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Solar Powered Weather Station Project using Thing Speak GUI

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Abstract:- Due to the proliferation of pollutants in the environment and uncertain climate changes leading to global warming. Scientists are keen to examine the minutiae of climatic changes and factors affecting the whole. Furthermore, to get real-time data about the changes. This weather station is designed to measure a range of environmental parameters driven by a solar panel. The system uses wireless sensors to measure the environmental parameters, which are then transmitted to a microcontroller for processing and storage. Additionally, it leverages the ThingSpeak platform to store and analyze data with the use of Wi-Fi. a selection of data analysis tools that may be used to visualize the data and spot trends, such as charts, and graphs.

Keywords:- *Arduino Mega 2560, BME280, Davis Anemometer, Hydreon RJ-11 Rain Sensor, MQ135, MQ7, Adafruit Feather M0, RFM95 LoRa Radio, ESP8266 NodeMcu V3 Wireless WIFI Module, Thing Speak, Wave share Solar Power Management.*

I. INTRODUCTION

This project primarily involves providing the user with a real-time reading of the environmental factors. Where the readings gathered from the various sensors are wirelessly sent to an individual electronic device using the ThingSpeak platform.

ThingSpeak is a user-friendly web interface that allows users to view real-time and historical data, as well as set alerts for specific weather conditions. Along with, a custom PCB board for the microcontroller, which includes features such as overvoltage protection and battery charging circuitry for the Arduino mega to work efficiently in the harsh climate as well. Furthermore, adding a power management board to provide a constant supply of power to the microcontroller and work as a backup power source for the station as well.

The project demonstrates the working of various sensors alongside the solar management system and transmitting the data using the Lora and ESP8266 over the internet. Analog data that is obtained from the sensors is first converted to digital representation before being wirelessly communicated to the cloud.

Hence, allowing the user to access the data remotely with the help of various sensors and processing on ThingSpeak with the help of data visualization and analysis tool.

II. PURPOSE

- The main aim of this project is to provide real-time and historical weather data to individuals and communities.
- The main objective of the station is to provide an economical and sustainable solution for environmental monitoring.

A. Arduino Mega 2560

The Arduino Mega 2560 is one of the best microcontroller boards used for large applications. This board is designed with 54 digital and 16 analog inputs/outputs. It is based on the ATmega2560 chip and operates at 5V, with an input voltage range of 7-12V (recommended). One of the key features of the Arduino Mega 2560 is its 54 digital I/O pins, of which 15 provide PWM output.

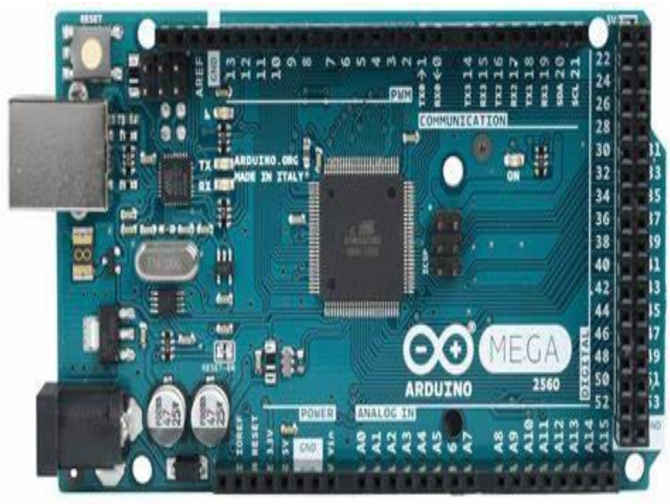

Fig. 1: Arduino Mega 2560

It also has 16 analog input pins and 4 UARTs, which are hardware serial ports. Having a capacity of flash memory i.e., 256 KB. Out of which 8 KB is used by the bootloader. It has 8 KB of SRAM and 4 KB of EEPROM. The clock speed of the board is 16 MHz, which allows it to handle complex applications and projects with ease.

B. Davis Anemometer

The Davis Anemometer is a high-precision wind speed and direction sensor designed for use in weather monitoring. Having high accuracy and precision, with wind speed measurements ranging from 0 to 200 mph (0 to 322 km/h) and wind direction measurements ranging from 0 to 360 degrees. Where the communication between the anemometer and the system is done using the wired or wireless interface such as RS-232 or RS-485.

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It uses a three-cup anemometer design to accurately measure wind speed, and a vane design to measure wind direction. Which also makes this meter design withstand harsh environmental conditions. Additionally, compatibility with low power consumption makes it suitable for use in remote locations and battery-powered applications.

Fig. 2: Davis Anemometer

C. MQ7

It is a gas sensor, the MQ7. This sensor's purpose is to measure the amount of carbon monoxide (CO) in the atmosphere. the only sensor with a 20–2000 ppm range and great sensitivity to CO gas. Also has been operatable at a voltage range of 5V, and its output signal can be read using an analog or digital interface on the Arduino Mega 2560. We could use to calibrate the sensor for optimal performance by using the adjustable potentiometer, The MQ7 is a low-power sensor, consuming only around 150mW during operation, which makes it suitable for solar-powered applications.

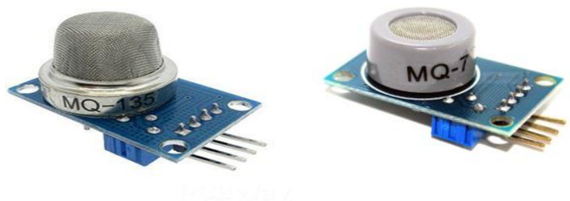

Fig. 3: MQ- 135 ad MQ-7

D. BME280

BME680 is a 4-in-1 sensor designed for environmental monitoring such as different gas, humidity, temperature, and pressure. Additionally, used for detecting volatile organic compounds (VOCs) and other gases such as carbon monoxide (CO) and nitrogen dioxide (NO2).

This sensor also has a humidity sensor with a range of 0-100% relative humidity, which is used for monitoring the moisture level in the air. The temperature sensor has a range of -40°C to 85°C, while its pressure sensor has a range of 300-1100 hPa.

The BME680 communicates with a microcontroller through an I2C or SPI interface and requires minimal power consumption, making it ideal for solar-powered applications.

The BME680's pressure, humidity, and temperature sensor use piezoresistive, capacitive, and bandgap sensors, respectively, to monitor air pressure, relative humidity (RH), and ambient temperature.

E. Hydreon RJ-11 Rain Sensor

The Hydreon RJ-11 Rain Sensor is a reliable and accurate sensor for measuring the presence and intensity of rainfall.

Having the best feature of great sensitivity to even light rainfall. It can detect rainfall as small as 0.01 inch (0.254 mm) per hour and can accurately measure rainfall rates up to 12 inches (304.8 mm) per hour.

The Hydreon RJ-11 Rain Sensor operates using a simple optical sensor system. A detector and emitter for infrared light make up the sensor. When raindrops fall on the shell, they create a change in the amount of infrared light detected by the sensor. This change is then converted into a rainfall rate value.

Where the communication between the microcontroller and the sensor is done using the standard RJ-11 connector for communication with a weather station or data logger and requires only a 5V power supply. The sensor is also compact, with a small form factor of just 2.5 inches (63.5 mm) in diameter.

Fig. 4: Internal circuit of Hydreon RJ-11

F. MQ135

The MQ135 is a gas sensor module designed for detecting levels of various air pollutants, including benzene, alcohol, smoke, and nitrogen oxides (NOx). This sensor has a high sensitivity to air pollutants, with a detection range of 10-1000 ppm.

The MQ135 is designed for easy integration with an operatable voltage range of 5V, and its output signal can be read using an analog or digital interface. It is a low-power sensor, consuming only around 100mW during operation. It is also compact and easy to install, with a small form factor of just 35mm x 22mm.

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G. RFM95 LoRa Radio

The RFM95 LoRa radio is a low-power, long-range radio transceiver module that is designed for use in wireless communication systems. It operates on the 868MHz or 915MHz frequency bands, which provides excellent range and penetration through walls and other obstacles.

It can receive signals with a sensitivity of -148dBm, which makes it ideal for use in low-power, battery-operated devices. The module also includes a power amplifier that can boost the output power to up to +20dBm, providing a maximum range of up to several kilometers.

The LoRa radio uses the LoRa modulation scheme, which allows it to achieve high data rates while using minimal power. The LoRa radio is integrated with the help of an SPI interface.

H. ESP8266 NodeMcu V3

The ESP8266 NodeMcu V3 is used to provide wireless connectivity to the internet and other devices. It provides support for both 2.4GHz and 5GHz Wi-Fi networks and includes a range of features, including TCP/IP protocol stack, DNS, and DHCP. This makes it ideal for use in wireless communication systems. It also includes a built-in antenna, which provides reliable wireless connectivity even in areas with poor signal strength.

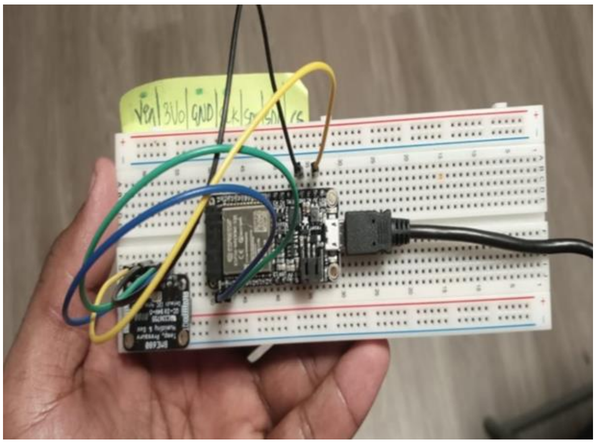

Fig. 5: Testing setup of the BME 680 and ESP32 for communication over the Internet

I. Thing Speak

IoT platform ThingSpeak enables users to gather, examine, and visualize data from connected devices. The platform works by providing a set of APIs that can be used to send data from IoT devices to the ThingSpeak cloud, where it can be processed and stored.

The platform also offers a range of tools and services for data visualization and analysis, making it easy for users to gain insights into their data. Which can be possible with the help of real-time data streaming. Where we can monitor their devices in real-time, receiving alerts and notifications as data is collected. With an in-built visualization tool, we can identify trends, track performance, and monitor key metrics.

J. Waveshare Power Management

The Waveshare Solar Power Management module is an electronic device designed to regulate the power supply to microcontrollers in remote locations with a high conversion efficiency of up to 97%.

It also includes several protection features such as overvoltage protection, Undervoltage protection, overcurrent protection, and short-circuit protection, which help to ensure the safety of the connected device. Along with a battery charging circuit that allows it to charge an external battery using solar energy. This makes it ideal for our station which requires a backup power source.

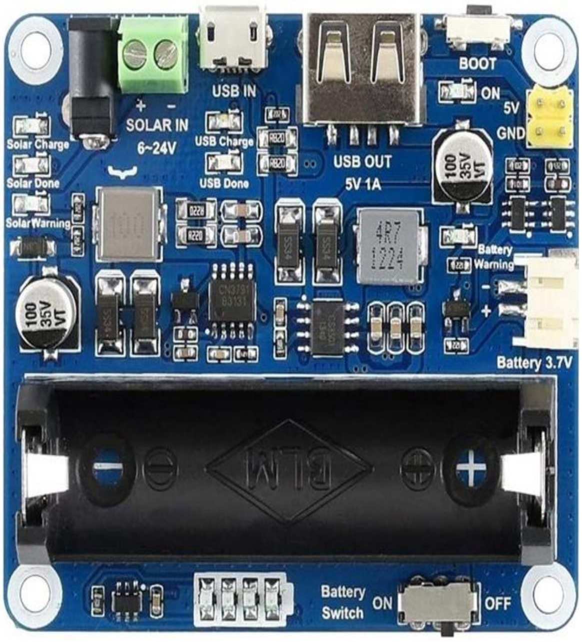

Fig. 6: Waveshare solar power management

K. Adafruit Feather M0

The Adafruit Feather M0 is based on the ATSAMD21G18 ARM Cortex M0+ processor used for communication, which provides a high level of performance while consuming minimal power. It supports both 3.3V and 5V power supplies, and its built-in battery charging circuitry allows it to be powered by a wide range of battery types.

It also includes a built-in bootloader, which allows the board to be programmed over USB without the need for additional hardware. Setting up a wireless communication protocol such as Wi-Fi or LoRa to send data from the weather station to ThingSpeak.

L. Solar Panel

A solar panel is a machine that uses sunshine to create electricity. The 5W and 12V solar panels can produce up to 5 watts of power at 12 volts DC. This panel typically consists of multiple solar cells that are wired together and encapsulated in a protective material.

The solar panel is connected to the Waveshare power management as shown in the figure below to regulate the constant 5v supply to Arduino Mega 2560.

Fig. 7: Connection of solar panel to waveshare solar power management board

III. CALCULATIONS

- Defining the no. of hours present in a year: 8760
- Yearly Sun Energy = 1200 kWh/ m²
- Estimated energy = ((1200 kWh/ m²/ 8760 h) = 137W/m^2)
- Estimated Solar Cells efficiency (15%)
- Estimated Energy to get = (137W/m² x 15%) = 20 W/m²
- Additional loss - batter charging process (33%) or (40%)
- Actual Energy to get = 14 W/m² = 1.4 mW/ cm²
- Size of solar panel = Microcontroller Power consumption/actual solar power = 0.5 W÷ (14 W/m²) = 357 cm² (size 19 cm x 19 cm or similar)
- Size of solar panel for maximum consumption = Microcontroller Power consumption/actual solar power = 1 W÷ (14 W/m²) = 714 cm² (size 27 cm x 26.5 cm or similar)

IV. PROPOSED SYSTEM

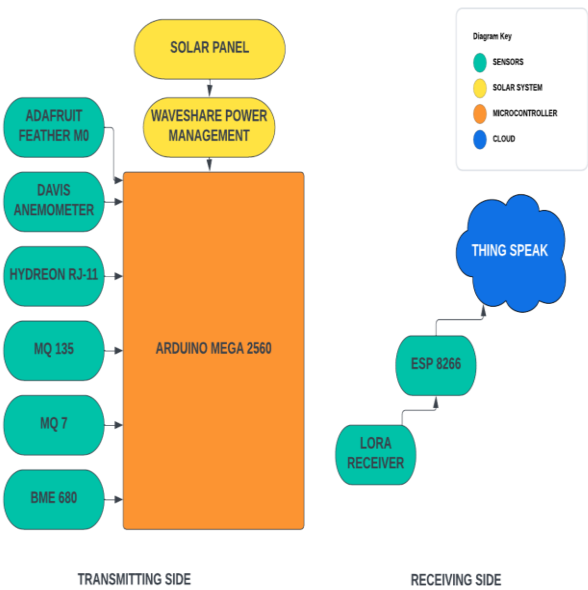

Fig. 8: Block Diagram

- The solar-powered weather project using Arduino Mega 2560 involves measuring various weather parameters using sensors BME680, MQ135, MQ7, Davis Anemometer, and RJ 11, processing the data using Arduino, and sending it wirelessly to ThingSpeak for visualization and analysis.
- Sensor connections: Connect the BME680 sensor to the I2C bus of the Arduino Mega 2560, the MQ135 and MQ7 sensors to the analog pins of the Arduino, and the Davis Anemometer to the digital pins of the Arduino.
- Implementing a solar power system using a solar panel, battery, and Waveshare power management for providing a constant power supply and an additional power backup source.
- Data acquisition and processing: Use Arduino code to read data from the sensors and store it in variables. Hence, by converting the raw readings to useful weather parameters such as temperature, humidity, pressure, air quality, and wind speed.
- Data transmission: Use the ESP8266 Wi-Fi module to establish a wireless connection to the internet and send the processed data to ThingSpeak in JSON format.
- Data visualization and user interface: Configuring ThingSpeak to display the weather data in real-time using various graphs and widgets such as line charts, gauges, and maps. And to display the weather data in an easily readable format for the users and provide options for data analysis and download.

V. RESULTS

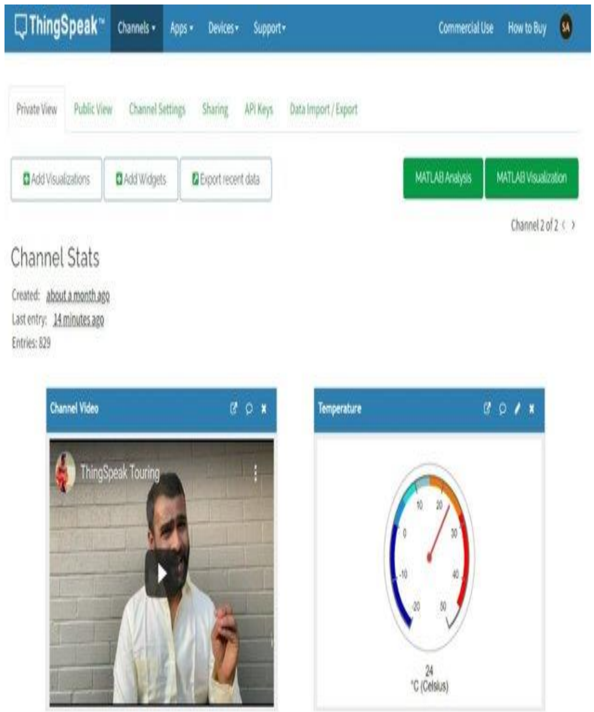

Fig. 9: The demo video of one author explaining the how-to-use the user interface and temperature meter of the current location

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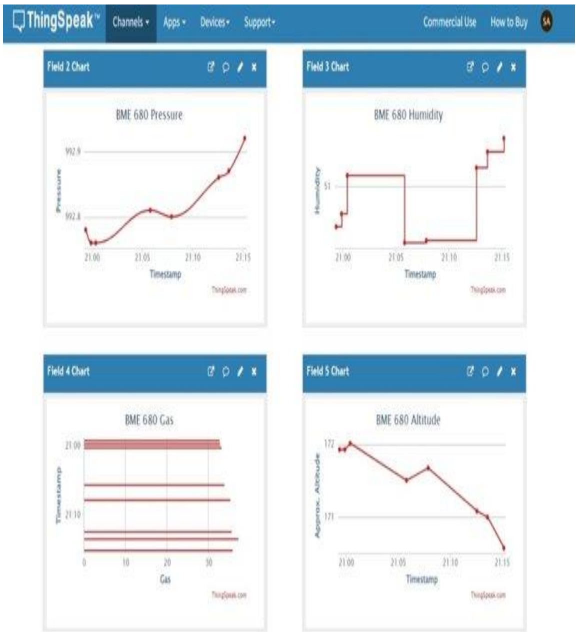

Fig. 10: Graphs displaying the various analog values such as pressure, humidity, level of gas, and altitude of the region.

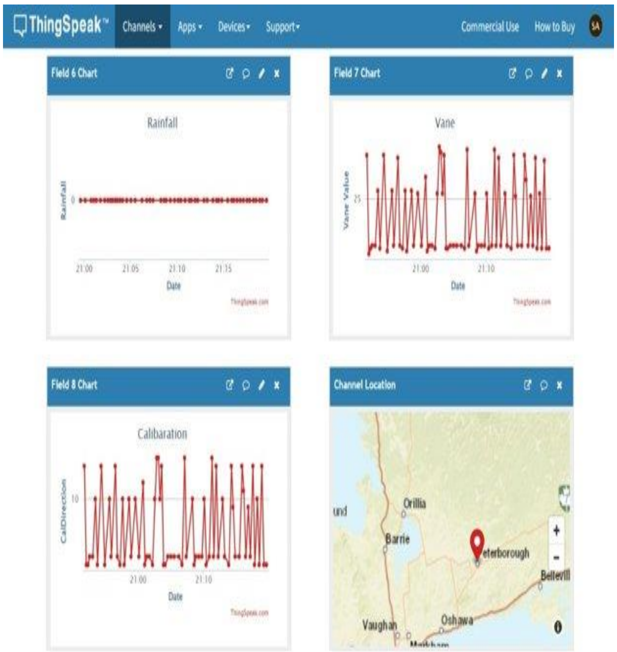

Fig. 11: Graphs showing the rainfall, wind speed, and location where the reading is being taken place.

VI. SCOPE OF PROJECT

- Data visualization and analysis using machine learning or statistical methods of the real-time weather conditions of a particular location.
- Provision of notifications or alerts when certain weather conditions are met, integration with other platforms such as Google Sheets or Twitter.
- The weather station also has practical applications in disaster management, as it can be used to monitor and manage natural disasters such as floods and hurricanes.

VII. CONCLUSION

- It provides individuals and communities with real-time and historical weather data, which can help them plan and make informed decisions regarding outdoor activities.
- Farmers can use the weather data to determine the best times for planting and harvesting crops and to monitor soil moisture levels.
- Meteorologists can use the data to improve weather forecasting and provide timely alerts for severe weather conditions.

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