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An IoT based Low-cost Weather Monitoring System for Smart Farming

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ABSTRACT

Background: Weather monitoring is an important aspect of crop cultivation for reducing economic loss while increasing productivity. Weather is the combination of current meteorological components, such as temperature, wind direction and speed, amount and kind of precipitation, sunshine hours and so on. The weather defines a time span ranging from a few hours to several days. The periodic or continuous surveillance or the analysis of the status of the atmosphere and the climate, including parameters such as temperature, moisture, wind velocity and barometric pressure, is known as weather monitoring. Because of the increased usage of the internet, weather monitoring has been upgraded to smart weather monitoring. The Internet of Things (IoT) is one of the new technology that can help with many precision farming operations. Smart weather monitoring is one of the precision agriculture technologies that use sensors to monitor correct weather. The main objective of the research is to design a smart weather monitoring and real-time alert system to overcome the issue of monitoring weather conditions in agricultural farms in order for farmers to make better decisions.

Methods: Different sensors were used in this study to detect temperature and humidity, pressure, rain, light intensity, CO_2 level, wind speed and direction in an agricultural farm and real time clock sensor was used to measured real time weather data. The major component of this system was an Arduino Uno microcontroller and the system ran according to a program written in the Arduino Uno software.

Result: This is a low-cost smart weather monitoring system. This system's output unit were a liquid crystal display and a GSM900A module. The weather data was displayed on a liquid crystal display and the GSM900A module was used to send the data to a mobile phone. This smart weather station was used to monitor real-time weather conditions while sending weather information to the farmer's mobile phone, allowing him to make better decisions to increase yield.

Key words: Arduino Uno, Internet of Things, Precision agriculture, Smart weather station, Sensor.

INTRODUCTION

Around the world, crop production depends largely on local weather conditions. Most agricultural production is very closely related to atmospheric conditions, apart from the few crops grown in greenhouses or controlled environments. The term "weather" refers to the special state of the atmosphere at a given location and time. Wind speed and direction, air temperature, humidity, atmospheric pressure, cloudiness and precipitation are all factors that are measured. Weather patterns will shift from hour to hour, day to day and season to season. Weather predictions in the past were based on the observation of weather patterns, specifically the type of wind and cloud pattern and its color (Learning and Cookbook, 2019).

But today it updated and modern weather forecasting combined with technology. So currently use an automated system for weather monitoring. An automated weather station is a modernized version of a conventional weather station that uses sensors to measure its various parameters. It is either used to save human labor or to permit measurements from distant areas. A manual weather station, on the other hand, is a more conventional one that still requires human effort, expertise, power and energy to obtain its results.

An automated weather station (AWS) is described as a "meteorological station where observations are made and transmitted automatically." An automated meteorological station is an instrument. It uses sensors to monitor and calculate meteorological parameters without the need for human interaction. The measured parameters can be saved in a built-in data logger or sent to a remote location through a communication connection. If the data is stored in a data logger, it is important to physically download the registered data to a computer for further processing at a later time. However, particularly when the weather station is located in a remote, unattended area, this is not a viable option. In an automated weather station, the communication system is, therefore, an integral feature (Aroos *et al.*, 2011). Automatic

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Weather Station has been commonly used in various fields, such as geostatistical environmental science, temperature calculation analysis, wind energy potential position prediction, mass balance movement measurement and crop water requirement estimation (Munandar *et al*., 2017).

Weather forecasting information provided by metrological services is recorded by weather stations located in the nearby cities or towns and not necessarily the conditions at a farm located hundreds of kilometers away. The use of an onsite weather station can help farmers to monitor the weather conditions at their farms. Otherwise, they can't monitor the real weather forecast.

But the farmer has to bear a big cost for the built a weather station in his field because weather instruments such as rain gauge, barometer, anemometer, wind vane are very expensive. Farmer cannot afford it. Famer cannot keep manual weather stations because it is difficult and impossible. Because during farming operations farmers cannot monitoring weather stations or farmers need to get the labor for the monitoring weather stations. It may increase excess costs because farmers need to pay labor costs also. So it may cause for reduce profit also. Due to these reasons designed low-cost automated weather monitoring and real-time alert system.

The main objective of this study is to establish a prototype of low-cost solar-powered smart weather monitoring and real-time alert system that can be automated, controlled and monitored from anywhere in the world that has cellular coverage. Sub objectives of this study are to detect weather parameters accurately and quickly to make decisions for farmers, to minimize manual intervention to monitoring weather data, to find a cost-effective way to monitoring, to give real-time weather alerts to farmers and to control the damage caused to the cultivation by weather disaster.

In this study used automated weather monitoring system to measure weather conditions by automatically due to the limitation of conventional weather monitoring systems. The weather station measures weather conditions using various sensors such as DHT11, BMP180, FC37, LDR, MG811, Hall-effect sensor, IR sensor that measure temperature, rain, light intensity, relative humidity atmospheric pressure, CO_2, wind speed and wind direction. The primary instruments used are a solar panel, an Arduino and a smartphone application. A central micro-controller was used to collect all the real-time data from the sensors and send it to a user using a GSM network.

MATERIALS AND METHODS

The goal of this project was to design a prototype of a low-cost solar-powered smart weather monitoring and real-time alert system that can be automated, controlled and monitored from anywhere in the world that has cellular service. This study was carried out at Faculty of Technology, South Eastern University in 2021. Using several sensors, the smart weather station measured real-time weather parameters and sent them to a user through a GSM network. This system was mainly used two types of requirements called hardware and software. Arduino Uno microcontroller, sensors, I2C liquid crystal display and GSM900A module was used as hardware requirement. Arduino Uno software and Altium designer was used as software requirement. Table 1 shows hardware and software requirements.

Traditional weather monitoring systems use thermometers and hydrometer to measure temperature and humidity. In this system used DHT11 sensor to measure both temperature and humidity. So it is cost effective because using one sensor can have measured two parameters. FC37 rain drop sensor was used to detect whether it is rain or not. So instead of using tipping bucket, this sensor easily detects rainfall. Commercially available anemometers and wind vanes are very cost but a low cost anemometer and wind vane developed using cheaper materials was used in this system.

The Arduino Uno was the key component of this smart weather monitoring and alert system. All the weather parameters sensors namely temperature and humidity sensor, pressure sensor, rain sensor, real time and clock sensor, light sensor, CO_2 sensor, anemometer and Wind direction detector were connected to arduino uno and programme was created using Arduino IDE. Fig 1 shows how the sensors were connected to the Arduino Uno microcontroller. Sensors were captured weather data according to programme and sent that data to I2C Liquid crystal display to display weather data in the field. That data was same time sent to GSM-900A. If person need that data, can send "STATE" message to GSM module and can get weather to mobile phone. Fig 2 shows block diagram of the system. There is no any human interference and this method of weather data monitoring system was fully automated.

RESULTS AND DISCUSSION

This system was created to monitor weather conditions such as temperature, humidity, light intensity, rainfall, pressure, CO_2 level, wind speed and direction in a specific region. The designed system is more adaptive and distributive in nature when it comes to analyzing environmental parameters. This system was had three main units, which were power unit, sensing unit and output unit.

This system was used a 10W solar panel. In high irradiation, it caught 21.2V. This captured 21.2V was transferred to the system's solar charge control device. 21.2V was converted to 14V in the solar charge controller. That 14V was used to charge a 12V rechargeable battery and divided that 12V into 5V using a voltage regulator. Fig 3 shows diagram of power unit. That 5V was supplied to Arduino Uno microcontroller, all the sensors except BMP180, LCD and GSM-900A. The key component of this system was the Arduino Uno microcontroller. To run it, 5V was provided to the Arduino microcontroller and all other sensors were attached to the Arduino microcontroller. The program was written in Arduino software and uploaded to the Arduino Uno.

Table 1: Hardware and software requirements.

Hardware requirement		
Hardware used	Configuration	Function
Arduino Uno	UNO is based on ATmega328P. Arduino Uno board operate at 5 to 12 DC voltage. Arduino was had ample computing power and memory to run the software, as well as the ability to read several sensors at the same time.	Arduino Uno microcontroller was the main component and this system was operated by Arduino Uno microcontroller.
Solar panel	It was 10W, 17.5V, 0.57A solar panel.	Used to supplied power to system.
Rechargeable battery	12V rechargeable battery.	The system's primary power source, which was connected to the solar charge controller and solar panel. Used to supplied 12V to voltage regulator.
DHT11 sensor	Operating voltage is 3-5.5V and measuring range is 20-90%RH and 0-50°C.	Used to measured temperature and humidity in the atmosphere.
BMP180 sensor	Operating voltage is 1.8-3.6V and measuring range is 300-1100 hPa.	Used to measured pressure in the atmosphere.
FC37 sensor (rain drop sensor)	Operating voltage is 5V.	Used to measured whether it is rain or not.
Light dependent resistor	Operating voltage is 5V.	Used to measured brightness of the light.
MG811 sensor	Operating voltage is 5V and measuring range is 350-10000 ppm.	Used to measured CO_2 amount in the atmosphere.
Hall-effect sensor	Operating voltage is 5V.	Used to developed anemometer to measure wind speed.
Infra-Red sensor	Operating voltage is 5V and measuring range is up to 20 cm.	Used to developed wind vane to measure wind direction.
DS1307 real time clock sensor	Operating voltage is 5V.	Used to detected date and time.
16 × 2 Liquid Crystal Display	Operating voltage is 4.7-5.3V.	Used to displayed weather data.
SIM900A GSM module	Operating voltage is 4.3-5.5V and SIM900A is a dual-band GSM/GPRS engine that works on frequencies EGSM 900MHz and DCS 1800MHz.	Used to sent weather data to mobile phone.
Stevenson screen	Wooden type with louvre.	Used to positioned sensor.

Software requirement	
Software used	Function
Arduino Uno software	Used to written program of the system.
Altium design software	Used to created circuit diagram of the system. Fig 1 shows circuit diagram of the system.

Temperature and humidity were measured using a DHT11 sensor. *Via* voltage regulator, 5V was supplied to the DHT11 sensor.

BMP 180 sensor was used to detect pressure in the atmosphere and supplied 3.3V through Arduino because the operating voltage of the BMP 180 sensor is 3.3V. The FC37 sensor was used to detect rain. There were used three conditions for rain sensors in the programme. Requirements were titled "RAIN," "RAIN WARNING" and "NOT RAIN." Rain sensor was sensed rainy data based on values written on coding. In that range, the sensor was detected 0 value, it was displayed "Raining," the sensor was detected value 1, it was displayed "Rain Warning," the sensor was detected value 3, it was displayed "Not Rain." A light sensor was used to detect the brightness of the light. It had a light dependent resistor. That LDR was sensed the brightness of the light. As a working voltage, 5V was supplied through a voltage regulator. The LDR sensor program was provided five conditions: "VERY BRIGHT," "BRIGHT," "LIGHT," "DIM," and "DARK." Then five analog values were given for those conditions and the LDR sensor output was based on those analog values. MG811 CO_2 sensor was used to detect CO_2 amount in the atmosphere and supplied 5V to the sensor via voltage regulator to operate the sensor. Real time clock sensor was used to provide real time weather data. For this, 5V was supplied through a voltage regulator.

Anemometer was used to detect wind speed. In this system, a cup anemometer was used with a hall effect sensor to detect wind speed. Three cups were used in an anemometer and, based on the rotation of that cups and converted into km/h and used to detect wind speed. Wind vane was used to detect wind direction. 8 IR sensors were

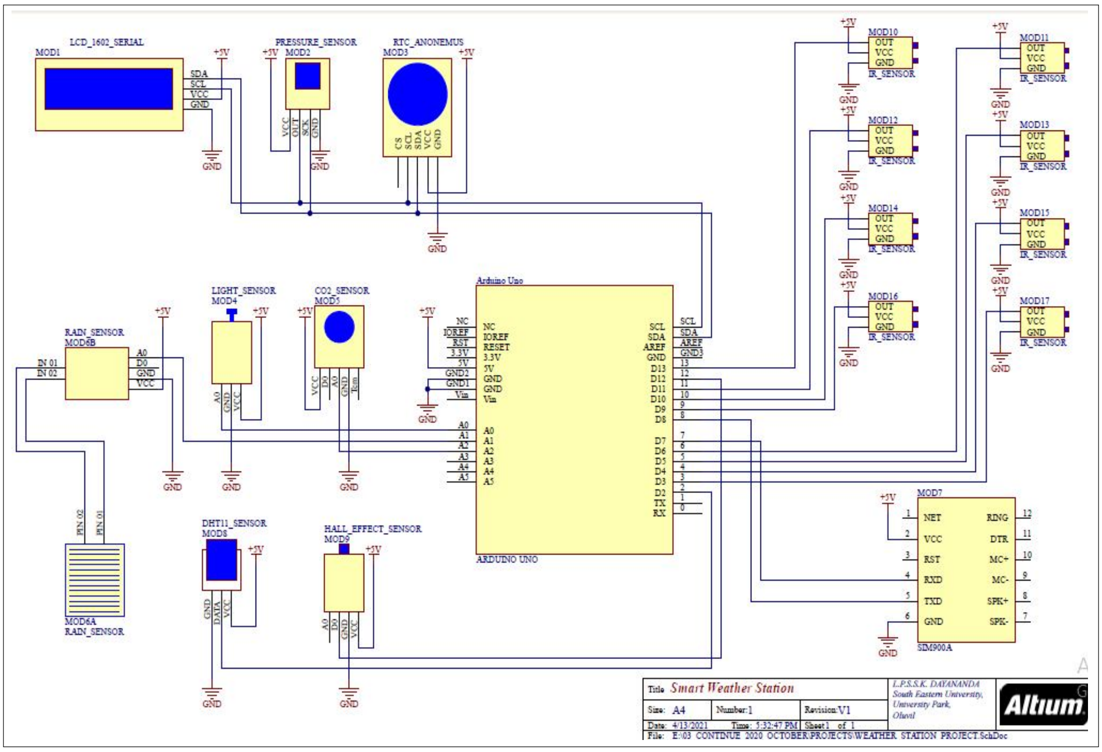

Fig 1: Circuit diagram of the system.

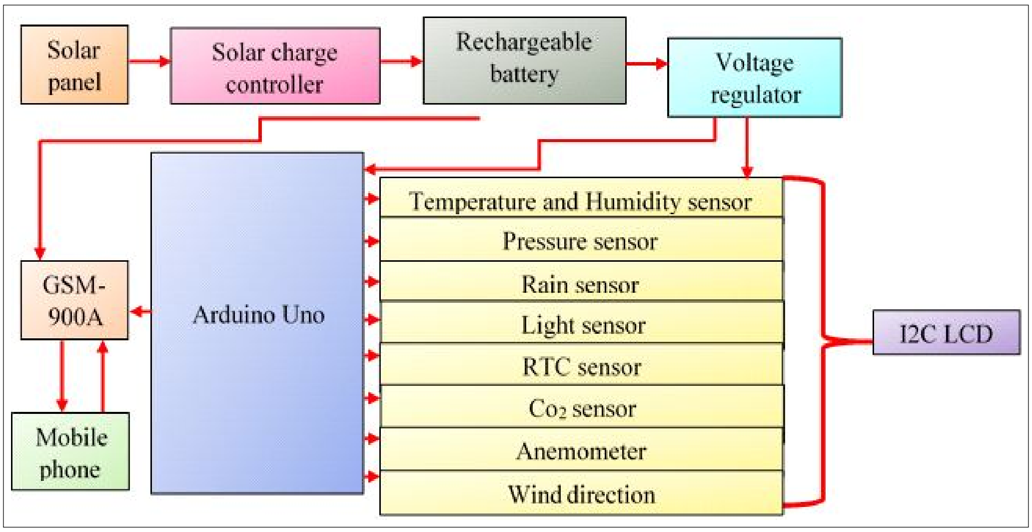

Fig 2: Block diagram of the system.

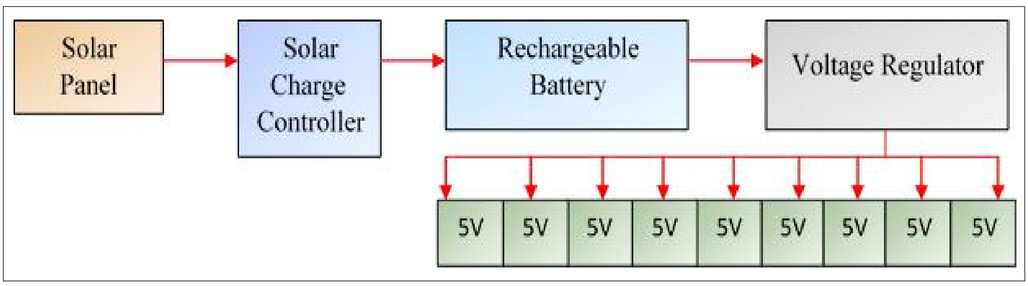

Fig 3: Diagram of power unit of the system.

Fig 4: Output Unit of the system.

used to detect eight directions in the Wind vane. Both these anemometer and wind direction are very low cost because cheaper materials were used to develop that device. All these sensors were operated according to the programme written on Arduino IDE.

The out-put unit was had I2C liquid crystal display and GSM-900A. Fig 4 shows output unit of the system. LCD was used to display weather data in the field. 16×2 LCD was used in this system but it was difficult to connect 16 pins to the Arduino board. So I2C module was used to reduce 16 pins into 4 pins. It was fixed near to the weather station and anyone who came to the field can easily show the weather situation in the field. GSM was used to send weather data to user in this system. GSM (Global System for Mobile Communications) is a wireless cellular infrastructure that is open and used to transmit mobile voice and data services. In this system, GSM 900A was used because it consumes low power. The standard mobitel sim card was inserted into GSM and 5V was via voltage regulator and connected to Arduino board. If the user needs to know weather data infield, can get weather data without coming to the field. Anywhere, anytime can get weather data to mobile phone through GSM. When the user sends message as “STATE”, user receives weather alert. All these sensors, microcontroller, LCD and GSM placed in louvered type Stevenson screen.

Finally, this system was implemented in the “Smart Agro Tech Park” module. Fig 5 shows smart weather monitoring system. It was sensed all of the accurate weather data in the area, such as temperature, humidity, pressure, light intensity, rain, CO_2 level, wind speed and direction and the data was displayed on the LCD and sent it to the mobile phone.

Using real-time data on weather conditions related to the current location and season assists farmers in taking care of soil and crops as well as managing any weather-related hazards. The applications of IoT in agriculture are domain. IoT sensor based weather monitoring system is one of the main application used to monitor weather automatically. IoT sensors set the groundwork for a larger linked system for agricultural weather monitoring. These systems are based on a network of linked sensors that collect data in the field. The acquired data is then processed by cloud computing systems, which provide warnings and messages about potential weather dangers impacting crops. Farmers can use IoT systems to gain real-time access to environmental and soil data, allowing them to plan actions ahead of weather changes. Advantages of using IoT based

Fig 5: Smart weather monitoring system.

Fig 6: MG 811 Co_2 gas sensor.

weather monitoring system in agriculture are reduce crop hazards by keeping an eye on severe weather patterns, assist farmers in optimizing resource usage and crop protection, improve product quality by advising on the optimal time to harvest, send real-time alerts to many devices and platforms and collect accurate data in the field that is relevant to the location of the farm and the current season.

Sharma, 2019 created an automatic weather station that is operated by electricity. Using electricity is not cost-effective and farmers would pay a premium for it. Today, electricity is the world’s most limited resource. A wide range of industries is now using renewable energy sources. So in this system used solar power to supply power to the system. It is both an energy-saving and cost-effective system. CO_2 is essential for photosynthesis and evidence suggests that increasing CO_2 concentrations will accelerate plant growth. So knowing CO_2 level for farmers is very important. Veeramanikandasamy *et al*., 2020 used MQ 135 gas sensor to detect gases.

Fig 7: Low-cost wind vane.

The MQ135 gas sensor detects oxygen, alcohol, ammonia, nitrogen, sulfide, aromatic compounds and smoke. It not exactly senses only CO_2. In this system, used the MG 811 CO_2 sensor which sensed the exact amount of CO_2 level in the atmosphere. Fig 6 shows MG 811 CO_2 gas sensor. MG 811 sensor is better than MQ 135 sensor because farmer can accurately get CO_2 level.

Satyanarayana *et al*., (2016) used an automatic tipping bucket rain gauge in their weather station to detect rain. Rahut *et al*., (2018) created another smart weather station and they used an ultrasonic sensor to detect rainfall levels. In this system was used raindrop sensor. More maintenance need for the automatic tipping bucket rain gauge so difficult to use for farmers. But the raindrop sensor only needs to be installed in the proper place and no need for any maintenance. The automatic tipping bucket rain gauge needs more space to compare to the raindrop sensor. Raindrop sensors only monitor whether it is raining or not and do not provide a rainfall rate. If farmers need to know the rainfall rate they can use the ultrasonic sensor with the raindrop sensor to detect the rainfall rate. So using a raindrop sensor to detect rain is cost-effective for farmers.

Aroos *et al*., (2011) develop an automated weather station for measuring ground-level weather measurements. In that system, they used a data storage module. Micro SD card used as data storage module and it saved real-time weather data. But in my system, data storage is not available. The data logger is important because for analysis purposes can get previous data. Munandar *et al*., (2017) developed a real-time automated weather station. They used a user-friendly interface. The color of the graph varies depending on the weather parameter to improve the accessibility of the user interface. This makes it easy to differentiate between parameters. Temperature increases, temperature changes, atmospheric pressure changes, precipitation changes and solar radiation changes are all represented by the colors red, cyan, purple, blue and pink.

Chawla *et al*. (2015) used the android interface to showcase the weather data. The key benefit of using this application is that it has a user-friendly interface that eliminates all ambiguity for the user. The interface is divided into several panes for configuring the system and displaying the incoming data. On the terminal pane, the data to be sent or displayed is illuminated. Other panes, such as the toolbar pane, have their own basic application, such as the special characters' button. These user-friendly interfaces help in clearly displaying weather data to users. However, in this system, weather data is sent to the user's mobile phone as a message.

The direction of the wind is stated by the direction from which it originated. A north or northerly wind, for example, blows from north to south. Wind direction is typically provided in cardinal (or compass) directions or degrees. As a result, a wind coming from the north has a wind direction of 0° (360°); a wind blowing from the east has a wind direction of 90° and so on. Wind direction measure using wind vane and there is available automatic wind vane. Kong, (2017) include market available automated wind vane for his smart weather station. The Wind vane has eight switches, each of which is attached to a separate resistor. The WeatherRack calculates the resistor's resistance value by calculating the voltage around a resistor divider (with 10K Ohm onboard resistor). Normally, the Wind Vane can only sense 8 directions. It is possible to read 16 directions on occasion (when two connections are closed at the same time), although this is an uncommon occurrence. This study created a low-cost wind vane and used 8 infrared sensors. Fig 7 shows wind vane of this system. The wind vane used by Kong in 2017 is very pricey and needs a higher voltage to operate. However, the wind vane that used in this system is inexpensive and uses low power to operate.

Chawla *et al*. (2015) created an automatic weather station with a HC-05 Bluetooth module to send weather data. Hussein *et al*. (2020) developed another automated weather station. The weather station system created using Arduino Uno and ZigBee technologies in combination with sensors. ZigBee technology used to transmit weather data to the end-user. Srivastava *et al*. (2020) developed one automated weather monitoring system. In that system used ESP8267 Wi-Fi module to transfer weather data. Wi-Fi, Bluetooth and ZigBee wireless technologies have very short transmitting ranges. But in this system used GSM to send weather data to the end-user. The transmission range of ZigBee is 10-100 m and the Bluetooth module is 10 m meanwhile the transmitting range of a Wi-Fi module is up to 1 km. GSM has a transmission distance of 35 km. From Wi-Fi, Bluetooth module, ZigBee and GSM, GSM has the longest range, making it suitable for outdoor use. Wi-Fi, bluetooth modules and ZigBee are more suited for indoor use. Otherwise, there could be problems with data transmission limitations.

Conclusion

Monitoring the weather is useful in a number of realistic scenarios including agriculture, archaeology, construction, tourism and many other areas. Weather can be monitored manually or automatically. Many areas use IoT-based technologies as a consequence of the growing use of the internet. As a result, the manual weather station has now been updated to a smart weather station. This research developed a smart weather station that can reliably monitor the weather and deliver real-time weather information to the end-user.

The project was finished, reviewed and the intended result was achieved, monitoring real time local weather conditions. The user would be able to monitor real time weather conditions such as temperature and humidity, pressure, rain, light intensity, CO_2 level, wind speed and wind direction using this system. The project's fundamental goal is to create a modular and cost-effective mechanism for monitor real time weather conditions using renewable energy and improve local agriculture using IoT.

Recommendation and Future Works

Based on the project's expertise and difficulties, it is recommended that these steps be implemented to increase project quality. Installing more sensor to detect solar radiation, soil moisture sensor, rain intensity which parameters are important for agriculture. Developing user friendly interface to send data to end user. Developing data logger for storage data to future works. Supplying power using electricity also to use rainy season. Making indoor climate controller by using this smart weather station for greenhouse. Implementing in hospitals or medical institutes for the research and study in "Effect of Weather on Health and Diseases", hence to provide better precaution alerts. Introducing to aircraft, navigation and military because there is a great scope of this real-time weather station.

These steps will install to optimize smart weather monitoring and real-time alert system. More sensors will install to system such as solar radiation sensor, soil moisture sensor, rain intensity sensor which are important to agriculture. Data logger and user friendly interface will develop to storing weather data and sending weather data to end user easily. Power circuit will develop by using electricity to use in rainy season otherwise solar power is not enough in rainy season.

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