Journal of Manufacturing Engineering, June 2025, Vol. 20, Issue. 2, pp 076-094
DOI: https://doi.org/10.37255/jme.v20i2pp076-094

UNMANNED WEATHER STATION REAL-TIME DATA DISSEMINATION VIA TWITTER

Hewa Thalagahage[1], *Dushan D[2], Sannasgama[3], Ashen K[4]

[1,2] MSc (Applied Electronics), [3,4] BSc (Hons) in Engineering Physics, Department of Electrical Technology, University College of Rathmalana, Rathmalana, Sri Lanka

Abstract

Knowing what the weather will be like is important for most human activities. Therefore, most meteorological services are available online but provide generalized information. It is more reliable if a person can get weather information from their real-time environment. This project aims to create a point-specific online platform to distribute rapid and accurate meteorological data from a real-time environment of interest and send those data on social media without human involvement fully automated system. This project used industrial sensors such as BME 280 for temperature, humidity, and pressure, ML8511 sensor to measure Ultraviolet radiation as an index, and customized sensors to get wind speed, wind direction, solar light intensity, and rain gauge. ESP 32 is a microcontroller used to process data and send that data to Google Sheets and Twitter. All the weather parameters are in standard units, and 0.01 accuracy of the reading. This is a fully automated system that uses a solar panel to run during the day and at night, using battery power that is charged during the day using solar power. In this instrument, most of the sensors are calibrated using chemical methods and laboratory instruments. The instrument is tested for several days indoors and several weeks outdoors. In testing, there are different weather scenarios, so all the instrument parameters are tested in real-time in the real world. In indoor testing, under less solar light conditions, it runs smoothly all day with the built-in battery for 4 to 5 days without charging. Using solar panels and batteries as a power source, it can run without human involvement. The purpose of the project is to send a designed unmanned weather station that sends weather data as a Twitter message, so the system is working smoothly; hence, the overall project is completed.

Keywords: *Unmanned weather station, Twitter, DIY Wind speed sensor, DIY Wind direction sensor, DIY rain gauge, Solar charger for ESP 32, ESP 32 Twitting.*

1. Introduction

When people are doing jobs in agriculture, construction, naval-related, aviation, etc.. The weather is the most effective and impactful parameter on production. So, knowing the current time and weather parameters is essential for a great outcome and quality production. Some weather parameters, such as wind speed and direction, light intensity, are sudden moving parameters, and they depend on small area effects. In modern technology, many smart IoT devices can connect humans to real-time information. Nowadays, people are very active on social media, so sending the nearest weather parameter as a social media message is great, and it is easy to close that information to a human. This project aims to construct a weather station that can send weather data as a Twitter message without human involvement. As electronic devices work without human involvement, we need to consider their power supply. Sri Lanka is a country that gets very high-intensity solar energy. So, in this system, solar panels are used as the primary power source, and a light sensor and rechargeable battery array are used as a secondary power source. To measure temperature, Humidity, and Air pressure, we used a BME 280 sensor, a wind speed, direction sensor, and to measure rain, we designed it by using SolidWorks 2017 and using PLA plastic to print using a 3D printer, and used ML8511 to measure UV light intensity $m^2\ and$ UV index unit. An ESP 32 microcontroller board is used to process data, and Wi-Fi is used to connect the system to the internet. This system sends data to several platforms, such as Twitter, Google Sheets, and MQTT. For further analysis purposes, we can use the Google sheet data to determine whether the data can be used on Twitter or MQTT.

2. Methodology

The stand of the weather station was designed using SolidWorks 2017, and it was built from a 25mm x 25mm galvanized steel box bar with a wall thickness of 1.2 mm by using MMA welding. This was

**Corresponding Author -E-mail: htddinushka@gmail.com*

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DOI: https://doi.org/10.37255/jme.v20i2pp076-094

an instrument that worked outside in any weather condition, so to protect it from environmental conditions, two coats of anti-rusting paint were applied. In Sri Lanka, the solar panels are needed to make a 5° to 15° [2] offset from their perpendicular position with respect to the ground. So, in our design, we used a 10° offset. (Tilt angle)

2.1. Wind speed sensor

A sensor was created using SolidWorks 2017 and 3D printed to measure wind speed. This sensor uses IR light as a sensor with a rotary encoder. When this sensor was operated, there were several unrelated high-frequency noises. So, those were removed by using a low-pass passive filter in which the cut-off frequency is nearly greater than the wind speed 120 km/h frequency [1]. The rotating frequency was calculated and it corresponded to the wind velocity by using mathematical equations. t_1, t_2 were pulse high and low times in ms, f was frequency in Hz, ω was angular velocity in rad/s, v was velocity in km/h, and r was the radius of this sensor, 235 ± 0.5 mm.

$$f = 1/(t_1 + t_2) \quad (1)$$

$$\omega = 2\pi f \quad (2)$$

$$v = r\omega \quad (3)$$

In the sensor, blue color arms and red color buckets Figure 1(a) are specially designed in order to reduce air resistance and to get maximum performance. When assembling this sensor, a low-friction bearing was used, so it is very sensitive and very small wind can rotate the sensor. Operation under the sunlight, these plastic parts get hot, and it will have some effect on moving parts and assembled connections, so Figure 1(c) shows the heat-blocking aluminum reflector.

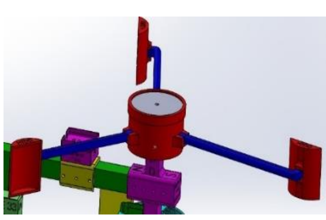

Fig. 1 (a) This is an assembled and complete wind speed sensor that was designed and assembled using Solid Works 2017.

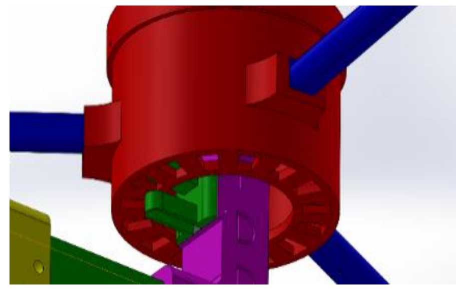

Fig. 1 (b) The wind direction sensor sensing part is an encoder wheel with IR as a light sensor. This shows that the sensor unit.

Fig. 1 (c) The actual sensor that was 3D printed and assembled is shown here.

2.2. Wind direction sensor

The wind direction sensor was also designed and 3D printed in the same way as the wind speed sensor. This sensor used three IR transmitters, receivers, and a 3D printed three-bit absolute rotary encoder, which gave a unique binary three-bit pattern in each direction. This sensor also generated the same high-frequency noises, so three passive RC filters were included inside this sensor.

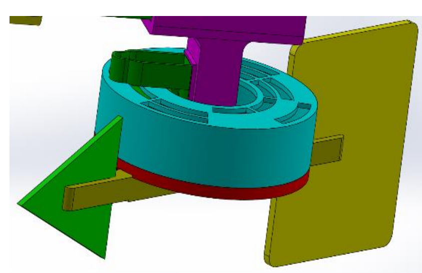

Fig. 2 (a) Wind direction sensor design using Solid Works 2017 and 3D printed. This sensor arrow direct the wind coming direction

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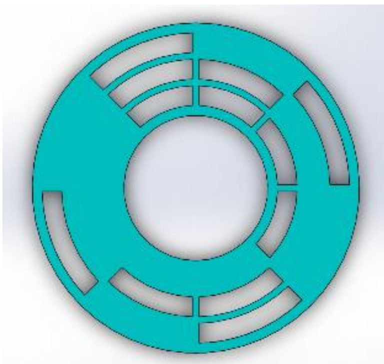

Fig. 2 (b) Absolut Encored Wheel is special encoding wheel that used several IR sensors to indicate direction as a binary number.

Fig. 2 (c) This is the 3D printed and assembled wind direction sensor

It used a smooth 3 mm bearing and 3 mm bolts. Rainwater that can collect on a rainy day can be automatically removed by a set of holes in the underside of the sensor cup.

2.3. Rain gauge

The rain gauge was designed and 3D printed using PLA. This sensor was designed to work accurately and save power. 3 kg of load cell was used to measure the weight of the water and water collecting area is 200 mm × 200 mm and water sensor was used inside of water collected bin to identify the weight changed was actually due to rain and 6 V water pump was used to remove water when water tank tried to overflow or data collected day was over that day is assume 12.00 noon the time that maximum sunlight was available. The load cell was connected to a 24-bit ADC, so it gave a very accurate reading, and in this system, the minimum value that was measured was 10 mg. Using data on weight and water collecting area, it can measure 0.01 mm of rain accurately. The maximum volume of water a tank can handle is 1800 ml, so it equals 45.00 mm of rain. If rain on that day was greater than that value, the pump was activated and emptied the tank. The pump can handle 100 l/h, so it can empty the tank in less than 1.5 min.

Fig. 3 (a) This shows the inside mechanism of the sensor. There is a water level sensor, a submerging pump, and a water particle filter.

Fig. 3 (b) This is the water collecting bin which used to collect rainwater in the area of 200 mm × 200 mm. There is a particular filter that can remove particles such as leaf insects, etc.

Fig. 3 (c) Final 3D print and assembly of the rain sensor

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Fig. 3 (d) The water collecting bin is on the load cell, and it is permanently attached to the instrument body by using a nut and bolt.

2.4. Solar panel light sensor

Measure light intensity in lux; the weather station used solar panel voltage. Using the datasheet value of panel resistance, it was 28.224 Ω in its maximum operating condition. The real-time power of the solar panel in watts was calculated by using (〖voltage〗^2/ resistance). The efficiency of solar panels was 8.8 % [2] so by using that value, the actually effective power of incident solar radiation in watt was calculated and dividing that value by the area of the solar panel and multiply the value by the coefficient of 0.0079 W/m^2 was equal to 1 lux [2] the actual lux value was calculated.

Fig. 4 (a) This is the calibration setup of solar light intensity. Sensor data and LUX meter readings are recorded.

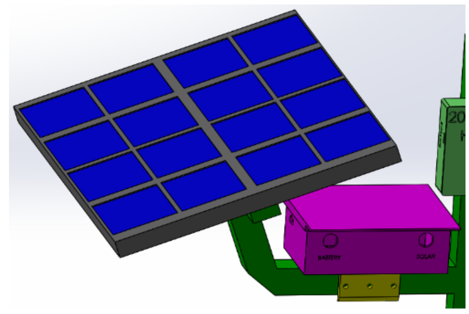

Fig. 4 (b) When using solar panels in Sri Lanka, it must offset from 7 ^{o}to 12 ^{o}, so this instrument used 10 ^{o} offsets to earn maximum solar energy. Voltage regulators, charging circuits, and other electronics related to power are assembled in the box that is placed under the solar panel.

2.5. Humidity, Temperate and Air pressure

BME 280 sensor was used to read temperature, humidity, pressure, and altitude with respect to sea level [3]. Arduino IDE and BME 280 libraries were used to connect and read the data from the sensor.

Fig. 5 (a) BME 280 is an I2C communication base multivariable sensor.

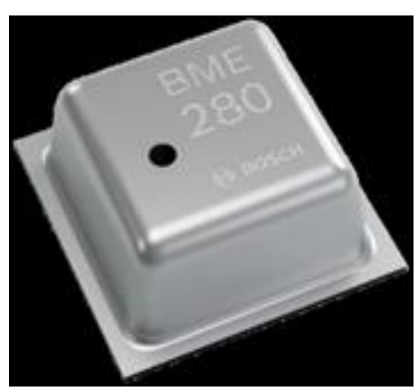

Fig. 5 (b) BME 280 sensor chip with cover

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2.6. UV index

ML 8511 sensor [3] was used as a UV sensor; it was used to measure UV light intensity in W/m2, and those data were used to calculate the UV index value [3].

Fig. 6 (a) ML 8511 is a UV sensor; it needs a reference voltage to work, and the given voltage output is converted to UV index by using a microcontroller.

Fig. 6 (b) The UV index is an international standard measurement of the strength of sunburn-producing ultraviolet (UV) radiation at a particular place and time.

2.7. System power supply

This weather station used two buck voltage converters to convert solar panel voltage to 5 V and 5 V to 3.3 V for ESP 32 and sensors. In some low-quality converters, the output voltage spicks when there were input voltage spicks. Hence, before assembly, a signal generator and an oscilloscope were used to analyze this scenario. The yellow color showed the input signal, and the blue color showed the output voltage.

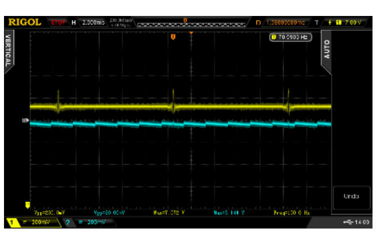

Fig. 7 (a) This is the buck converter voltage analysis, supply short-time pulse voltage as an input shown in yellow color and its output in blue color. So, in the output voltage, there are no pulses.

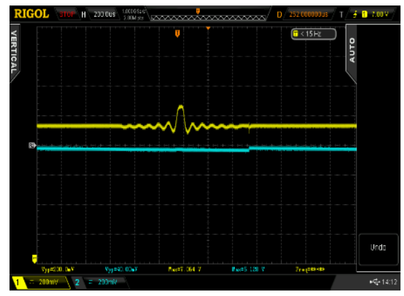

Fig. 7 (b) This is the buck converter voltage analysis, which supplies a long-time pulse voltage as an input shown in yellow color and its output in blue color. So in the output voltage, there are no pulses.

Fig. 7 (c) The buck converter, which can adjust its voltage, or by soldering the appropriate jumper, we can generate a very stable and consistent voltage.

2.8. Electronic circuit and system

This project used two main circuits. To power the instrument, we used two types of power supplies: a 10-W solar panel and 18650 batteries. Solar panel voltage is 0 V to 21.5 V, so we used a buck converter to convert that voltage range to 5 V and drive the sensors and actuators, and used another buck converter to get 3.3 V to the ESP 32 board. When the solar panel voltage is greater than 6 V, the circuit starts to use solar voltage, and if the voltage is less than or equal to 6 V, it changes to operate by the battery voltage.

We used three relays on this power board. One is a changed battery voltage or solar voltage, and the others are used to change the battery charging or discharging mode. When changing the circuit power mode, there is a small-time gap where there are voltages that are less than 5 V and 3.3 V, so we used a capacitor bank to hold power until the change is completed. Another circuit was used for sensors, transducers, communication, and data processing, which used ESP 32. Eagle CAD 7.6.0 was used to design the PCB, and a toner transfer method was used to build it.

Fig. 8 (a) Assembled power circuit: There are three relays; one is used for power output battery or solar, and the other two are used to charge and discharge the batteries. There are two buck converters, one is used for solar panel voltage to 5 V, and the other is used to convert battery voltage to 5 V. The capacitor banks help to supply power when the circuit voltage changes.

Fig. 8 (b) This is the main control circuit. There is an ESP 32 as the main controller, a buck converter as a voltage converter that uses 5 V to 3.3 V. The Relay module is used to turn on and off the water pump. TIP 120 transistors are used

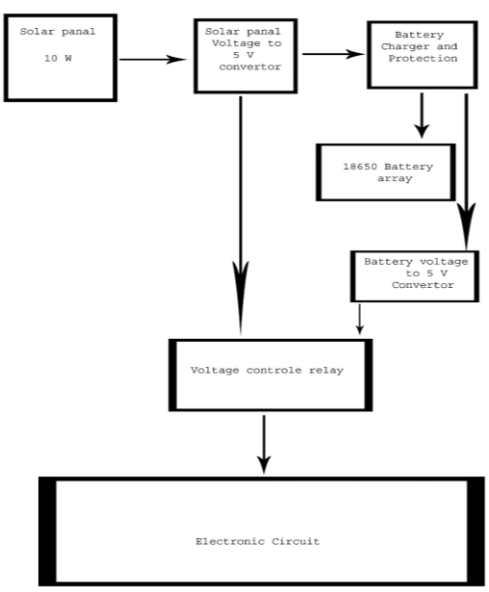

Fig. 8 (c) Block Diagram of battery circuit

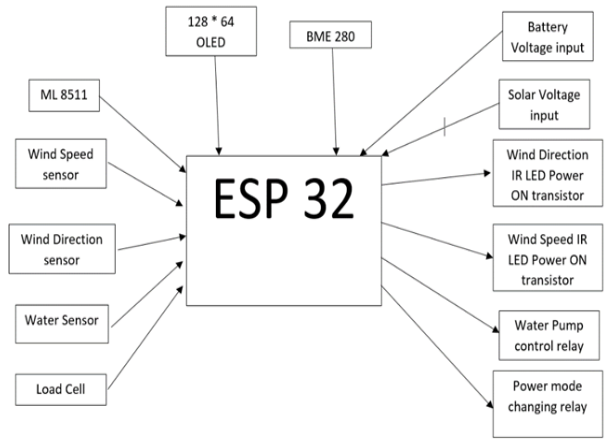

Fig. 8 (d) Block Diagram of control circuit

3. Results and discussion

The purpose of this project is to construct a weather station that must fully operate without human interference and send data through Twitter. So, the system was designed to work by itself, and a solar panel was used to power up the system, charge the battery during the day, and run the battery at night. This nighttime function works when the solar panel voltage is less than 6V. The system sends a Twitter message every minute, and if you want, you can change the time interval at which the message is sent. Project task is to send only Twitter, but for analytical purposes, every row of data is sent to a Google sheet and an MQTT broker. So, by using Google sheet you can plot graphs with respect to time and get an idea about whether parameters behavior and by using those data anyone can predict the future weather conditions.

This instrument gives us weather parameters such as temperature, humidity, air pressure, altitude with respect to sea level, wind speed, wind direction, UV index, light intensity, and rain gauge. Temperatures, humidity, wind speed, and light intensity parameters are calibrated by using laboratory instruments and some chemicals. The system was uploaded with data without any incident, and it has been working strait for more than 5 days only it battery power, so it can run any weather conditioning and the cover of circuits are customized designing for each circuit and using PLA plastic it was 3D printed so each cover is the weatherproof seal by using constructive adhesive silicon. For 3D printing, the material was PLA plastic, which was biodegradable; hence, this product is also environmentally friendly.

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When we use the sensor, the transfer function is the design on parameters, most at 25 0C and laboratory conditions. But when we are using those sensors in our projects, we need to calibrate those sensors regarding our environment. So, in this project, most of the sensors are calibrated using several instruments and a set of chemicals.

In calibration for temperature used several steps. First to calibrate the multimeter k-type probe the sensor part was attached to a mercury thermometer and put in a double distal water beaker. While the increasing temperature on water and mixed it at 240 rpm speed to spread heat evenly. By reading the thermometer reading and the multimeter plot graph using MATLAB, and finding the coefficient of relationship. After finish reading then cool the setup and reading thermometer and changed potentiometer value on the multimeter until both reading equal. second, using hot glue multimeter k-type temperate sensor was passed on BME 280 sensor and using hot air gun temperature around sensors was increased and keep several seconds until it comes on saturation state and read both meter and sensor reading on OLED display. By using those data and plat graph on MATLAB and coefficients of the relationship was obtained.

Whenever it needs to calibrate for humidity in this project used chemical method. Several chemicals can saturate humidity for certain saturated values in a given temperature. For this calibration used 99.99 pure KCl, NaCl, and KNO3 with double distilled water. The chemical and distilled water were put on the small bin and do not dissolve the chemical keep it semi solid-state and sealed the container with BME 280 sensor and additional humidity sensor and temperate sensor. Then setup was kept 48 hr until the reading was saturated. The final saturated value was recorded with the corresponding temperature. The calibration process was repeated for the other three chemicals. Using the temperature of saturated value the actual temperature was calculated and repeat for the other three chemicals and by using the sensor value and actual chemical saturated humidity value the graph was plotted and calibration coefficients are taken.

Calculating light intensity used solar panel power. By using its datasheet values and efficiency of the panel can back-calculate the real solar incident intensity in lux. For calibration used "KIMO LX-200" lux meter. Instrument light intensity and instrument reading in lux were recorded and plotted the graph by using MATLAB and relationship coefficients are discovered. Calibration for wind speed used "NKTECH NK-W0 Digital Anemometer", used the wind source, and read the sensor value and meter value. Record the values, plot them using MATLAB, and calculate those coefficients.

In the calibration process of the rain gauge, the sensor is initially completely assembled, and hence its value is observed on the serial monitor of the Arduino IDE with 24-bit resolution. In the next step, this procedure was extended with standard weights and their combinations to take various weight measurements. Finally, the graph for the respective ADC value vs the weight value was plotted in MATLAB, and a linear relationship between them was obtained, along with the corresponding intersection and gradient values.

To calibrate the lux sensor, the Arduino code needs an accurate voltage, and both voltage inputs are greater than 3.3 V. So, the original system uses a voltage divider with appropriate resistors. Using a variable voltage source, both the solar panel and battery voltages were measured with a multimeter and then recorded. MATLAB is used to plot the data and find the corresponding relationship coefficients. Even though the main scope of this project is sending weather data to Twitter, an additional feature of sending and storing data in a Google sheet is implemented. This data can be used for future research or analysis. A few analytical illustrations can be found in the ANNEXURES.

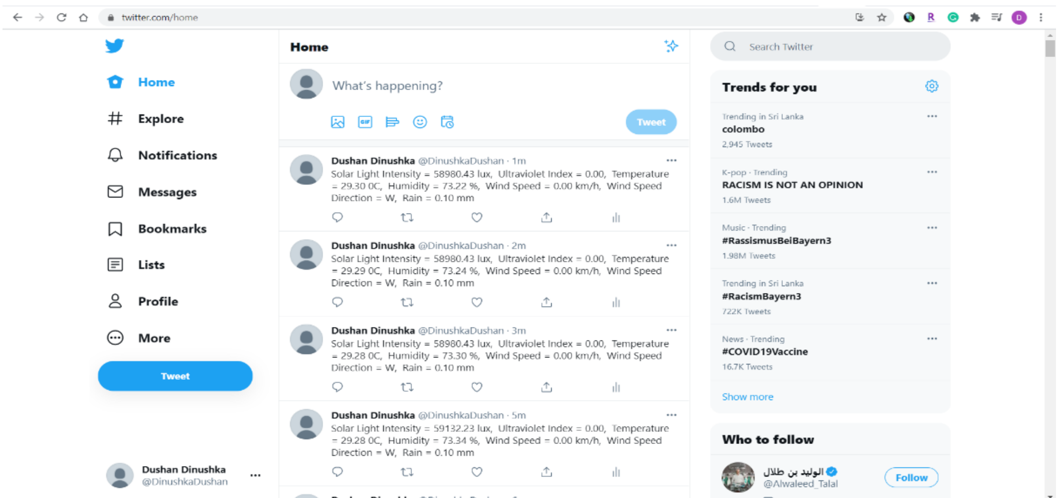

Fig. 9 (a) Every minute, the system sends a Twitter message with real-time selected weather parameters.

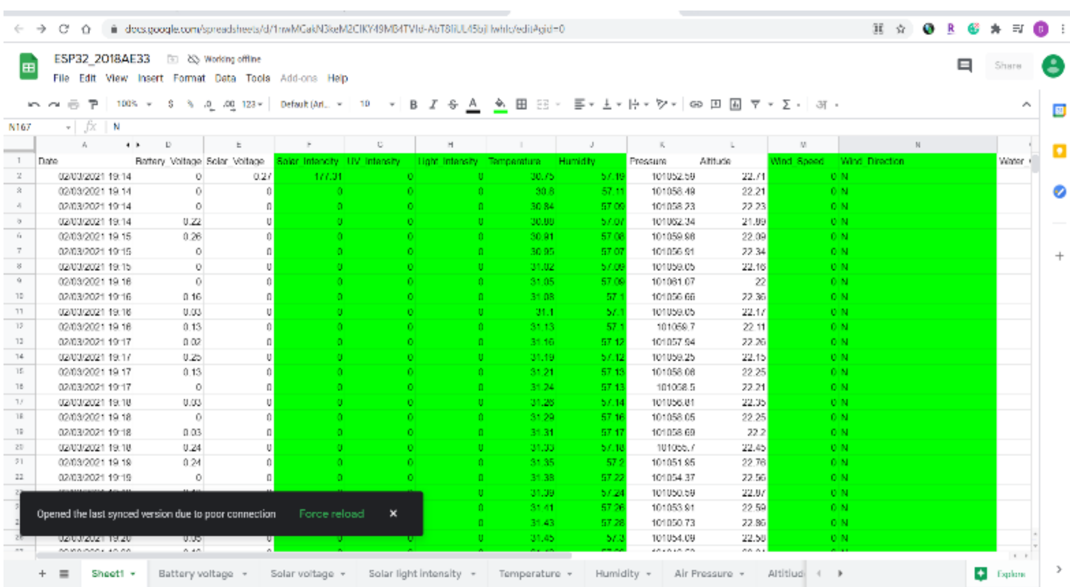

Fig. 9 (b) Every minute, the system sends all the weather parameters to the Google sheet so anyone can analyze the signal or multiple parameters with respect to date and time.

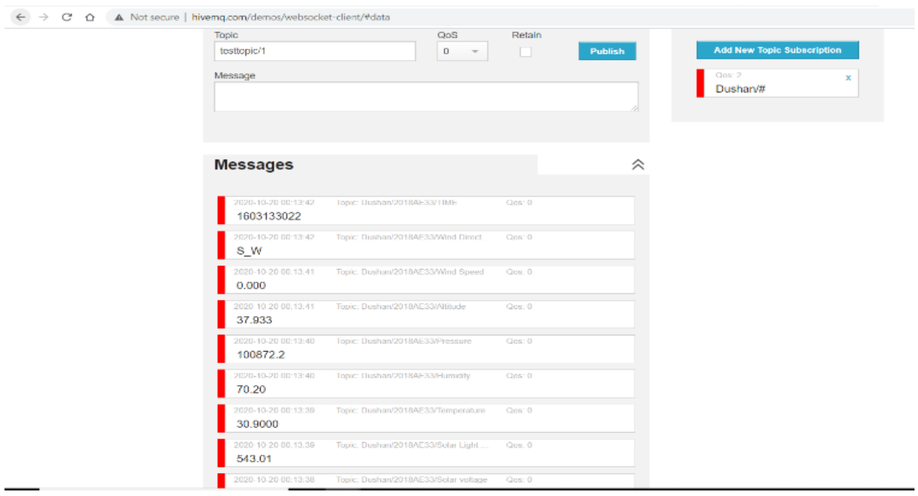

Fig. 9 (c) Every minute, the system sends selected weather parameters to the MQTT broker so anyone can collect the data by subscribing to the appropriate MQTT broker ID.

Fig. 9 (d) This is the temperature calibration setup for the BME 280 sensor. A K-type multimeter temperature probe is attached to the sensor using glue. Collect sensor readings on OLED display, and temperature readings of K-type sensor are collected using a multimeter.

Fig. 9 (e) connecting a K-type thermal sensor to a mercury thermometer for calibration.

Fig. 9 (f) This is the overall multi-meter calibration setup. By increasing the water temperature, multi-meter and thermo meter readings are recorded.

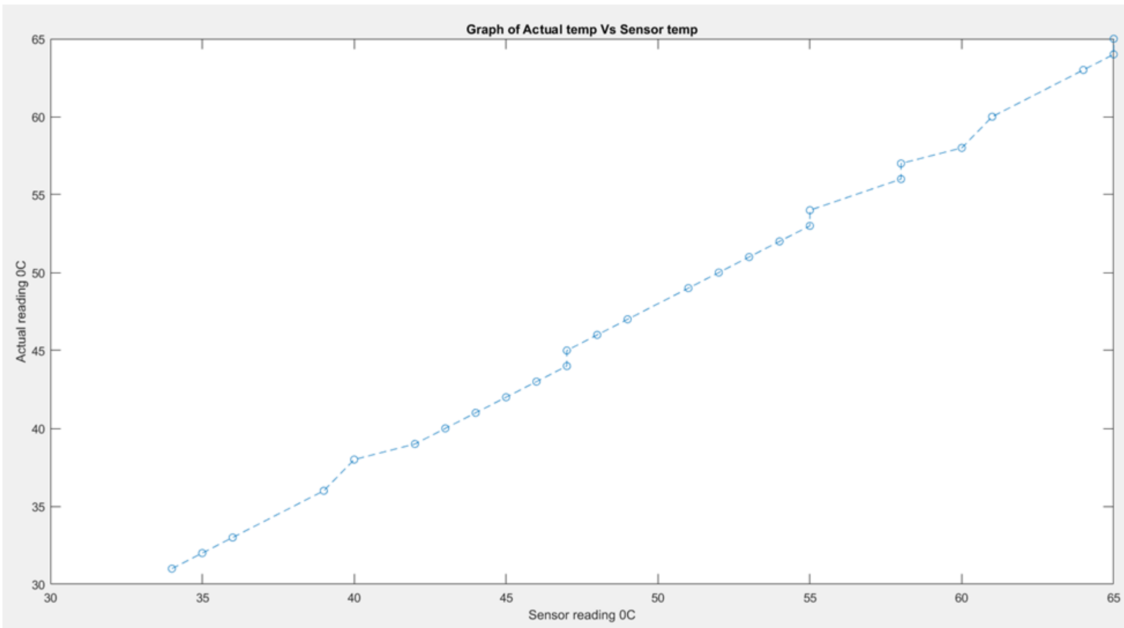

Fig. 9 (g) This is the relationship curve of thermometer reading and multimeter reading. By using the readings on MATLAB, we can find that the relationship coefficients are 1.0785 and -6.0245.

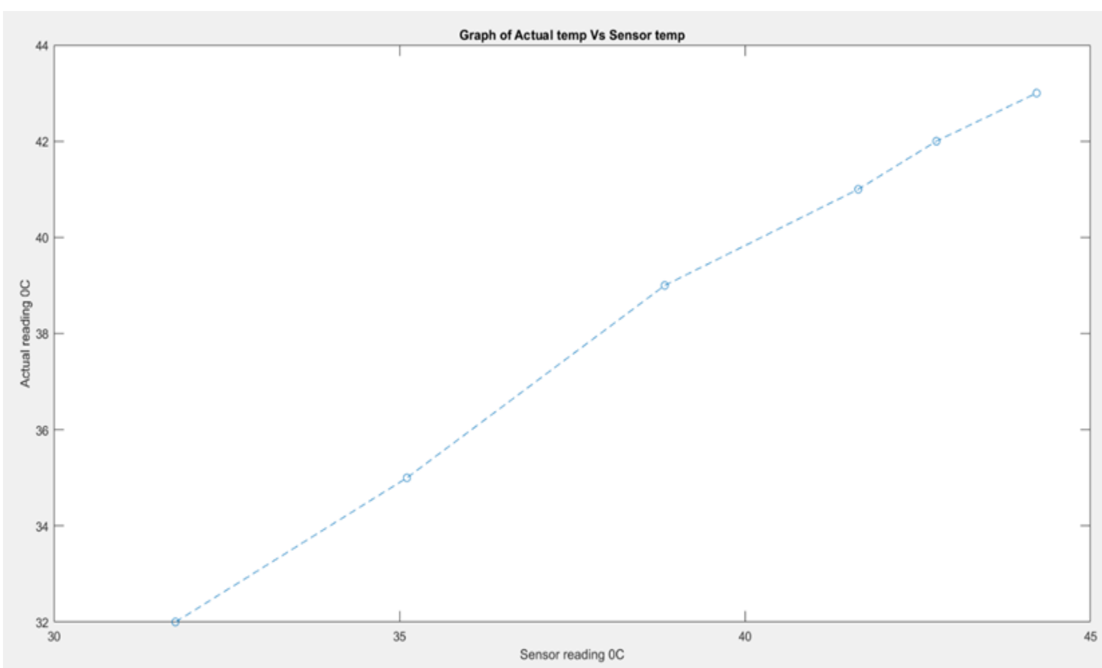

Fig. 9 (h) This is the relationship curve of the BME280 reading and the multimeter reading. By using the reading on Matlab, we can find a relationship coefficient of 0.8951, 3.7059

Fig. 9 (i) This is the overall setup of the humidity calibration. To measure humidity, we used BME 280 and an industrial available instrument, and for temperature, we used the same items and a multimeter with a K-type sensor.

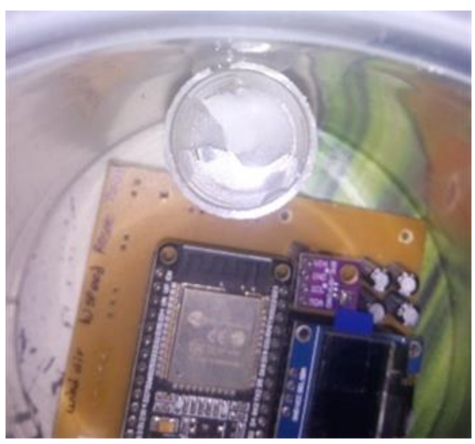

Fig. 9 (j) For calibration, several chemical salts were used. So, I used this container to fill it with salt and double-distilled water to wet that salt.

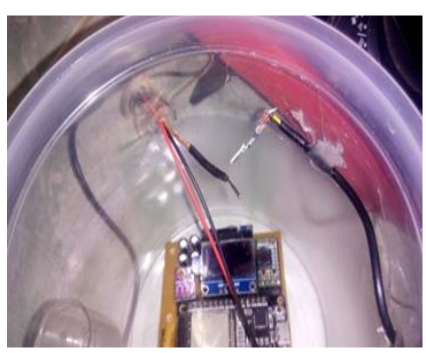

Fig. 9 (k) This is how those sets of sensors are arranged in a sealed container. To make a container airlock, use silicon and duct tape.

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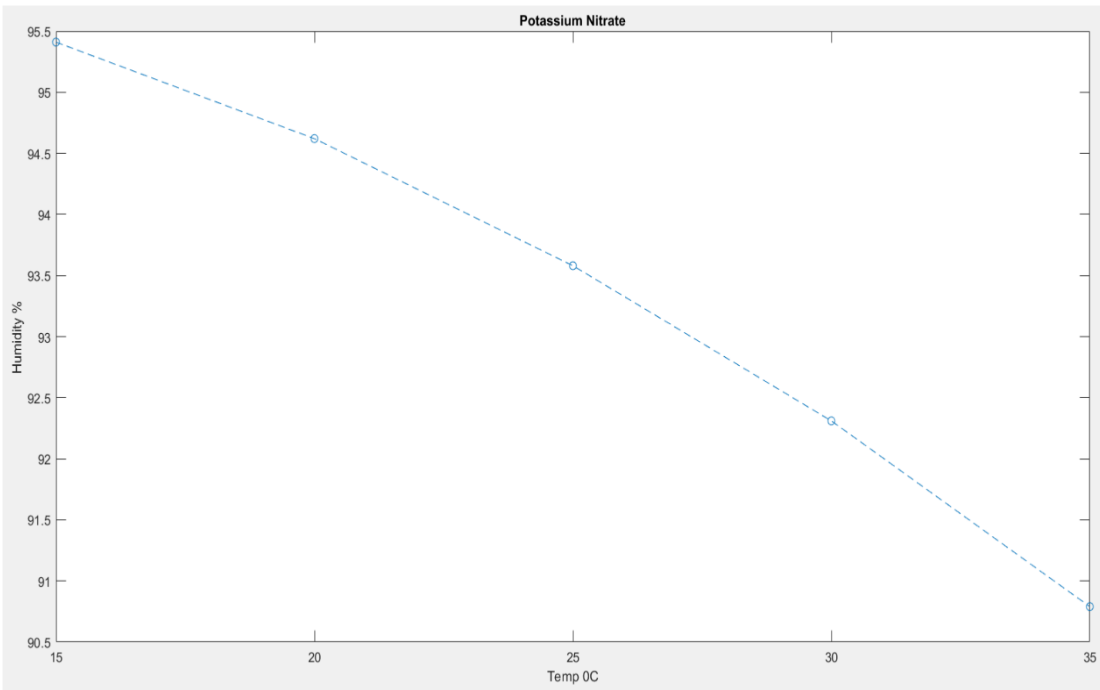

Fig. 9 (l) This is the relationship between humidity and temperature of Potassium Nitrate. By using this curve, we can determine the humidity that belongs to any given temperature.

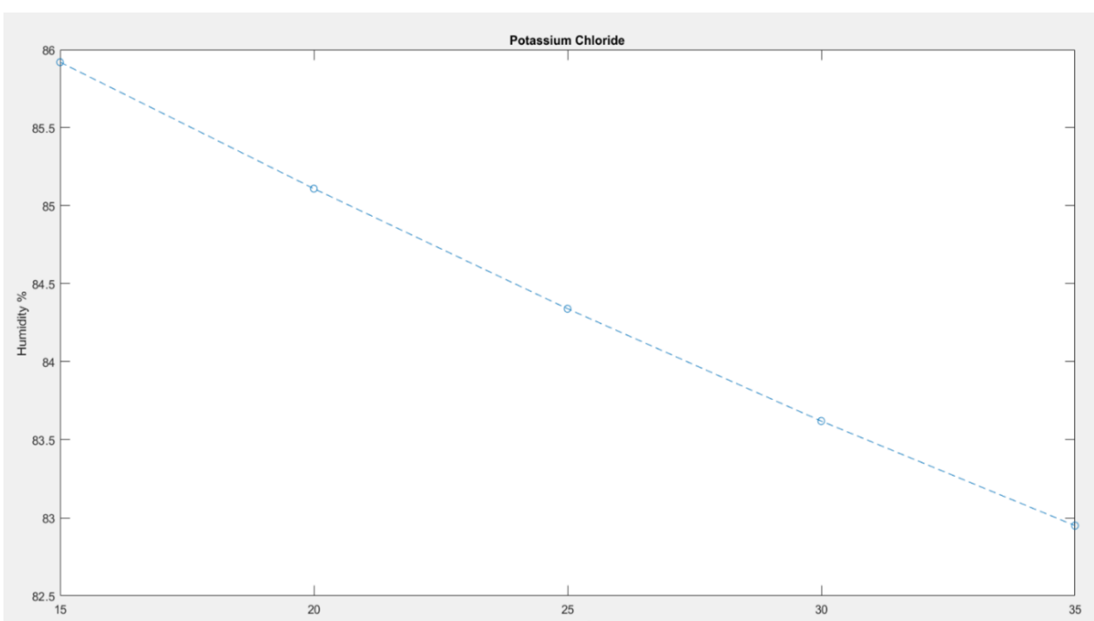

Fig. 9 (m) This is the relationship between humidity and temperature of Potassium Chloride. By using this curve, we can determine the humidity that belongs to any given temperature.

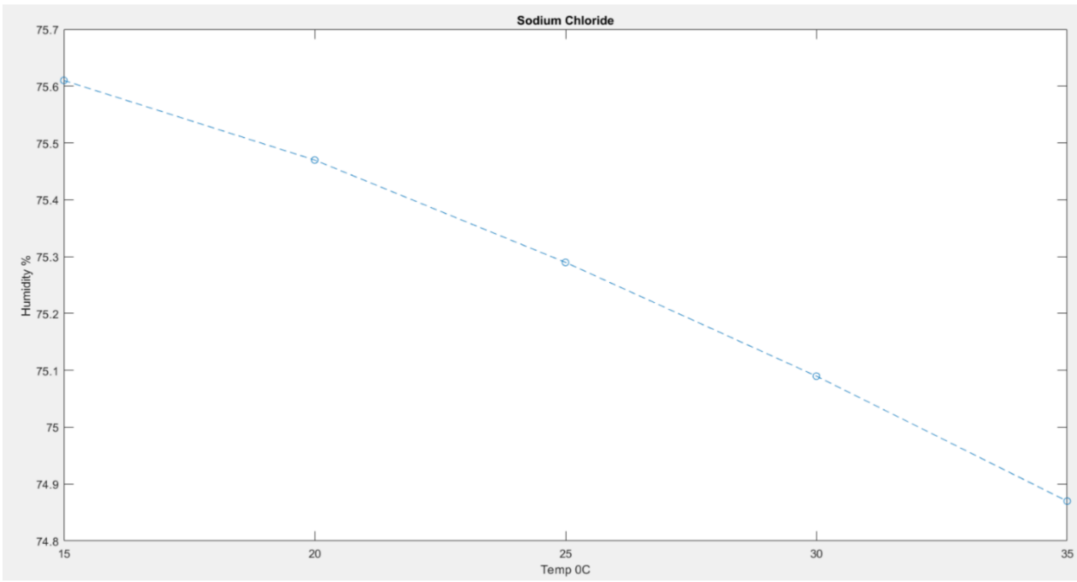

Fig. 9 (n) This is the relationship between humidity and temperature of Sodium Chloride. By using this curve, we can determine the humidity that belongs to any given temperature.

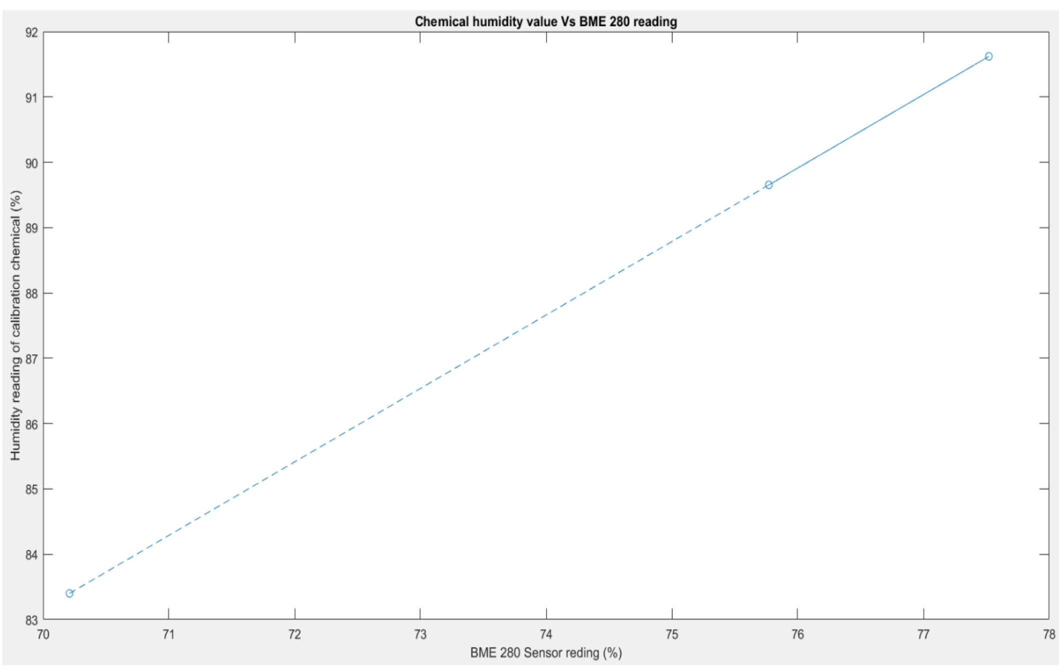

Fig. 9 (o) This is the humidity relationship of the actual and BME 280 sensor values. So by using the relationship coefficient 1.1245, 4.4498, we can get the actual humidity value.

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Fig. 9(p) This is the Calibration of solar light intensity. Put the solar panel and light meter sensor simultaneously and get the same reading.

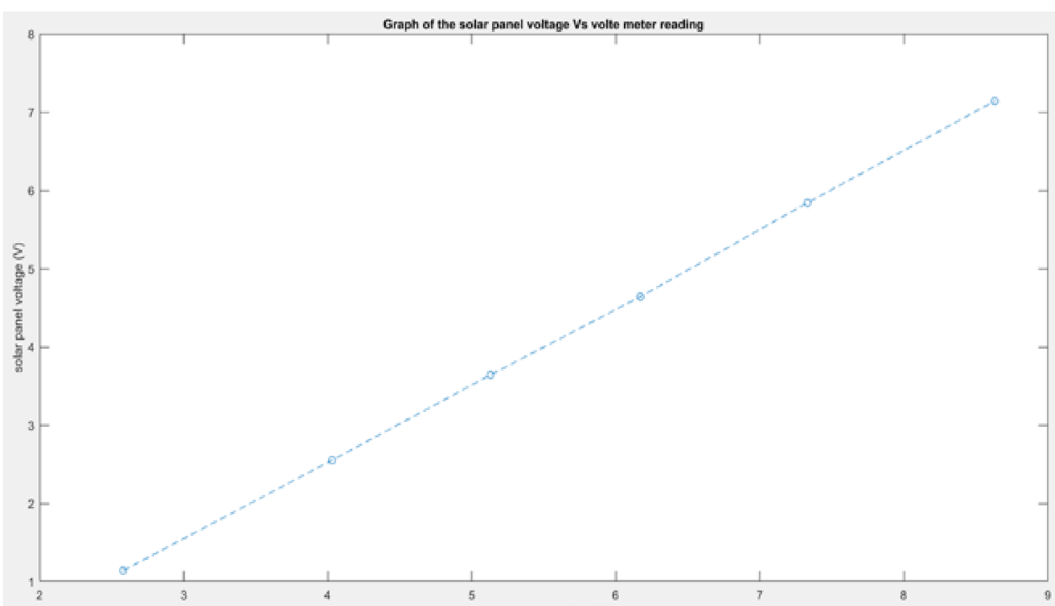

Fig. 9(q) To get accurate light intensity, we need to calibrate the solar voltage pin, so using a voltmeter gets both voltage readings and calibration coefficients of 1.0078 and 1.4543. By using this reading, we can get the actual voltage reading.

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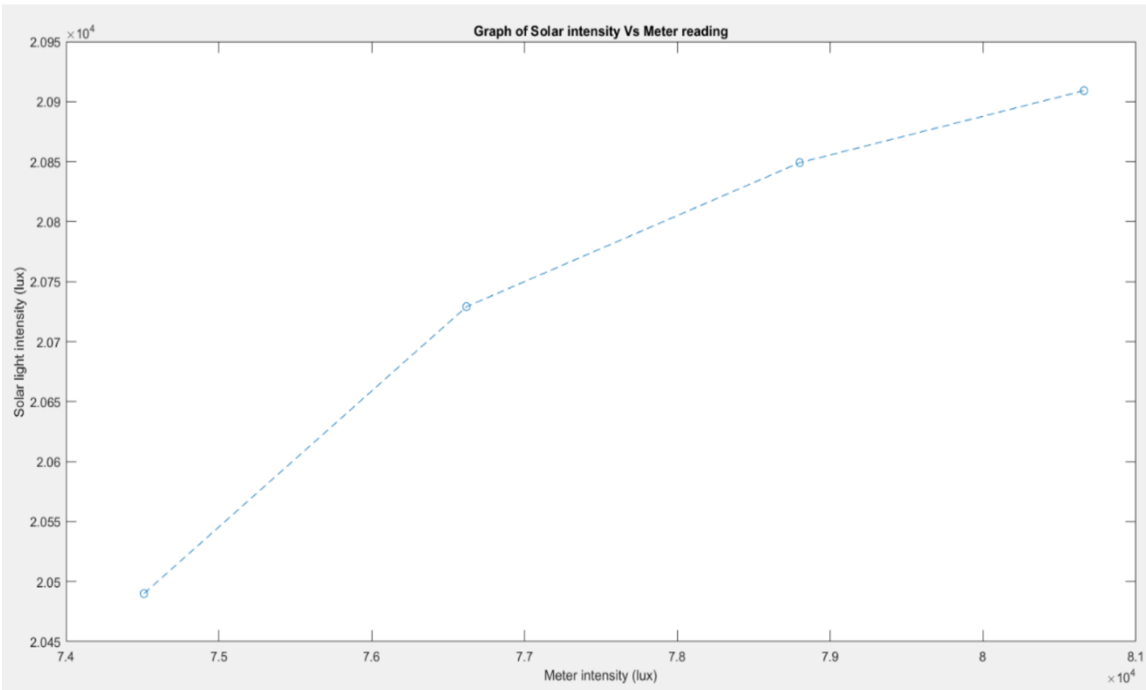

Fig. 9(r) shows the graph of actual light intensity in Lux and sensor reading in Lux. Using this curve's relationship, we can get the correct light intensity value.

Fig. 9(s) shows the Calibration for the wind speed setup. We used a glue tap to hold the anemometer and a fan to create different wind speeds.

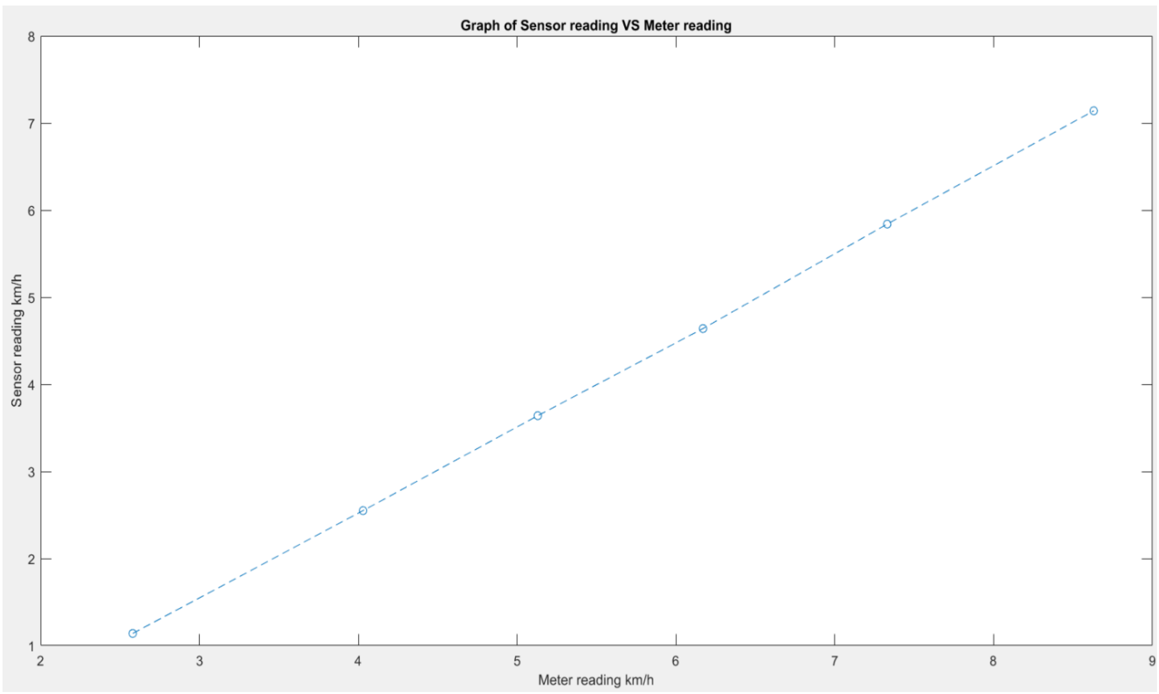

Fig. 9(t) This shows the linear relationship between the wind speed sensor reading vs the anemometer reading. The coefficients of the relationship are 1.0078 and 1.4543.

Fig. 9(u) This is the set of standard weights that we used for the calibration.

Fig. 9(v) This is the water collection bin in the rain gauge. This is the area we have used to put weights for calibration.

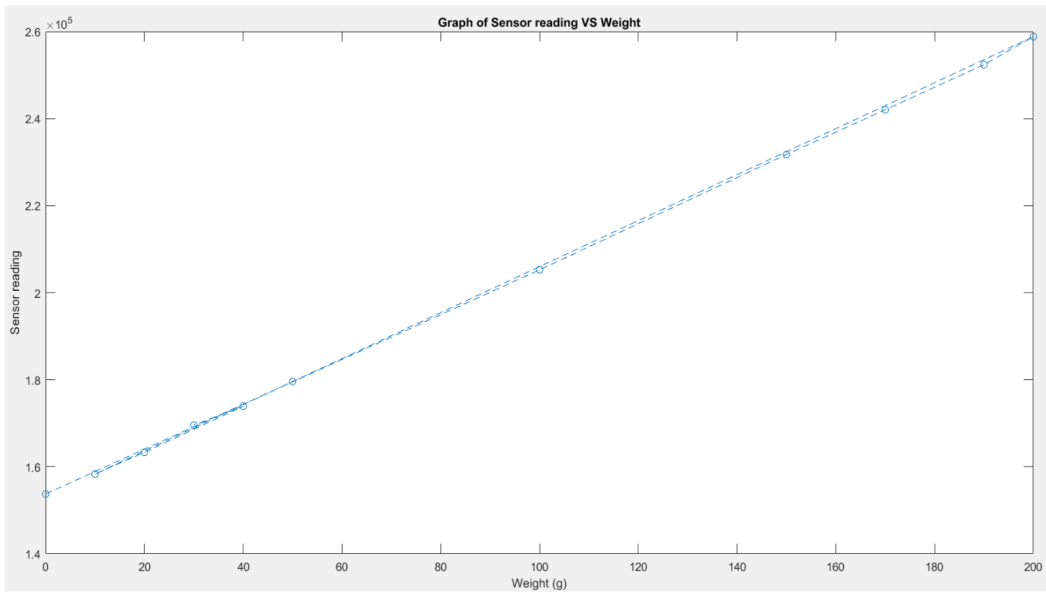

Fig. 9(w) This illustrates the linear relationship between the load cell ADC variations vs Weight. For a particular day, the amount of rain can be calculated using the corresponding weight put into the mathematical relationship obtained using the coefficients of this graph.

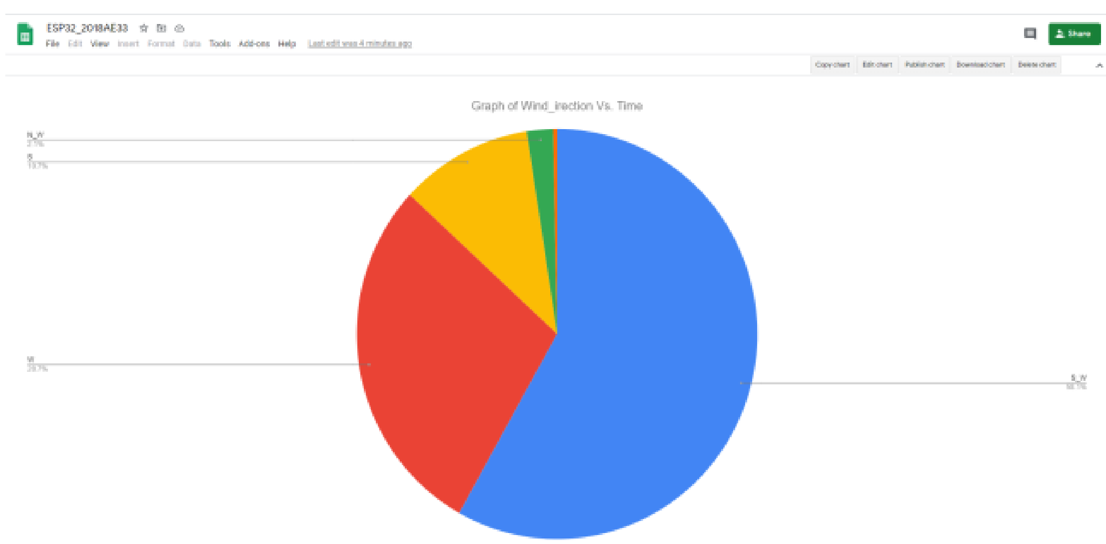

Fig. 10 (a) Graph of battery voltage vs. time

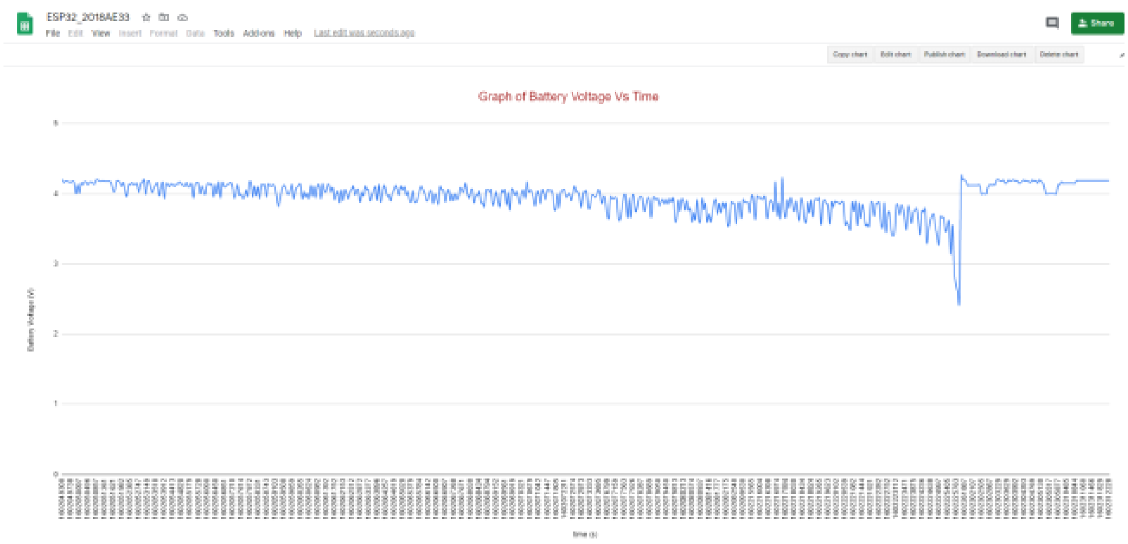

Fig. 10 (b) Graph of Wind Direction Vs Time

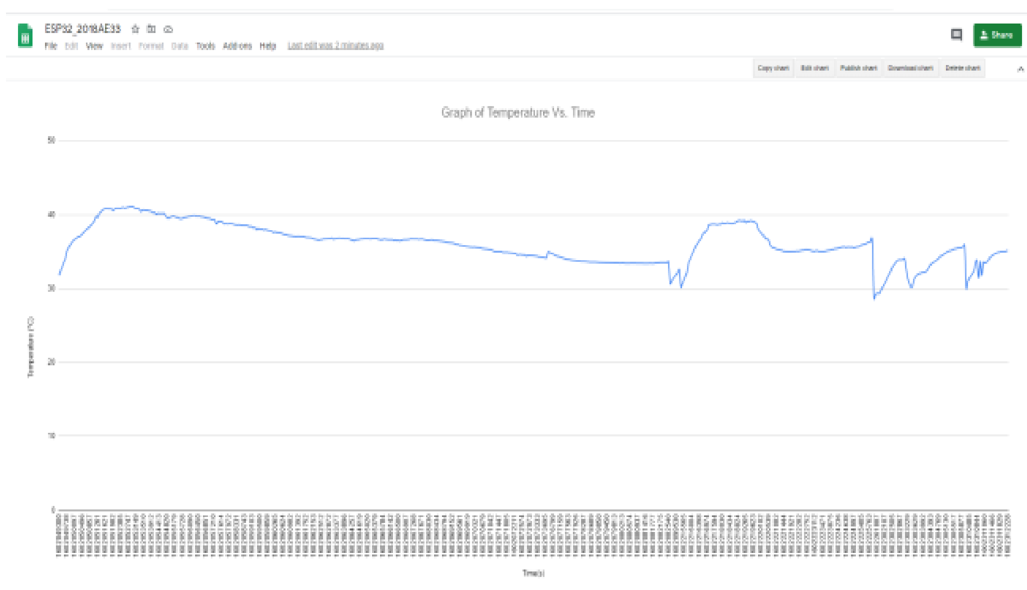

Fig. 10 (c) Graph of Temperature vs Time

Journal of Manufacturing Engineering, June 2025, Vol. 20, Issue. 2, pp 076-094
DOI: https://doi.org/10.37255/jme.v20i2pp076-094

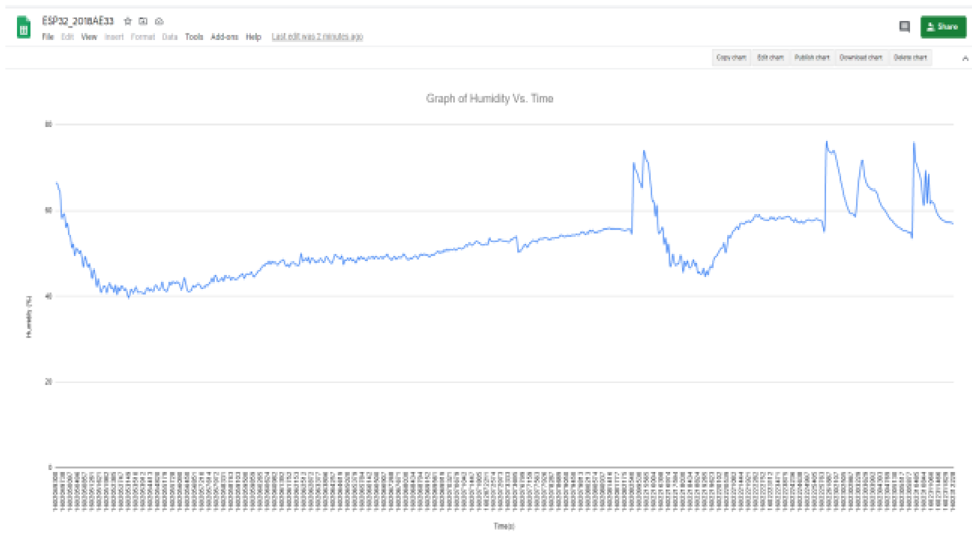

Fig. 10 (d) Graph of Humidity Vs Time

4. Conclusions

The task was to build an unmanned weather station to send data to Twitter. In the process, several sensors were customized and calibrated so that the instrument gives an accurate reading and successfully sends data and information to Twitter, Google Sheets, and MQTT. Hence, the project can be said to be successful. This data is saved in a Google sheet so anyone can get the data for their use, maybe for training a model that can predict the future weather forecast.

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