler pumps). Voltage and current data processed through Blynk was developed as an IOT cloud service. Data was stored into the Blynk and displayed on mobile devices in real time. The functional status (switching on and off for periods of time, current consumption) pushes notifications through Blynk IOT cloud service on the Blynk application. The equipment and tools used in this research were NodeMCU, voltage and current sensors, relay modules, DC sprinkler, and fog pumps. A small off-grid solar cell was applied. The solar cell system consists of a charger, battery, and solar panels.The IOT cloud used is Blynk. The results of the research shows that using IOT with voltage and current sensors enhances the prototype of a smart farming as an alternative and green electrical resource.**

Keywords— IOT ,SOLAR ENERGY, NodeMCU

I. INTRODUCTION

A. Background

The Thai government would like to promote Thailand 4.0 to use a new technology for Thai agriculture. Therefore, Maejo University Chiangmai, has a concept to develop a prototype of a smart Lingzhi mushroom farm by using current information technology to control the environment. The reason for developing the smart Lingzhi mushroom farm is to promote a new modern agricultural technique to Thai farmers. Controlling the environment of mushroom light, temperature, humidity and air flow are all needed [1]. However research done by Maejo University shows that humidity was the most important factor for the growth of the spores and leaves of the Lingzhi mushroom. The previous research applied the use of IOT with the humidity sensor to measure and monitor the humidity in the Lingzhi mushroom farm as well as control the irrigation automatically [2, 3].

In this research, IOT with voltage and current sensors, were there to monitor the status of the solar cell system, which deployed as a green and alternative energy for a prototype of a smart Lingzhi mushroom farm. The status of the solar cell system consists of a voltage battery, amp (ampere) of current charging from solar panel into a battery and (ampere) of current loading from a battery to an irrigation systems (fog and sprinkler pumps).

B. Research objective

This research aims to deploy an IOT technology to develop a prototype of a smart solar cell system (as energy for the smart farm). Status of current charging and loading solar cell can be observed real time online on computers and mobile devices.

II. LITERATURE

Internet of Things is an internet application which involves three kinds of technologies; they are 1) perception, 2) transmission and 3) intelligent processing [4]. Internet of Things combines sensor technology, communication networks, internet technology and intelligent computing technology to achieve reliable intelligent processing [5]. The protocol commonly used for the internet of things is MQTT. MQTT (Message Queuing Telemetry Transport) is a broken-based publishing/subscribing, instant messaging protocol. It's designed to be open, simple, lightweight, and easy to implement. The advantage of the MQTT protocol is that it solves the problem of instantly pushing various messages from the server to the mobile devices.

NodeMCU is an open source IOT platform. It includes firmware which runs on the ESP8266 WI-FI SoC (System-on-chip) from Espressif Systems Company (from Shanghai, China). It is a 32 bit Microcontroller. In this research NodeMCU used an ESP-12 module or NodeMCU version 2. NodeMCU is similar to the Arduino which has built in input and output ports. NodeMCU is compatible with Arduino IDE where programming C++ can be written. Compiling and flashing programming codes can be done using microB-USB. NodeMCU has advantages on Arduino where it is smaller and can connect to WIFI [6].

Blynk is a platform service to connect the nodeMCU and the mobile app [7]. There are 3 main services of Blynk. 1) Mobile app, it is used to monitor data from NodeMCU on the mobile app. In this research, the data from the solar cell charger and solar cell loader from nodeMCU can be monitored in real-time on the mobile app. 2) Cloud service, it is used to store the data from the nodeMCU and historical information can be retrieved on the mobile app as a CSV. In this research, historical data of the solar cell charger and solar cell loader can be retrieved as a CSV. A CSV is used to analyze the solar cell system to management.. 3) Library, it provides aconnection for NodeMCU and Blynk cloud services. In this research, nodeMCU connecting with voltage and current sensors were used to observe the balance of the charger and loader from the solar cell system. Blynk provided the library to connect between nodeMCU and those sensors and Blynk app (on android).

Solar cell or Photovoltaic (PV) cell is a device that converts sunlight directly into electricity [8]. In this research, 2 solar panels with 40 watts are connected together in parallel for the purposes of increasing the output current. The solar cell system consists of solar panels, a solar charger, and a battery. Solar cells produce direct current (DC). Therefore, in this research DC irrigation systems are used (sprinkler and fog pumps).

Previous research

Previous research aimed to prototype a smart Lingzhi mushroom farm [2, 3]. Their research applied the use of IOT with a sensor to measure and monitor the humidity in the Lingzhi mushroom farm. The humidity data is processed through NETPIE was developed and provided by NECTEC as a free service for IOT. Humidity data was stored into a NET FEED (a sub service from NETPIE) and displayed on mobile devices and computers through NET FREEBOARD (another sub service of NETPIE). This research also controlled sprinkler and fog pumps automatically and the functional status (switching on and off for periods of time) and pushes notifications through the LINE API on the LINE Application. The equipment and tools used in this research were NodeMCU, humidity sensor, RTC (real time clock), relay module, sprinkler and fog pumps. C++ and Node.JS were used as programming. The services and protocol used were NETPIE (Network Platform for internet of everything) with subservices such as NETPIE FEED, NETPIE FREEBOARD, and NETPIE REST API. The results of their research show that using IOT with the sensor enhanced the prototype of smart farming.

In this research, researchers would like to expand using the solar cell system for a smart Lingzhi mushroom farm as an alternative and green energy resource. The IOT with voltage and current sensors apply to measure and monitor the status of solar energy. The status of the solar cell consists of the solar cell current charging from solar panels to the battery and the loading from battery to irrigation systems (fog and pump). In addition, all the data of the solar cell status are preceded into a Blynk as an IOT cloud service. All data can be monitored in real time on mobile devices.

III. RESEARCH METHODOLOGY

This research followed the waterfall model of the system development life cycle (SDLC) as a research methodology. There are 5 steps in this research. These steps are the requirement and feasibility study, system analysis and design, implementation, system validation, and maintenance.

A Requirement and Feasibility

The requirement of this research was to prototype a portable solar cell system as an alternative energy source for the smart Lingzhi mushroom farm. Hence, famers can apply this solar system in isolated farm areas. The status of solar cell system (current charging and current loading) were needed to be monitored on mobile devices.

For current usages, watts of sprinkler and fog pumps neededattention. A total daily current usage (watts) of both pumps was 225.6 and is shown on Table I.

TABLE I. TOTAL WATTS USAGE PER DAY

Pump	*Total*	*Usage (Hours/Day)*	*Power rating (Watts)*	*Total daily used (watts)*
Sprinkle	1	0.25	96	24
fog	1	8	25.2	201.6
				225.6

The daily usage of solar cell system can be calculated as 225.5 watts/ (5 hours for solar charging) = 45.12 watts. Therefore, the minimum solar panel needed = 45.12 watts. However, in this research 2 panels of 45 watts were used. The size of the battery for storing the solar energy can be calculated as Ah (Amp-hour) = total energy usage / [battery voltage X 0.6 (% battery current usage) [9], Ah = 225.5/ (12x6) = 31.33 Ah, then the 45 Ah battery (lead acid) was applied to this research. The reason lead acid battery is used is because it is cheaper than deep cycle battery. In other cases, famers can find a new brand or a secondhand lead acid easier. For this research, we selected IOT as smart technology for monitoring real-time of solar cell energy status for the smart farm. The tools, software and protocol used are shown in table 2-4.

TABLE II. HARDWARE AND PURPOSES OF THE USE

Hardware	*Purposes of use*
2 x Solar Panels 40 watts 12V Mono-crystalline	Convert light into electricity
EP solar charger LS1024R 12/24V 10A (Rated Current 10A)	Control solar charger
45Ah Lead acid Battery	Store solar energy
NodeMCU (V2 (ESP8266-12E) + Expansion Board	Control devices and send voltage and current data into internet via WIFI connection
ET-Mini MCP3424 ADC Module	Analog to digital converter (ADC)
WCS1700 hall current sensor	Measure input and output current
Voltage sensor	Measure voltage
ET-NINI PWR5/ADJ-3A	2ch Step-Down Voltage Regulator

Hardware	*Purposes of use*
Relay 1ch 30A 12VDC	Control (switch on and off) sprinkler pump and fog pump
2ch 10 A 5V relay Module	Control (switch on and off) sprinkler pump and fog pump
Sprinkler pump Non-Automatic Blige Pump 12VDC , 2000GPH Flow rate, 6M Head, (9.0A Max Current)	Sprinkler irrigation
Fog pump Diaphragm Pump 12VDC , 40PSI , (4.0A Max Current)	Fog irrigation

TABLE III. SOFTWARE AND PURPOSES OF THE USE

Software	*Purposes of use*
C++ on Arduino IDE	Programming language on Node MCU

TABLE IV. SERVICE AND PROTOCOL AND PURPOSES OF THE USE

Service and Protocol	*Purposes of use*
Blynk App	IOT cloud service

B. System Analysis and Design

The average amount of time it takes to charge a solar cellsolar in Thailand is approximately 5 hours [10]. In this research, a small off grid system was used along with DC fog and sprinkler pumps.. The solar cell system was able to support the irrigation for the smart farm for 2 days without the sun or charging. The battery was 45 Ah, which means that the battery was able to provide 12 volts X 45 Ah = 540 watts and the daily maximum irrigation usage is 225.6 watts.

Concept diagram

In this research, IOT was applied with voltage and current sensors, to measure the status of the solar cell current charger from the solar panel and current output from battery.

NodeMCU was applied as a hardware with WIFI for the IOT to connect with the Maejo University access point. This allows it to be able to connect to the internet. A service used to send solar cell current charging and loading data to an internet was Blynk, to real-time display those data and time stamp on smartphones and computers (the measurement was in watts). The historical data of solar cell status retrieval used was into CSV format. Notification of the current usages with irrigation system (pumps) was notified on Blynk pop up message on mobile devices.

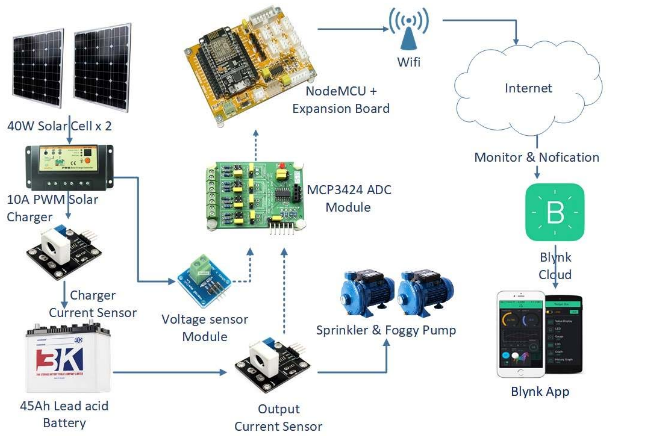


Figure 1: a concept diagram of IOT for solar cell system with Blynk

For more details of IOT for solar cell system, nodeMCU with WIFI integrated with current sensors. There were two types of current sensor used in this research. One was the charger current sensor module, to measure the current power from solar panel into a battery. Second was the output current sensor module, to measure the current consumption form battery by irrigation systems (sprinkle and fog pumps). The voltage sensor module was used to measure the status of charging. The DC (direct current) step down voltage 12 VDC to 5 VDC was used as nodeMCU consumed 5 voltages and battery was 12 voltages. MCP3424 module was used as a signal convertor. The input and output current sensors were measured in analog signal and nodeMCU communicated in digital mode. And to be noted, NodeMCU and MCP3424 communicated with I2C protocol (Inter Integrate Circuit Bus) as Synchronous and Serial.

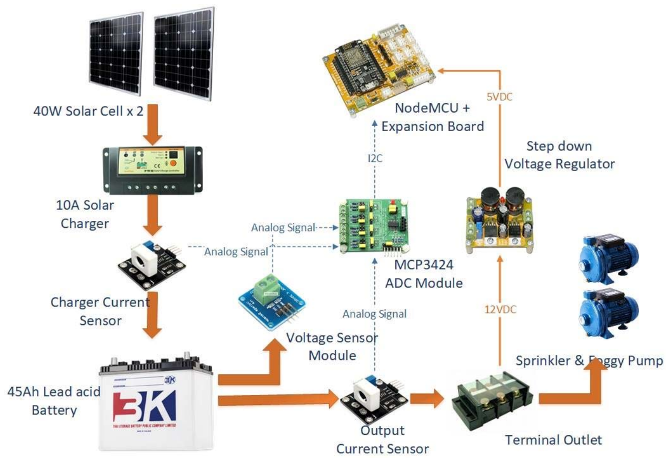


Figure 2: a detail diagram of IOT for solar cell system

From the previous research [2,3], the water sprinkler needs to go off three times a day (09.00, 13.00 and 15.00) for five minutes long each time. For water fog, the moisture must be controlled and is needed throughout the Lingzhi mushroom cultivation. The fog is meant to keep the between 90 to 95 percent. Irrigation data proceed by nodeMCU via NETPIE IOT cloud service and the notification of the status of pumps was on LINE API (Line application).

For this research, the flow chat of the solar cell system was used to validate and check the notification mentioned above, status of pumps. However, in this research, if the current usage was from 2 to 8 amps that meant the fog and sprinkler pump were working and current data proceed through Blynk IoT cloud service and notification was shown on the mobile devices automatically.

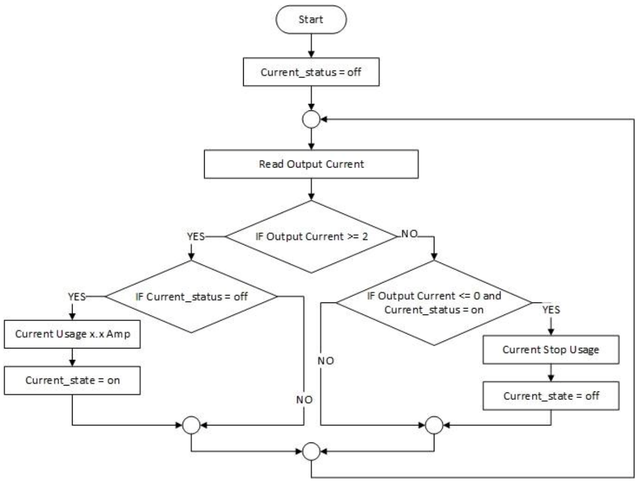


Figure 3. The flow chart of condition of notification on Blynk (the current usage of irrigation system)

C. Implementation

All electronic devices are put in waterproof control boxes. The solar panel and battery are put in a portable stand. The photo of IOT solar system is show in figure 4-5. NodeMCu with expansion board, MCP 3424 ADC module and step down voltage regulator were put together in a small waterproof box. Voltage, current charge, output and 10A chargers were put together in a big waterproof box.

Figure 4. All electronic devices are put in a waterproof control box.

The portable stand was designed to be easily moved if famers would like to use it in an isolated area. The solar panels were also designed to move up and down, up to a 45 degree angle. On the bottom of the stand there is space for more batteries to be stored. All electrical lines can be stored neatly on the stand.

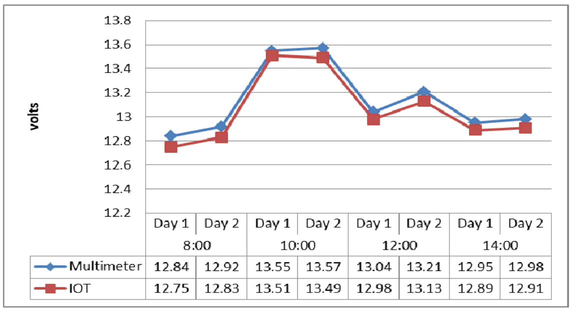
Figure 5. A portable solar cell system for a smart farm

D. IoT solar cell system Validation

In order to make sure the voltage and current sensor and IOT system could measure the solar charging and current loading correctly, the multi meter was used for validation.

Figure 6. A comparison between using IOT and multi-meter to measure current voltage

The comparison of the results of the solar charger (volts) read by IOT and multi meter (manual read) were taken into account. The samples of the solar charger data were 8.00, 10.00, 12.00 and 14 o'clock. The solar charger data in the fig. 6 shows that the solar charger data read by IOT system and multi meter went the same direction and were very similar. However, the solar charger data read by the multi meter was more sensitive as the digits had more decimal places.



	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
	8:00		10:00		12:00		14:00	
Multimeter	12.84	12.92	13.55	13.57	13.04	13.21	12.95	12.98
IOT	12.75	12.83	13.51	13.49	12.98	13.13	12.89	12.91

Figure 6. A comparison between solar charger data measured by IOT system and multi meter (manual)

IV. Results

The voltage and current data read from sensors can be displayed in real time online. It can be shown on mobile devices via Blynk services (app). The research is designed to show the data of the voltage of solar charging from the solar panel into a battery. The power from the sun (ampere)and the fog and sprinkler pumps usage were displayed on screen. In addition, this data can be shown by the historical time series.

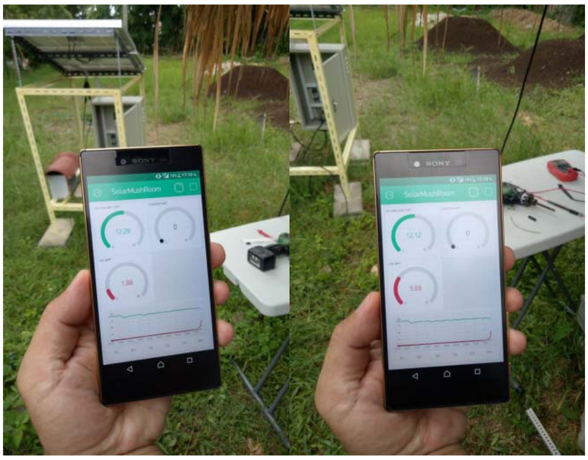


Figure 7. The timestamp with amp used were shown real time on mobile device

The status of the current usages with the irrigation system (fog and sprinkler pumps) was notified on Blynk message box. The message was automatically displayed on mobile screens. In fig. 9, Blynk notifications were shown on the mobile screen displaying the current usage and activity (pump was on)

Notifications from the Blynk app can appear on farmers phones who have subscribed to the same App ID. In this research, SolarMushRoom was created as a group App ID.

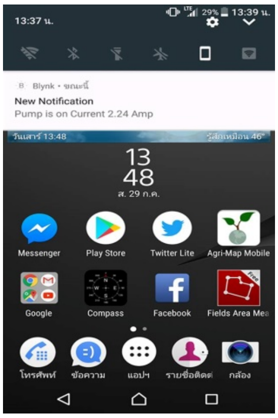


Figure 9. Blynk notification was shown on the mobile screen

Blynk app is an IOT cloud service. It is supported by Android and IOS. In this research, voltage and current data can be displayed every 5 minutes or when activities happen such as a sprinkler or fog pumps turn on (amp used). The voltage and current data can be read from the voltage and current sensors that were stored in a cloud computing service by Blynk. Information could be displayed in a time series graph to monitor the change of the voltage and amp. Historical information of the voltage and amp of the solar system can also be retrieved.

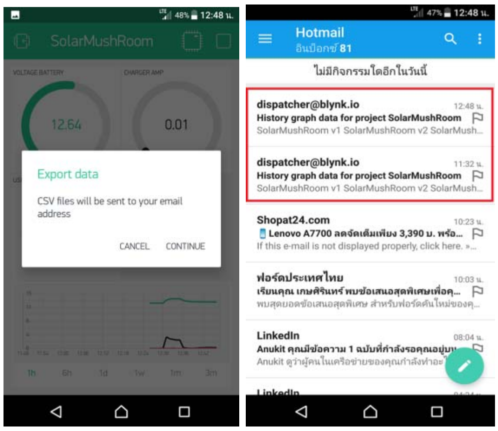


Figure 9. Functional Status of the sprinkler and Fog pumps were notified on LINE Application

The historical voltage and amp data was stored in a service by Blynk which could be retrieved by using function exporting data as CSV (coma separate value files). Those CSV files would send an email to the farmers' email address. In this research, 3 CSV files consist of voltage data, amp charged, and amps used are separated.

For example, the data shows the voltage data and time stamps separately. The time was shown as GMT UNIX Timestamp (milliseconds). As a Thailand time, UTC + 7 was needed to be added. According to fig. 10, the UNIX Stamp was 1500528360000 and was converted to Thai time as Thursday 20 July 2017 at 12:26:00 PM (UTC).

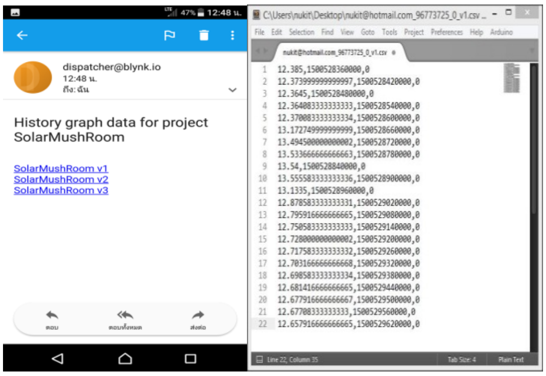


Figure 10. CSV file retrieved from Blynk service

V. Discussion

There were 2 points to discuss in this research. One was on the economic perspective using an IOT system to monitor if the solar cell system was worth the investment. Second, was on the limitation of using the Blynk IoT cloud service.

Firstly, for economic perspective, a newly developed IOT for the small smart solar system was considered not worth the investment. However, it was worth the investment in the isolated area where there was no line electrical supply. The electronic equipment cost approximately 2,000 Baht including NodeMCU V2 (ESP8266 -12E), voltage and current sensors, analog to digital convertor module, step down voltage regulator and relay modules. DC irrigation systems (fog and sprinkler pumps) cost approximately 2000 Baht. The small off grid solar system cost approximately 10,000 Baht including solar panels, solar charger, lead acid battery, stand, and waterproof and control boxes.

The traditional smart Lingzhi farm consumed electricity around 20 units per month. Due to the fact that there is no fee for electricity usage under 50 units, the bill was free of charge [10].

Secondly, the Blynk IoT cloud service used in this research was available free for users. Data of voltage current used cannot send more than 100 values per second. It may cause flood error and IoT solar cell system will be automatically disconnected from the Blynk server. In addition, Blynk IoT cloud accepts 1 message per minute per pin. In case Iot solar cell system sends voltage and current data more frequently data values will be averaged. For example, in case send current value of charging 12.38 volts at 12:12:05 and then again 12.40 volts at 12:12:45 as result in history graph you'll see value 12.39 for 12:12.

VI. Conclusion

IOT Technology was applied for the smart Lingzhi mushroom farm in the previous research, to measure the humidity and control the irrigation automatically. Humidity data and status of pumps (on and off) proceed though NETPIE and LINE API consequently. In this research, IOT technology was applied for the solar system as the alternative energy resource for a smart Lingzhi mushroom farm. Blynk IoT cloud service was applied. Voltage and current (in and out) data was considered reliable and accurate (if compared to the information done manually by using multi- meter). The functional status of sprinkler and fog pumps were done correctly. The project leaders of smart Lingzhi mushroom farm from Maejo University, ChiangMai were satisfied.

VII. Future research

Future research could be done for the improvement of the IOT system, Linkit One with GSM should be applied to replace NodeMCU, in case the Lingzhi mushroom farm and solar cell system have no WIFI, GSM would be an option. Furthermore, LoRa was another optional channel for communication. Moreover, the charger module should be applied to notify the status of the battery online (empty, half, and full). For Maejo University, the comparison of the growth of the Lingzhi mushroom between the farm using the IOT system and using traditional data collection is taken.

VIII. Acknowledgments

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