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***Abstract*—This study presents the use of a wireless data acquisition system and the power management system for the development of mooring buoys. The Data Acquisition System is a system for controlling more than one group of sensors and reporting the findings of each sensor through microcontroller. The Power Management System oversees controlling the electrical system of the buoy. The main task is to ensure the electrical system of the buoy is safe and efficient. The proposed study consists of seven sensors gathering different parameters namely: air temperature, air pressure, relative humidity, wind speed, rainfall, solar radiation, water temperature, and salinity profile. For more precise data, three (3) moored buoys are stationed one kilometer from the shore and apart each other to collect information from different areas of the deployment area. It gathers climate characteristics of different areas, which records data accurately. The construction of the device consists of a tower, a polystyrene, and a rope. Its tower has beacon light that serves as an indicator and solar panels as the primary energy source of the buoy. The buoy carries approximately 15 to 20 kilograms of load, and it sustain three (3) solar panels and a 12-V battery. This device has a long battery life and uses idle mode between continuous samples to conserve power. Sleep mode is activated if the information gathered following 15 minutes of samples are consistent, and the power starts again after an additional 15 minutes. The buoys for weather monitoring were deployed under the CGSS-CCP of the Philippine Coast Guard. The results are transmitted to the base station and analyzed by the forecasting system.**

Keywords*—*data acquisition, mooring buoy, Power Management System (PMS), sleep mode, weather buoys.

I. INTRODUCTION

In the Philippines, there is a lot of geographical problems that emerge from natural disasters which are clearly uncontrollable. According to the National Aeronautics and Space Administration, one of the serious problems the world is currently facing is climate change. That is the reason why researchers are following the trend of creating solutions to this problem. One of the answers is the development of mooring buoys to became weather prediction equipment. Data from meteorological and hydrological parameters will be gathered using different sensors to gather data namely: anemometer, water temperature, air temperature, barometer, precipitation, relative humidity, salinity, and solar radiation sensors.

In this paper, a data-acquiring mooring weather buoys using sensor network through LoRa is proposed. For the power source of the weather buoy, solar power is used and introduced the sleep mode power management system. The proposed buoy device is supplied by a 12V battery and three (3) photovoltaic arrays. In addition, the proposed Power Management System (PMS) oversees controlling the buoys' system. It controls the network for electrical supply, usually providing data on total and individual power usage, power quality, and warnings for incidents. This helps identify, and carries out schemes for reducing power usage and energy costs. This device ensures the battery a long battery life used for energy conservation in idle state between continuous tests. Lastly, the Arduino microcontroller supervises the weather buoy operation sets a condition for the sensor/s to undergo sleep mode operation for 15 minutes if there are no changes in the data for the system to conserve more energy. The transmission mode used in the weather buoy is long range communication technology [1] and the encoding used is Huffman coding [2].

II. RELATED WORKS

There are different studies related to weather data acquisition. Nugroho et al. developed a weather buoy system that notifies weather details at a certain position in water getting precise data and weather predictions [3]. This device is composed of multiple sensors and data storage and transmission system such these sensor data transmits remotely to the land base workstation. The land base station has a prediction system, acquisition system, control system, and delivery network. The retrieving, collecting, displaying, and processing of the data desired is made by the acquisition system. Weather forecasts and predictive information for distribution and transportation were generated from the processed data by the acquisition system. The sensor data consists of air density, humidity, air temperature, wind velocity, global location, and wind direction. In particular, wireless modems and software for data communication were used for the communication by the data acquisition system. Lastly, a multiplexer was realized to carry out the combination of multiple sensor data inputs in one single output. To give more information, a study from García et al., focuses on measuring the height and period of the waves, wind, and marine current intensity and direction [4]. This study dedicated a set of sensors in the buoy system to monitor marine energy parameters, in order to sample wind, wave, and marine current energy resources. The stability of the buoy system used in this study has been successful in real operating conditions. For the energy consumption of the prototype, it incorporates wind and marine current turbines.

Upon looking for low-cost buoy considering that the materials are quite expensive, a paper is found in Laun et al. the possibility of fabricating and designing a weather buoy for as low as 500 USD [5]. It is a small sized floating system that provides real time data for data acquisition with the use of low-cost materials. It also gathers data from different parameters like water temperature, salinity profile, and current behaviors.

The sensors of traditional buoys collect water data at a fixed height below the surface of the water but the study by Wei et al. considers the influence of different depths of water to the accuracy of data acquisition in hydrological environment, so it included a movable part to take water samples at different depths [6]. This study has more sensors for the observation of hydrological environment than meteorological environment which is limited to anemometer and wind speed sensor. Also, the design of the buoy indicates it is moored at a fixed location. An experimental investigation by Zhang et. al. focuses on the designing of a DAQ system for a buoy for underwater operation which uses optical cable for the transmission of data [7]. Its DAQ composed of two sections, the Small capacity cache and mass storage device. For the small capacity cache, it uses an SD card as its primary storage of data whereas for the mass storage it uses a SSD and the storage are connected via SATA. Basically the SD card have less power consumption than the SSD due to its capacity but for a fast transmission it introduced the Huffman encoding to minimize the power consumption of the DAQ system.

As discussed, buoys for observation in the ocean offers great help and a reliable and long-lasting duration of energy of the weather buoys is a great advantage. The study of Guerriero et al. focuses on harbor monitoring and their buoy has a communication device that consumes a large amount of power to suffice the needs of the buoy, it used two (2) sources of power – solar energy and mechanical energy [8]. For solar energy, it used solar panels and dc-dc converter for mechanical energy, it used a permanent linear generator and ac-dc converter, and both converters are also connected to another dc-dc converter and backup battery. Meanwhile, the NTU Buoys used 40 Type battery cells, which take up about a year of high-frequency analysis at a time of 6 minutes [9]. Its monitoring system adjusts the most sensing devices than the conventional ATLAS watercraft and transmits information at modifiable interim via antenna terminals or through radio transmission seen between vessel and the buoy.

In addition to the study of the waves as energy source, the study of Hirakawa et al. focused to create a lighter, smaller, thinner, and affordable construction of the buoy [10]. The weight is below 20 kg, the duration of the tripod's leg is about 0.6 m, and one man can handle it. For the buoy power source, the buoy uses sea waves, and in the short-term, the "Ultra-Small-Directional-Wave Buoy" improved, the buoy consisted of 3 bends fixed at the side of the telephoto lens. The buoy gathers sea levels and tide layer and monitors the tide path. The buoy has MLM and is used for measuring the amplitude of directed waves. Additional information for the sleep mode of the power management system of special buoys, the study of Cho & Yu also used sleep mode to lengthen the energy of the system and it focused on long-range communication with an application for fishery buoys detection [11]. This study used a battery for the power source of the fishery buoys and the entire system is controlled by a microcontroller. The buoy consumes small power since it does not have many devices installed in it but to further conserve its energy, it has a sleep mode that will turn-off at given intervals.

These previous related works used to figure out improvements for our study. Some studies used the buoy for detection, and others for navigation. Some gathers data from the hydrographical parameter, and some measures the meteorological parameter. Some studies measure air density, air temperature, humidity, wind velocity, wind direction and global location and it focused on the Meteorological part of the system. In this study, a sensor network is categorized into two parts: Meteorological and Hydrological. The differences in the parameters the other studies gathered, it came out to measure both meteorological and hydrological parameters for more reliable and accurate weather predictions.

The salt water increases the speed of the rusting of metal tips of water sensors, it usually built with materials that help reduce this effect and prolong the use without maintenance thus making the price expensive unlike their counterpart for pure water. The measurement for different hydrological parameters at the same location have a reading that changes as the depth of water changes. Therefore, the prototype has more meteorological sensors than hydrological sensors. Our study did not include adding a GPS hall sensor because its location is fixed. Another point taken from previous papers, it only measures and observes the marine energy resources which gives way for an improvement in our prototype which is designed to gather data for weather prediction and not only for observation. Both studies successfully achieved the stability of the buoy system which is a good point to prove the buoys' ability to stay safe even alone in the water when experiencing surging waves.

The data gathered by the system transmits to the station on land via LoRa and stored in a micro-SD card for back-up of the data. For the DAQ system, an SD card for the storage of the gathered values for accessibility if needed.

III. System Architecture

This section discusses and illustrates the design of a network of sensors to gather data from both meteorological and hydrological environments. The mooring buoys that can withstand surging waves and carry up to a maximum weight of 20 kg and power management system integrated in each buoy that will supply electric power to the sensor network for a long period of time. The objectives are collected primary data that stored in SD card and sent through wireless electronic communications. To build buoys that are powerful enough to support the tower and stay pinned at a specific location in the Manila Bay with the best power management configuration to keep the sensor network operating for months without the need for maintenance.

Fig. 1. Actual image of the proposed weather buoy

In Fig. 1, the buoy is moored so that it will not be dragged by waves away from its deployment area. The desired size of the buoy is the small-scale version of industrial mooring buoys just enough for research purposes. The framework of the mooring buoy can support the chassis of data-gathering sensor network which are the pyranometer, rain gauge, anemometer, relative humidity sensor, air temperature sensor, barometer, water temperature sensor, and salinity sensor, and power management system which includes the solar panels, battery, beacon light and solar controller. The mooring buoy is made of fiber-reinforced plastic with a height of 1200 millimetres and the outer diameter of its donut-shaped buoy is approximately 940 millimetres. The design of the mooring buoy in this study follows the standards instructed by the Philippine Coast Guard.

Fig. 2 shows the 7 sensors are connected to the microprocessor, Arduino Mega 2560. The power comes from the solar panel through the battery. This is connected to the Arduino Mega 2560 and connected to the sensors. The sensors connected are: Adafruit 1733 Anemometer, Bosch BMP180 Barometer, DHT22 Humidity and Air Temperature Sensor, Acrobotic FC-37 Rain Sensor, SI1145 Solar Radiation Sensor, DS18B20 Water Temperature Sensor, and Electrical Conductivity (EC) Sensor. Raw data is the only output of the sensor network which is used for power management and data logging purposes.

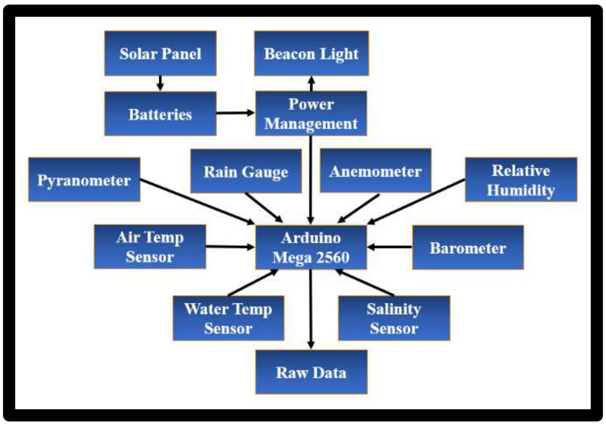

Fig. 2. Overall Block Diagram

The corresponding circuit and wiring diagram shown in Fig. 2 of the sensor network presents the 7 sensor modules and an SD card module. All the data from each sensor is read then logged for every second on the SD card and transmitted through a wireless communications module by the Arduino Mega 2560. The calibration of sensors, which was conducted by the researchers to make sure it functioned in the best condition possible and provide more accurate results, is the basis of their placement on the framework of the buoy.

After discussing the final design, as shown in Fig. 3, to the personnel of the Coast Guard of the Philippines in assistance for the deployment. They instructed to make changes to the design based on the standards provided by International Association of Marine Aids and Light House Authorities (IALA). The color of the mooring buoy is changed from orange to yellow and the beacon from red to yellow to indicate that it is not a navigational equipment when deployed in Manila Bay. The yellow St. Andrew's Cross, a special mark used to indicate a feature, was added to the design of the mooring buoy.

Height: 1000 millimeters
Weight: 42 kilograms
Diameter (Outer): 350 millimeters
Diameter (Inner): 200 millimeters
Length of the sides of the Triangular portion: 303 millimeters with 30 millimeters square-shaped support
Color: Yellow
Solar Panel Holder: 350 x 240 x 17 millimeter

A. The Hardware

The corresponding circuit and wiring diagram shown in Fig. 4 of the sensor network presents the 7 sensor modules and an SD card module. All the data from each sensor is read then logged for every second on the SD card and transmitted through a wireless communications module by the Arduino Mega 2560. The calibration of sensors was conducted by the researchers to make sure it functions in the best condition possible and provide more accurate results, is the basis of the placement on the framework of the buoy.

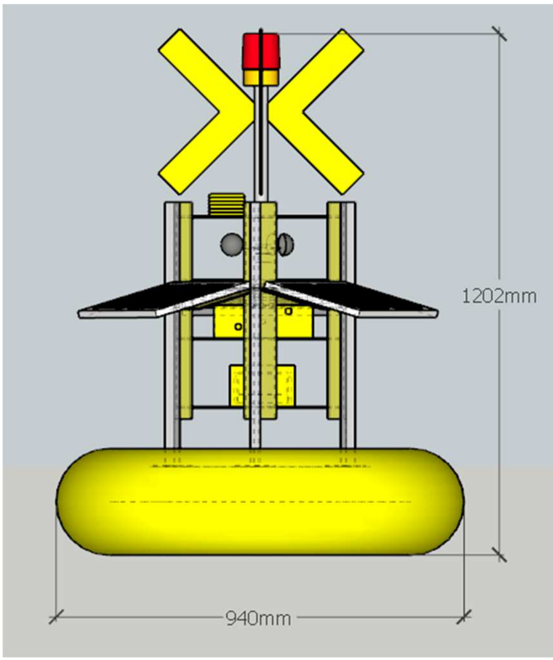

Fig. 3. Design of the Mooring Buoy

A Power Management System as shown in Fig. 5 was designed using 3 solar panels with 10 W capacity, 12 V 18 Ah lead acid battery, 20 A solar charge controller and an Arduino to prolong its power capacity in to sustain the buoys required power consumption and run simultaneously.

In Fig. 6, the mooring buoy system has three parts, the tower which has 4 levels, the buoy and the mooring system. The mooring system is comprised of chains, rope which has a length that is twice the average depth of the Manila Bay and anchors that weigh 4 times the weight of the buoy and the tower combined. The tower of the mooring buoy holds the three chassis of 1st, 2nd, and 4th layers; the components of power management system: beacon, solar panels, battery and solar controller; the anemometer and a special mark. The battery and solar controller are placed inside a sealed chassis at level 1. The wireless electronic communications module, Arduino Mega 2560, power supply, SD card module, and relay module are secured inside a well-ventilated chassis to prevent the Arduino from overheating at level 2. Level 3 is dedicated for anemometer. The chassis for barometer, air temperature sensor, relative humidity sensor, rainfall sensor and solar radiation sensor are secured at the level 4 with good ventilation and clear glass top cover. The water temperature sensor and water salinity sensor are attached to the open middle part of the donut-shaped buoy and submerged at a set height below the water surface. The yellow beacon and yellow St. Andrew's Cross is a special mark used to indicate a feature and was added to the design to comply to the standards provided by International Association of Marine Aids and Light House Authorities (IALA) as instructed by the Philippine Coast Guard.

When the integration of power management system, network system and the mooring buoy system is completed, a stability test was conducted to one mooring buoy to make sure the mooring buoy stays afloat, not flip at surging waves, and not replicate noticeable flaws in the design. The naval architect suggested the donut-shaped buoy must be submerged at 60% of its height to remain stable on water. There are not enough studies conducted to know the types of waves that occurs at the Manila Bay considered in the design of mooring buoys. For this reason, the limitation of this study includes the undetermined stability of the mooring buoys at harsh weather conditions.

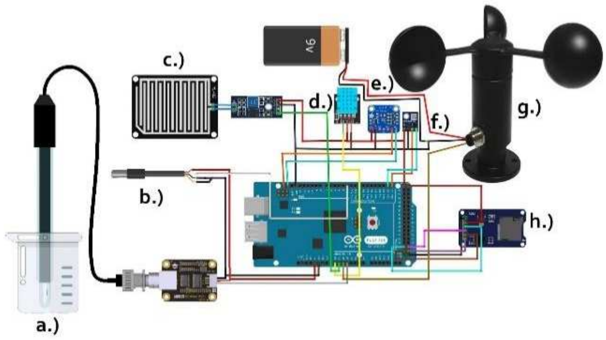

Fig. 4. Circuit and Wiring Diagram. (a.) Salinity sensor, (b.) Water Temperature Sensor, (c.) Rainfall Sensor, (d.) DHT22 Air Temperature Sensor and Relative Humidity Sensor, (e.) BMP180 Barometer, (f.) SI1145 Solar Radiation Sensor, (g.) Anemometer, (h.) SD card module

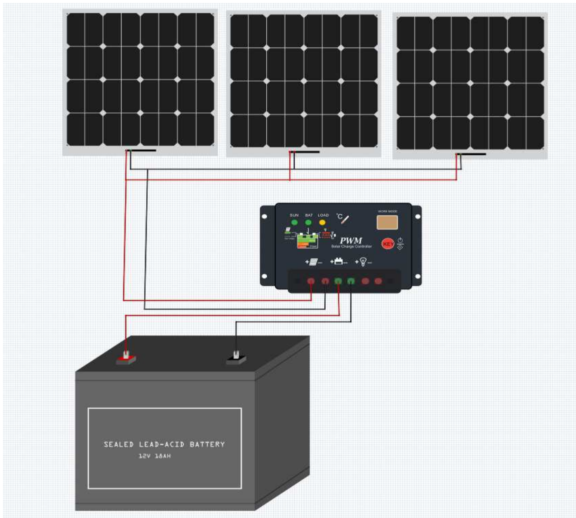

Fig. 5. Power Management Wiring Diagram

B. *Software Development*

Arduino IDE is used in the development of the software section of the Data Acquiring Mooring Buoys using Integrated Sensor Network with Sleep Mode Power Management System. Arduino Mega 2560 is the microcontroller used for gathering, storing, and processing of integrated sensor readings.

Fig. 7 shows the overall flowchart of the system. There are 7 different sensors that gathered meteorological and hydrological parameters. For the meteorological section, it composed of 5 sensors – the Air Temperature and Relative Humidity sensor, Air Pressure sensor, Precipitate Sensor, UV (Ultraviolet) Index Sensor and Windspeed Sensor; whereas for the hydrological section, it composed of 2 sensors – the Water Temperature sensor and Electrical Conductivity Sensor. All sensors are integrated as a network to gather parameters that is used for weather prediction.

The system gathers two sets of 15 minutes values; the 1st set is called the previous and the 2nd set is called the current data. After the 2nd set, the two sets are compared whether the same or not, when the values are the same the microcontroller will turn

OFF specific sensor/s for 15 minutes for the system to conserve energy and make the previous data as its current data while the sensor/s is OFF, and the sensors without the same values is continuously gather reading current values. After 15 minutes, the sensor/s is turn ON again to gather the actual values again.

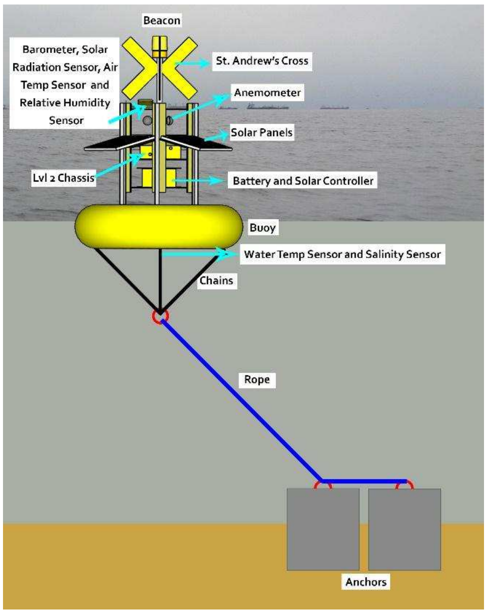

Fig. 6. Mooring System

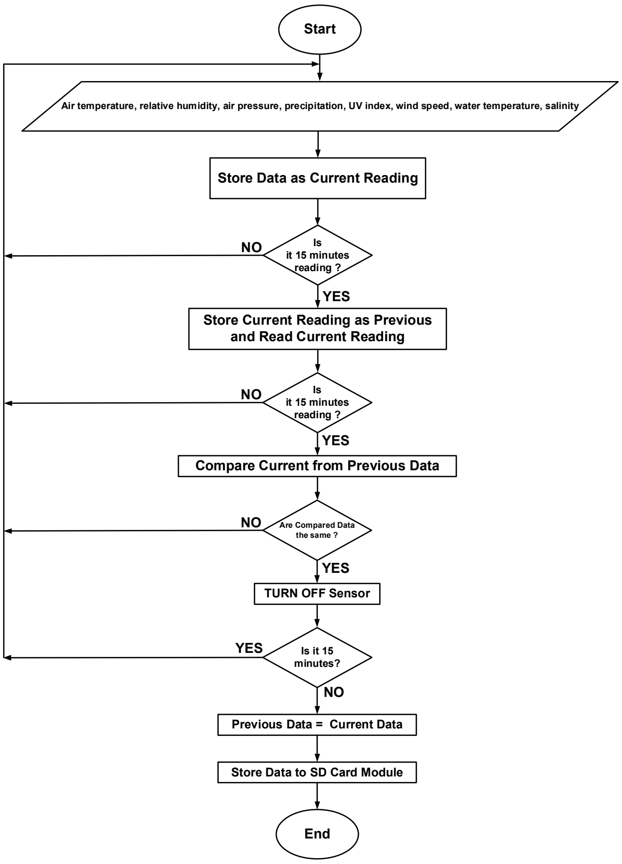

Fig. 7. Overall System Flowchart

IV. Results and Discussion

For this prototype, the Arduino gathered data every second, stored into an SD card and sent to the receiver for the prediction. Moreover, this section includes the graphical representation of the actual data gathered by each sensor within 1 hour and table representation of the power management system design.

Fig. 8 shows the graphical representation of the measured Air Pressure. The graph value of the gathered parameter is 1006 mb which is equal to a Typical low-pressure system. Fig. 9 shows the graphical representation for the Air Temperature in Celsius and as seen from graph, the temperature plays between 24.5 and 24.7 degrees Celsius. Fig. 10 shows the graphical representation for Relative Humidity which plays between 60%-62% humid content. Fig. 11 shows the graphical representation for the wind speed in miles per hour (MPH). From the table the average windspeed recorded was 12.72 MPH. Fig. 12 shows the graphical representation of sensor reading of a rain module, from the table its average is 24.62 which is within the range of a sunny weather. Fig. 13 shows the graphical representation of sensor reading for water temperature and based on the table, the average water temperature is 25 degrees Celsius. Fig. 14 shows the graphical representation of the sensor reading for UV index. As seen from the graph it value is mostly equal to 0.02 which signifies to a low level of UV radiation

Table I shows the electrical specifications of each sensor required which were used as basis for the power management design where they come up with a total of 13W/hour total power required for the buoys to be operational.

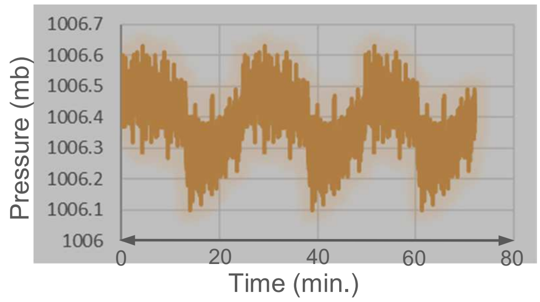

Fig. 8. Barometer readings

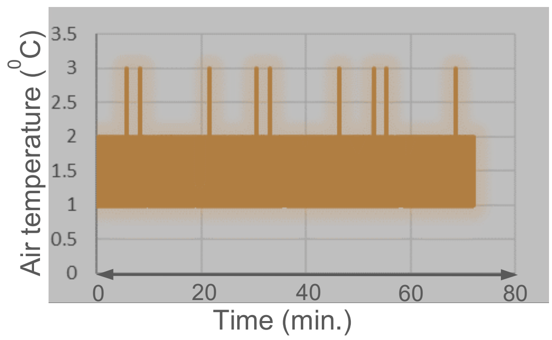

Fig. 9. Air temperature readings

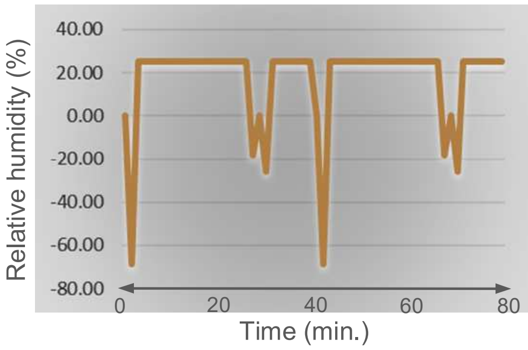

Fig. 10. Relative humidity readings

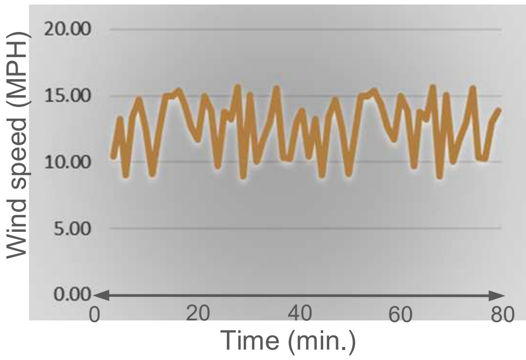

Fig. 11. Anemometer readings

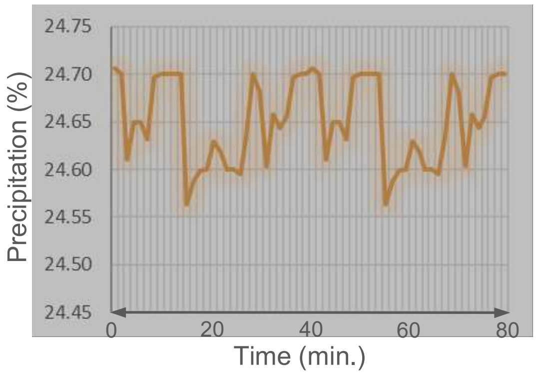

Fig. 12. Precipitation readings

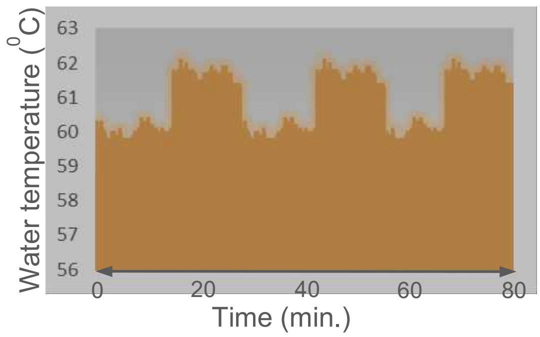

Fig. 13. Water temperature readings

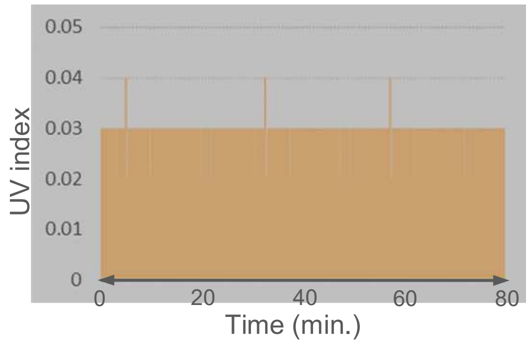

Fig. 14. UV index readings

TABLE I. LOAD ELECTRICAL REQUIREMENTS

Device	Voltage (V)	Current (mA)
Anemometer	9V	200mA
Arduino	9V	1000mA
BMP180	5V	1mA
DHT22	5V	1.5mA
DS18B20	5V	1.5mA
Elec. Conductivity	5V	15mA
RN2483	5V	100mA
Rain Sensor	5V	15mA
Relay Module	5V	120mA
SD card	5V	200mA
SI1145	5V	5.5mA

Table II shows how the power management system helps in prolonging the buoys' power to stay operational. It shows that with the sleep mode function our power management design is up to 75% efficient rather than without sleep mode option.

TABLE II. DIFFERENCE BETWEEN WITH AND WITHOUT SLEEP MODE OPTION

Sleep Mode	Operating Hours
Without	16
With	17 - 21.5

V. CONCLUSION

A data-acquiring mooring weather buoy is developed. The buoy measured air temperature, air pressure, relative humidity, wind speed, rainfall, solar radiation, water temperature, and salinity profile at its location. Three (3) moored buoys are stationed one kilometer from the shore and apart each other to collect information from different areas of the deployment area to have more precise data. Each buoy gathered climate characteristics of different areas, which marked data accurately. The construction of the device consists of a tower, a polystyrene, and a rope. Its tower has beacon light that served as an indicator and solar panels as the primary energy source of the buoy. The buoy carried approximately 15 to 20 kilograms of load, and three (3) solar panels and a 12-V battery. This device has a long battery life and use in idle mode between continuous samples to conserve power. The buoy has a sleep mode that is activated if information gathered after 15 minutes of samples were found consistent, and the power starts again after an additional 15 minutes.

For future works, the buoy system can be equipped with a level of security that can log its location, capture photos of people or objects closed to it and notify the owner about its current condition. Moreover, its size will be increased, and its stability will be tested in a close-controlled environment.

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