IMPLEMENTATION OF A SOLAR POWERED IoT WEATHER STATION IN A REINFORCED COMPOSITE PLASTIC EMBODIMENT FRAME

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Abstract

Researchers and related organizations that use weather data still have difficulties in accessing real-time meteorological information. In order to read and record temperature, relative humidity, rain drop frequency, pressure, light intensity, wind speed, and wind direction in real-time, this work built a solar-powered Internet of Things weather station employing an embodiment frame made of reinforced composite plastic. The weather parameters were measured using an anemometer, wind vane, BMP 180 sensor, DHT22 sensor, rain drop sensor, and LDR. The central processing unit in the design is a microcontroller, which uses internet of things (IoT) technology to enable processed data from the microcontroller to be transmitted to a dedicated webpage via a Wi-Fi module for real-time observation of weather data measured by the device. The microcontroller also converts measured weather parameters into a useful and observable format for on-site users on an LCD. The device's backup battery and solar panel were used as power sources so that it could operate continuously.

Keywords: *Microcontroller, Electronic Sensors, LCD, Wi-Fi module, solar panel*

1.0 INTRODUCTION

Because it is so important to so many aspects of civilization, weather monitoring is highly valued. It makes it possible to gather data on weather variations, which is crucial for the meteorological study, atmospheric research, agricultural field, industrial condition monitoring, aviation, and communication sectors (Ehigiator *et al.*, 2024).

Research has shown that in the coming generations, climate change will have a significant impact on human activity, global weather conditions, and agricultural productivity (Walthall *et al.*, 2018). The security of food and water, human health, and socioeconomic growth are all at risk due to rising sea levels, changing precipitation patterns, temperature swings, and more extreme weather events (Ukim *et al.*, 2023).

The short-term state of the atmosphere, including temperature, relative humidity, cloud cover, rainfall, wind speed, and fog, at a certain time and place is called the weather (Anthony *et al.*, 2019).

Without the aid of an external source, a microcontroller weather station uses sensors to read and record meteorological data. The gathered meteorological data can be wirelessly transferred via a server or stored as wired data that can be downloaded onto a computer (Ughanze *et al.,* 2019).

A sensor is a device that measures a physical quantity and converts into analog or digital signal that an observer or instrument can read (Anuj *et al.,* 2010).

The term "internet of things" (IoT) describes the technology that enables communication between physical objects, structures, cars, and other components like sensors and actuators (Maulik and Irshad, 2018). IoT is regarded as one of the most potent technologies since it connects a vast array of items and people over the internet. Unlike other technologies, such as sigtox, RFID, and Bluetooth, it also has its own communication system (Annita and Rahul, 2023).

Temperature, relative humidity, light intensity, atmospheric pressure, frequency of raindrops, wind direction, and speed will all be measured by the weather station that is being created. This weather station's central processing unit, a microcontroller, will retrieve and process measured parameters from the sensors into a format that is readable and useful for observers both on-site (on an LCD) and off-site (on a web page). It will also archive all measured weather data in an Excel file format for future study and analysis. The weather station's power source for continuous operation will be solar panels.

Compared to wired systems, wireless weather monitoring systems have the advantage of not requiring a human's physical presence. This improves the measurement, analysis, acceptability, and accuracy of meteorological parameters. Furthermore, end users can easily configure a wireless system to connect to other devices, such web servers and smart phones, enabling them to use their internet-capable electronic gadgets for various purposes (Tanmay *et al.,* 2023). ThingSpeak is an open source internet of things (IoT) application and API that stores and retrieves data from devices over a local area network or the internet using the HTTP protocol, according to its developer. ThingSpeak makes it possible to build a social network of things with status updates and sensor tracking apps. ThingSpeak's integration of support for MathWorks' numerical registering programming MATLAB enables users to analyze and visualize transferred data using MATLAB without needing to purchase a MATLAB license (Bullipe *et al.,* 2016).

2.0 MATERIALS AND METHODS

The developed solar powered IoT weather station in a reinforced composite plastic embodiment consist of different sections: power supply section, electronic control section, temperature and relative humidity monitoring section, pressure monitoring section, wind direction monitoring section, wind speed monitoring section, light intensity monitoring section, rain drop frequency monitoring section, display section and data transmission section. The outlines of various design stages and some of the procedures involved in the implementation of the weather station are detailed in this section. Also, a block diagram is utilised in the system design. Stages involved in the implementation of the device are itemized below:

a. Block diagram showing the system design
b. Section by section explanation of the system design
c. Circuit diagram utilised in the implementation of the work
d. Hardware materials employed to develop the composite plastic embodiment

2.1 Hardware design

The block diagram of the device in figure 1 below depicts the different sections that make up the solar powered IoT weather station.

2.2 Power supply section

Because solar radiation is abundant in Africa, the device is powered by solar energy through the power supply component. The solar panel, charge controller, voltage regulator, and backup battery are the main components of this area. The weather station can run around the clock thanks to its solar panel power supply. The weather station is kept operational by the device using the backup battery at night when there is no sunshine. The solar panel's output is connected to a charge controller, which lowers the voltage to 12 volts so that the 12 volt battery can receive it. Also, a voltage regulator is interfaced at the output of the battery to regulate the 12V to 5V which is the required operational voltage of the circuit.

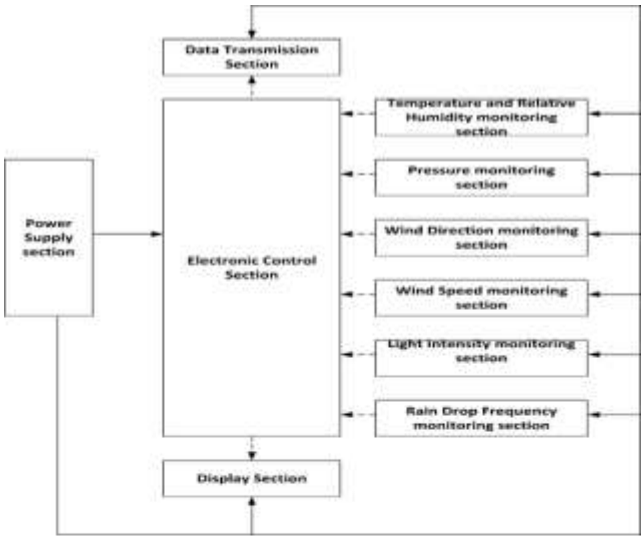

Figure 1: Block diagram of the device

2.3 Electronic control section

The weather station's central processing section is the electronic control section which is made up of the microcontroller. It retrieves data from all of the weather parameter sensors by connecting its input pins to the output sensors' pin connections, processes the data into an LCD format that is readable by on-site observers, and uploads the data to a server for off-site observers. Additionally, meteorological data that is shown on the LCD and server is saved in an Excel file format for analysis by researchers in the future. An 8-bit, low-power CMDS microcontroller is the Arduino Pro small. It can carry out strong instructions in one clock cycle. Microcontrollers are available at 5V and 3.3V voltages. Since 5V operates at a crystal frequency of 16 MHz and doubles the speed at which instructions are executed, we used it in this work (Dhore and Rajbhoj, 2019). Six of the input/output pins can be used as PWM outputs. There are also six analog inputs, an on-board resonator, a reset button, and mounting holes for pin headers. The board can be powered and communicated with by connecting the six-pin header to any FTDI or Spark fun break out wire (Rusimamto *et al.,* 2021).

2.4 Temperature and relative humidity monitoring section

By using the proper pin connections to connect the sensor and microcontroller, the temperature and relative humidity detection unit is able to generate an electrical signal that indicates the ambient air temperature and relative humidity. The DHT22 is a low-cost digital temperature and humidity sensor. It employs a capacitor-based humidity sensor and a temperature sensor component to sense the air around it. The output sensor component sends a digital signal to the appropriate data pin; this sensor is precise and faultless, and it functions in a broad range of temperature and humidity (Ndaliman *et al.,* 2023).

2.5 Pressure monitoring section

Pressure monitoring section utilises BMP 180 sensor. The BMP180 is used to detect atmospheric pressure in its surroundings. The four pins of the I^2C device BMP180 are SDA, SCL, VIN, and GND. Via the Lim 317 voltage regulator, 3.3V connects Vin and GND. The Arduino D2 pin is connected to SDA, and the Arduino D3 pin is connected to SCL. A high-precision server is the BMP180. Pressure is detected by the BMO 180 sensor and is transmitted as digital data. (Abinav *et al.*, 2023)

2.6 Raindrop frequency monitoring section

A basic rain detection device is the rain sensor module. It is employed to gauge the intensity of rainfall. The module features an adjustable affectability potentiometer, a power pointer LED, a rain board, and a separate control board for additional accommodations. When the DO output is high and there are no raindrops on the induction board, the LED connected to a 5V power supply will turn on. The switch marker will illuminate when the DO output is low, as you drop a small amount of water. Remove the water beads, and the system will output a high state after it has returned to its initial state (Adil *et al.,* 2017). The rain drop sensor module produces analog output. It has an analog pin connected to it A0 (Ambr *et al.,* 2016).

2.7 Light Intensity Monitoring Section

This section uses an LDR sensor light dependent resistor, also known as a photo resistor or photocell, to measure light intensity. When it interacts with light, it provides the value of changing resistance. Reduced light yields a lower value of light intensity, and vice versa (Amber *et al.,* 2016).

2.8 Wind speed monitoring section

The wind speed is measured using three cup anemometer equipment. A reed switch is positioned perpendicularly to the magnet at the base of the shaft, which holds the three-cup anemometer. A magnet is fastened to the shaft. The reed switch causes a logic zero to be sent to the microcontroller with each rotation of the three-cup anemometer caused by wind and the passing of the magnet. The microcontroller counts the triggers as the procedure proceeds. For every rotation made after the selected interval of time the microcontroller calculate the wind speed using Davis equation;

$$V = P\left[\frac{2.25}{T}\right] \quad (1)$$

Where V is the speed in miles per hour (m/h), P is the number of pulse during sampling period and T is the period per second (Ughanze *et al.,* 2019).

2.9 Wind direction monitoring section

A wind vane is put together so that the shaft is directly connected to a continuous moving variable resistor, producing an output of 0V to 5V, or 0° to 360°. The reference degree is 0° in the north, 90° in the east, 180° in the south, and 270° in the west (Ughanze *et al.*, 2019).

2.10 Display monitoring section

In the display monitoring part, an LCD is used. A 20x4 LCD that displays the microcontroller's processed data is connected to it. Connecting the microcontroller output pins to the LCD input pins allows viewers on the scene to see real-time weather parameters. (Muhammad *et al.*, 2021).

2.11 Data transmission section

The ESP8266-01 Wi-Fi module is used in the data transmission section to function as a communication link between the microcontroller and an online server so that processed data may be submitted. Atmospheric temperature, relative humidity, atmospheric pressure, frequency of raindrops, light intensity, wind speed, and wind direction will all be shown graphically and digitally on the internet server so that users that are of-site can assess weather information from the device from any location in the world. The ESP8266, a highly integrated system on a chip (SoC) with a transceiver module, 22 various pin types, including UART, GPIO, I2C, MISO & MOSI of the SPI interface, RST, and power supply, is the foundation of the Wi-Fi module. The 3.3 V DC low input power Wi-Fi module is great for delivering sensor data to a connected MQTT broker and to a local connected device for remote monitoring in the event of an internet outage. It has a low-power 32-bit CPU, a TCP/IP protocol stack, a TR switch, a power amplifier and corresponding network, a voltage regulator and power management components (Kirit *et al.*, 2016).

2.12. Circuit diagram of the device

Figure 2 is the overall circuit diagram showing the interconnections between components that were utilised to physically implement the weather station:

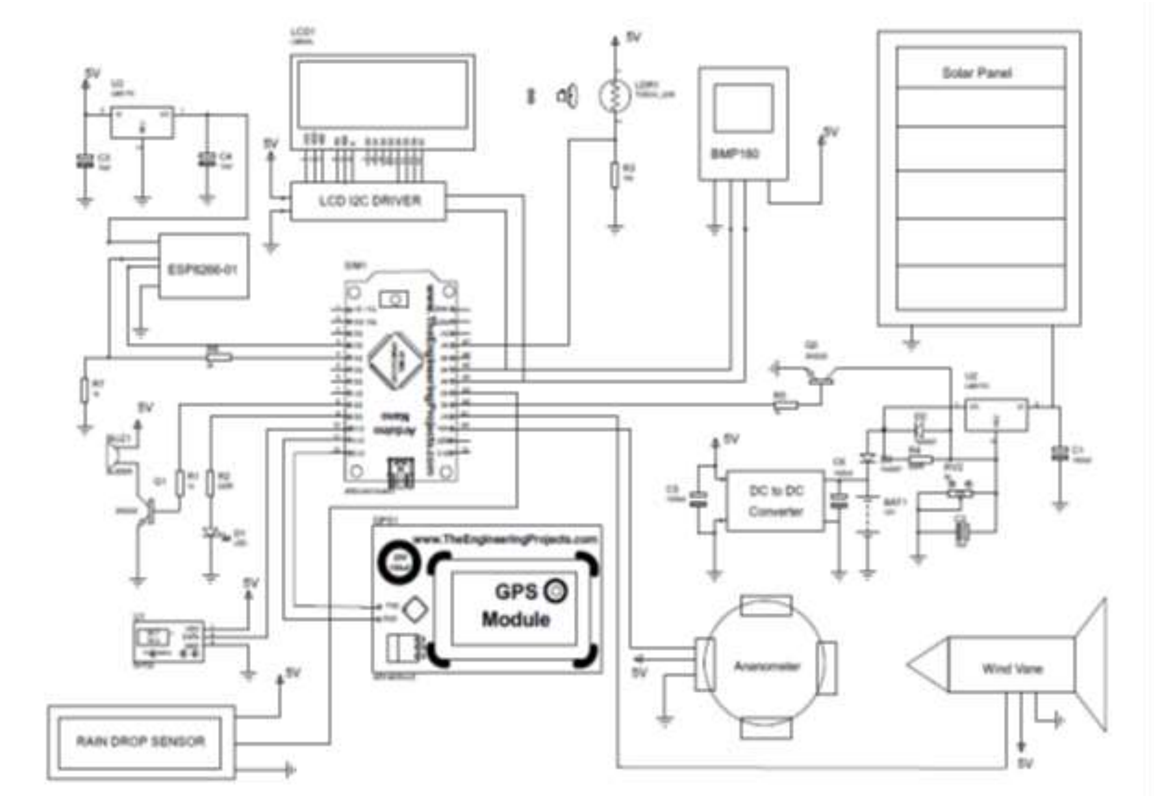

Figure 2: overall circuit diagram of the device

2.13 Development of the embodiment frame locally

For the development of the embodiment frame the following materials were considered:

1. Resin
2. Accelerator
3. Catalyst
4. Fiber mat
5. Calcium dust
6. High density wood
7. Sand paper of different surfaces
8. Lathe machine
9. Solid work soft ware
10. Drill bit machine and drill bits
11. Plaster of Paris

The embodiment frame model is modeled on 3D with the aid of solid work software, there after a high-density wood is physically used to form 3D model of the embodiment frame. Plaster of Paris (POP) is utilized to create the mould in the high-density wood already formed; the complete mould is waxed so as to enable easy removal of embodiment. Thereafter a composite material that will be used to produce the frame is made by mixing the following materials: 4 liters of resin in liquid form was mixed with 30 ml of accelerator 3.9 kg of calcium dust and 9 ml of catalyst are all mixed together. This transforms the liquid into a jell like solution. The solution is transferred in the mould and allowed to solidify after some hours. In order to reinforce the embodiment of the frame, fiber mate is inserted in the semi-solidified solution. At this point more resin is introduced to bond the fiber mate with the semi-solid solution already formed. The solution is allowed to completely solidify, there after the produced embodiment frame takes the shape, we want it to be, which is a rocket like shape The produced frame is taken to a lathe machine for purpose of uniform smoothing with aid of sand paper of different surfaces, after carefully using sand paper to uniformly smoothen the surface of the embodiment frame, the frame is neatly primed. At this point the primed frame is allowed to dry; thereafter the frame is sprayed with the choice color the producer wants which is silver color.

3.0 RESULT

3.1 Simulations with Proteus

Following the successful completion of the circuit design analysis, the design was virtually implemented using the Proteus software work bench in order to identify potential logical problems in the program and incorrect hardware design processes. Faults were not found during and after proteus simulations. Design simulation is shown in Figure 3.

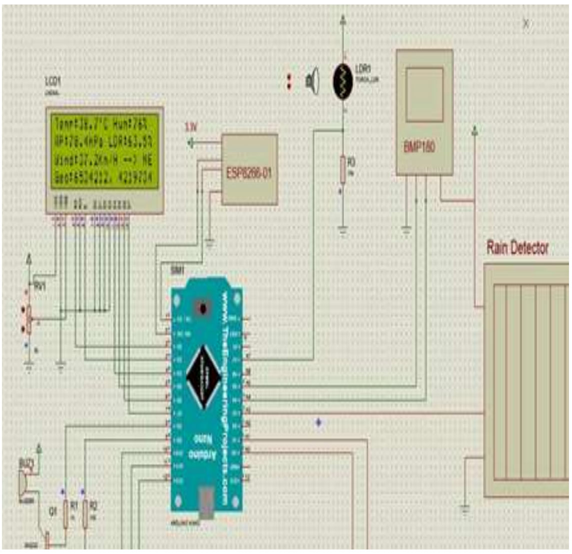

Figure 3: Design simulation

3.2 PCB Boarding

Electronic components and hardware were assembled on the PCB and weather parameters display on the LCD. This is required in order to look for potential hardware design flaws that proteus simulation might miss. After testing and making required modifications, the concept was successfully put into practice.

3.4 IoT Weather Station in a Reinforced Composite Plastic Embodiment Frame

Figure 4 and figure 5 show the front and back view picture of the developed solar powered IoT weather station in a reinforced composite plastic embodiment frame

Figure 4: Front view of the IoT mobile solar powered weather station.

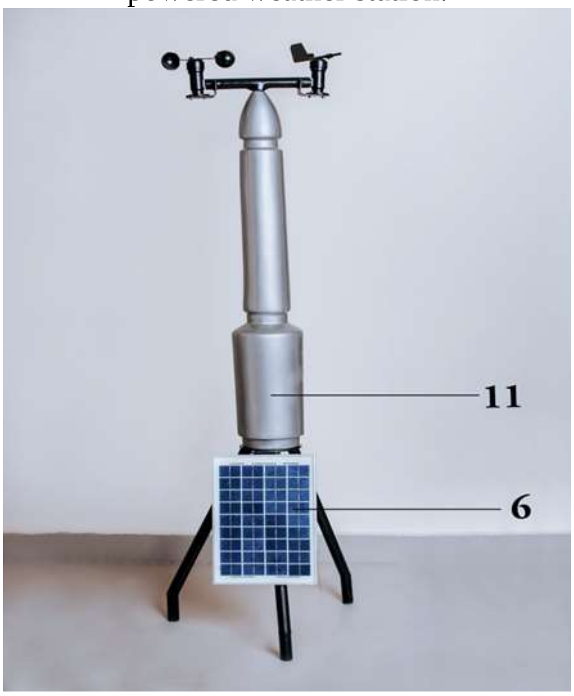

Figure 5: Back view of the IoT mobile solar powered weather station

The labels on the weather station are detailed below:

(1)Three cups anemometer, this component aids monitoring of wind speed.

(2)Reinforce composite plastic frame on upon which the wind vane and anemometer platform is resting on.

(3) Rain drop sensor, this sensor measures the frequency of rain drop.

(4)LCD, the screen that displays real- time weather information for on-site users.

(5) Switch button, this button is used to turn on or turn off the weather station.

(6)Solar panel, it the renewable energy source that power the weather station.

(7) Tripod stand, it the stand that supports the complete IoT mobile solar powered weather station.

(8)Wind vane, it responsible for wind direction measurement.

(9)Three coups and wind vane metallic frame, it Supports wind speed and wind direction components.

(10) LCD cover, it functions as a shield to the LCD when the weather station is deployed to the field for weather data collection.

(11) Reinforce composite plastic control panel frame, it the frame that houses the electronic atmospheric temperature sensor, relative humidity sensor, atmospheric pressure sensor, battery, charge controller and other circuitry components.

4.0 CONCLUSION

The aim of this work is to develop a low-cost, mobile, solar powered microcontroller-based IoT weather station in a reinforced composite plastic that will provide real-time atmospheric temperature, relative humidity, and atmospheric pressure, light intensity, rain drop frequency, wind speed and wind direction on an LCD for on-site users. Additionally, submit digital and graphical weather data to an online server for off-site observers in an excel file format for further study and archiving. This research was able to ttransform the design concept into physical reality for the benefit of mankind.Thus giving the weather station an advantage of mobility, efficiency, affordability, and real-time acquisition of meteorological information into one package.

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