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DESIGN AND IMPLEMENTATION OF A METEOROLOGICAL STATION WITH A WIRELESS DATA ACQUISITION SYSTEM (WDAS)

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RESUMEN

Our research describes the development of a wireless data acquisition system (WDAS) for monitoring weather stations. It is based on a GSM/GPRS module with a SIM card, so that we can communicate with it as if it were a mobile phone, obtaining communication between the monitored systems and the data collection server. The proposed system consists of a set of sensors to measure meteorological parameters (solar radiation, solar torque, ambient temperature, relative humidity, wind speed and direction, rain, etc.). The LabVIEW program is used to process, display, and store the collected data on the PC disk. The system has a TFT LCD to show the values of the variables monitored by the weather station. The proposed architecture allows rapid development of the system. It has the advantage of flexibility and can be easily expanded to control renewable energy systems such as photovoltaic system. The measured parameters are available online through the Internet for any user.

Keywords: meteorological station, automation, wireless data, arduino, GSM.

INTRODUCTION

In recent decades, technological evolution has lowered the prices of renewable energy sources, which has resulted in the installation of many renewable energy systems around the world [1]. The main objective of this type of fountain is to optimize its design due to the very high installation costs. Due to climate change, it is necessary to measure and regularly record various meteorological variables. These data are used both for the elaboration of meteorological predictions from numerical models and for climatic studies [2].

Another application is the collection of meteorological data and module performance data in remotely deployed renewable energy systems, particularly in photovoltaic (FI) installations [3]. The meteorological data that is collected consist of wind speed, wind direction, precipitation levels, ambient temperature, relative humidity, and sun radiation, among others [4]. The main meteorological parameters that affect the performance and efficiency of the photovoltaic module are solar irradiation, ambient temperature and wind speed [5].

For photovoltaic modules, the power output and therefore the power generation decreases with an increase in the module temperature. Climate change is a reality that is reflected, among others, in the frequency of floods in some regions, in high temperatures in winter, or simply in the anticipated flowering of some plants [6]. Likewise, as the name of phenomena such as the Greenhouse Effect, the El Niño Phenomenon and Global Warming is also commonly heard, which are a consequence of this change and which have repercussions on sustainable development and the balance of life [7].

Different authors have tried to improve the capture and treatment of meteorological magnitudes for use in industry, using software with greater data processing capacity or through new systems capable of measuring environmental variables. Most of the meteorological stations (M.E.) are automated requiring occasional maintenance [8]. In addition, there are synoptic meteorological observatories, which do have personnel (meteorology observers), so that in addition to the aforementioned data, those related to clouds (quantity, height, type), visibility and present and past weather can be collected. The collection of these data is called synoptic observation [9].

Se han desarrollado muchos sistemas de adquisición de datos para recopilar y procesar dichos datos, así como para supervisar el rendimiento de los sistemas de energía renovable en funcionamiento para evaluar su rendimiento [10-11].

A data acquisition system has been designed and built to take measurements of meteorological variables with a power supply system using photovoltaic energy and battery charging [12]. By means of analog-digital conversion systems connected to a unit based on an Arduino microcontroller, a set of sensor signals is recorded, while the collected data is stored in a local EPROM [13]. The data collected by the microcontroller is transmitted to a PC, using a card based on the SIM900 module that allows us to send and receive calls and SMS and connect to the Internet, transforming our Arduino into a mobile phone. The same architecture has been implemented for measurements of solar irradiation and ambient temperature [14].

This Arduino microcontroller platform features control mechanism modeling, programming, and simulation software tools that facilitate design work, and sufficient capacity to manage accurate analog and digital inputs and outputs, at a reduced economic cost and a leading position in the market [15]. In addition to the design, manufacture and validation of the electronic meteorological prototype, a validation station with more commercial measurement devices was implemented to calibrate and establish the measurement standards required

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by the station. Thus, the aim is to put into operation a low-cost weather station that can be used in different climatic conditions by increasing the potential of renewable energy design teams and building design through data collection [16].

The document consists of the following parts: Materials and Methods, where the components control and design tasks of both the prototype and the validation station are described. Results, where the collected data are presented; Discussion, where the results are justified and the prototype is validated with the station designed for this purpose; and finally the most significant conclusions and consulted references are presented [17].

MATERIALS AND METHODS

The meteorological station has a control module that monitors and collects data on different meteorological variables, such as the amount of rain, air quality, wind speed, relative humidity, ambient temperature and solar radiation. Once the objectives were established, a series of design, modeling. Simulation and prototyping tasks were carried out at the scale described in this section [18].

The first thing that is done once the objective of the meteorological station has been established is to define the type of sensors to be used for data storage and processing [19]. An Arduino Mega 2560 breadboard was used, it has enough storage capacity to keep all the measurements and the necessary inputs and outputs. Table-1 shows the components placed in the weather station.

Table-1. Component sensors of the weather station.

Component	Description
1	Rain gauge sensor.
2	Solar radiation sensor
3	Environmental temperature and humidity sensor.
4	Wind vane and anemometer sensor
5	Soil temperature, humidity and conductivity sensor

Rain Gauge Sensor

This sensor uses a common mechanism of tilting cups for the measurement of precipitation. The geometry and material of the collecting part allow an efficient water outlet, reducing contamination and errors. This can be seen in Figure-1. It has the following measurements: 18 cm in diameter x 30 cm in height. The collection surface is 200 cm2 and the measurement resolution is 0.1 mm according to the WMO recommendations [20].

The use of components in ground thermoplastic offer great resistance to corrosion. Includes leveling screws and bubble level useful for field adjustment. The water outlet is conducted through a tube that allows the verification of the total precipitation. It has an accuracy of 3% up to 25mm/hour. It is have an operation voltage of 18v.

Figure-1. Rain gauge sensor.

For the implementation of the rain gauge sensor, the HX711 load cell transmitter is used. This module is an interface between the load cells and the microcontroller, allowing the weight to be read easily. Internally it is responsible for reading the wheatstone bridge formed by the load cell, converting the analog reading to digital with its internal 24-bit A/D converter [21].

It communicates with the microcontroller through 2 pins (Clock and Data) serially. With one or the average of these data. We calculate the value of the scale that we will use, for this; we will use the following formula:

$$\text{SCALE} = \frac{\text{Read Value.}}{\text{Actual weight}}$$

The weight value must be in the units with which we want our scale to work, for example, it could be 4Kg or 4000g for Kilogram or grams respectively [22]. If the reading value is 1757721.

Therefore, the value of the Scale that we use is:

$$\text{SCALE} = \frac{1757721}{4} = 439430.25$$

Solar Radiation Sensor

This sensor uses a silicon photovoltaic detector mounted on a cosine head to provide measurements of solar radiation. The station incorporates a solar radiation sensor, which allows PYR and Global radiation readings [22]. The sensor is connected to the station directly by means of a 3-meter cable so that it can be installed at the desired height regardless of the position of the station. It has a resolution of 1 W/m^2 (see Figure-2). This allows us to keep track of the amount of light at the height we want, being able to vary this distance depending on the height of the tallest leaves, or any other criterion deemed appropriate [23]. It has a range of 0to 1,800 W/m^2. It has an accuracy of ± 5%. Its dimensions are $51\ mm\ x70\ mm\ x57\ mm$.

Figure-2. Solar radiation sensor.

The UVM30A transmission module is used for the solar radiation sensor. It is supplied with voltages between 3 V and 5 V and can deliver between 0 and 1200 mV (It does not exceed one volt) [24]. As above 1100 mV output corresponds to an extremely high UV index (an index greater than 10), the internal reference of 1100 mV can be used to better distribute the sensitivity, although giving up the possibility of determining how much the index 10 is exceeded. , only estimating that 11 has been reached, but saving a voltage divider to use as an analog input reference in Arduino [25].

Environmental Temperature and Humidity Sensor

The placement of these two sensors is integrated with the protector, so that the user only has to be in charge of the correct installation of the protector, depending on where they want to measure the variables offered by these sensors [26]. For the installation, we must fix, at the desired height at which the temperature-humidity and CO_2 levels are to be measured, the support. This sensor works with a voltage of 5.5v and consumes an average of 90 W. The sensor has an accuracy of 1.8% [27].

In addition, it is equipped with a sensor protector. This protector allows isolating the temperature and humidity sensor, protecting it from direct exposure to the sun so that the temperature does not rise and allowing the passage of air so that the reading of the sensors is very reliable both at high temperatures and in meteorological conditions adverse [28].

Figure-3. Environmental temperature and humidity sensor.

For the temperature sensor, the code for reading the analog input the resolution is changed. With this sensor, we can measure temperatures of 500ºC with 5V. This will never happen as it is outside the sensor's temperature range [29]. For this, we are going to use the analog Reference function that allows us to establish the reference value for input 1023. With 5V, but if we use the INTERNAL function we can have a higher resolution, 1.1V [30]. This is equivalent to being able to measure temperatures of up to 110ºC, within the sensor's operating range. For this, we only have to use the following formula:

$$\text{Temperature} = \text{Value} * 1.1 * \left(\frac{110}{1024}\right)$$

Anemometer and Wind Vane Sensor

It is used to measure the wind direction using the latest technology in wind sensors: i. Balanced wind indicator, ii. Close to zero friction, iii. High precision with the magnetic angle sensor, iv. Unique locking feature that allows you to choose “North” for orientation during installation [31].

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Figure-4. Anemometer and wind vane sensor.

Figure-5. Soil temperature, humidity and conductivity sensor.

The anemometer includes the wind speed and direction sensors. These sensors are capable of withstanding hurricane winds, as well as feeling a light breeze. Includes sealed stainless steel bearings for long life. Range and accuracy specifications have been verified in wind tunnel tests [32]. Digital filtering, with the time constant as specified below, is applied to wind direction measurements. The anemometer-wind vane assembly must be installed in the highest part of the building, at least one and a half meters from the lower horizontal base and without any artificial obstacle in its horizontal in its 360º of vision [33]. It has a rotor with three buckets; it has a range from 1 to 322Km/h. It has a reading precision of 4%. The rotor diameter is 152 mm. It operates with voltages of 5v, has a resolution of 0.1 m/s [34].

For this sensor, the following formula was established:

$$\text{Speed} = \text{Value} * 0.1 * \left(\frac{5}{1024}\right)$$

Soil Temperature, Humidity and Conductivity Sensor

The soil sensor measures soil temperature, soil moisture, soil electrical conductivity, complex dielectric permittivity of soil, and electrical conductivity of "water pores" contained in the soil hole [35]. Both soil and pore water conductivity is automatically compensated for temperature.

The soil sensor bases its measurements on the physics and behavior of an electromagnetic radio wave reflected off the ground. Based on the measurement of ground impedance through frequency domain reflectometry, the probe determines the dielectric permittivity [36]. The complex dielectric permittivity enables the sensor to simultaneously calculate soil moisture and soil electrical conductivity. The sensor uses a frequency of 50 MHz, which minimizes the effects of texture and salinity, making measurements accurate on most hydroponic substrates [37].

The electrical conductivity of "pore water" is calculated using algorithms based on soil moisture and soil electrical conductivity values. It has a conductivity range of 0 to 25 dS/m (bulk) operating in a temperature range of -40 to 60 ºC.

This sensor is designed to remain buried in the ground for many years. The probe is made up of three main components: i. Marine grade stainless steel tooth set, ii. Nylon. The outer shell is made of this material, iii. Epoxy resin. It provides internal electronic protection as well as a ruggedly constructed design for the probes [38].

To control the measurements of temperature, humidity and conductivity the sensor has three input pins and a reference signal. This sensor has a power requirement of 7 to 25 VDC [39]. It has an electrical conductivity of 0 to 20 dS / m, with a resolution of 0.25 dS / m, that is:

$$\text{Conductivity} = \text{Value} * 0.25 * \left(\frac{20}{1024}\right)$$

Proposed Weather Station

In Figure-6, we can see the sensors that the weather station has, the TFT LCD for data visualization and the SIM900 GSM data transmission card.

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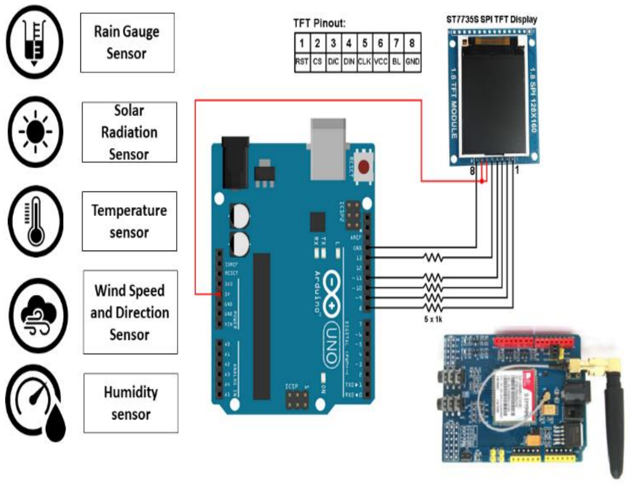

Figure-6. Sensors and electronic interface circuits in the weather station.

In Figure-7, the general flow diagram of the operation of the designed meteorological station is shown. The first step is the activation of the sensors [40]. The station sampling time is selected, that is, the period of time that the station will store and subsequently transmit via GPRS communication at a speed of 144 kbps. Likewise, it is selected which variables are to be measured. When starting the measurement, the system is constant presenting these data in a LDC TCT Nextion NX8048T070 - Generic 7.0 21].

The arduino Mega 256 initializes the sensors that connect to the device's ADC inputs. The rain gauge sensor is Davis® Rain Gauge Smart Sensors, the solar radiation sensor is the Davis® Instruments 6450, the ambient temperature and humidity sensor is the AO-330-01B Ambient Temperature Humidity, the wind speed and direction sensor is the Davis 6410 Wind Vane Anemometer Meter for Vantage Pro and lastly, the soil temperature, humidity and conductivity sensor CERES Temp. Humidity & CE Soil Sensor RS-485 [24].

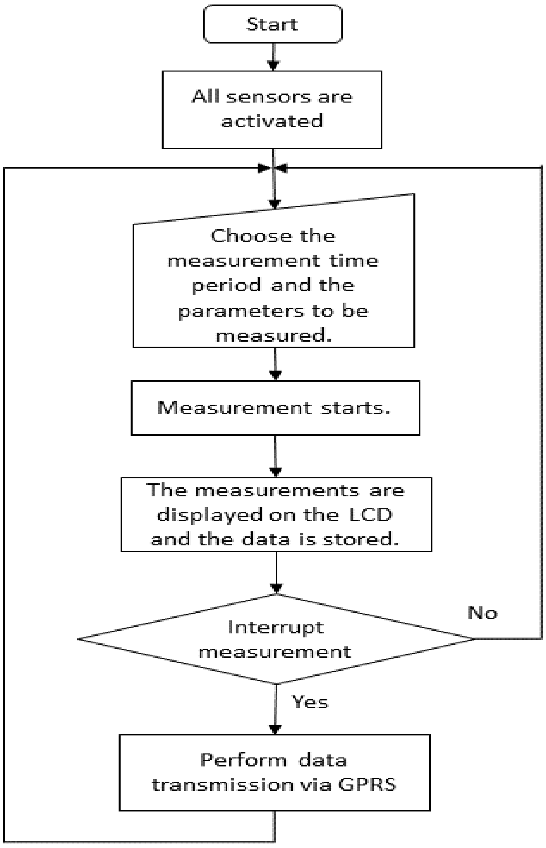

Figure-7. General flow diagram of the operation of the meteorological station.

METHODOLOGY

To verify the operation of the meteorological station, tests were carried out on the system for a month; during this period, it was calibrated. However, it is still necessary to verify the reliability of the selected sensors, as well as the veracity of the programming code to confirm that the system performs the required functions [25-26].

For this reason, it was decided to implement in parallel a validation station, assembled with duly calibrated commercial sensors, which allows the values obtained to be confirmed, working with the commercial Davis 6250 Vantage Vue meteorology station [27]. This validation module can be used not only in the commissioning process of the weather station but also for periodic tasks such as its reliability verification, validation of sensors in cases of replacement after failure, diagnosis of anomalies or detection of statistically abnormal values. [28]. Figure-8 shows the validation station used for the prototype calibration.

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Figure-8. Davis 6250 Vantage Vue commercial weather station used for system validation.

RESULTS

Next, the analysis and presentation of the data obtained for the calibration of the sensors is carried out.

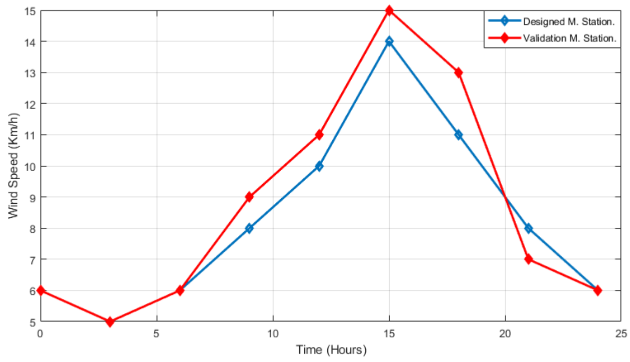

Figure-9. Wind speed measurements taken from the designed meteorological station and the validation station, on 10/28/2020.

In Figure-10, we can see the wind speed measurements of the designed meteorological station and the station taken for the validation. By analyzing these results after the first validation, the device obtains an absolute error in the measurement of wind speed ± 0.15 [32]. Likewise, an absolute imprecision of 0.03495 was obtained. These results show us a good quality in the measurement obtained with the meteorological station designed after calibration [34].

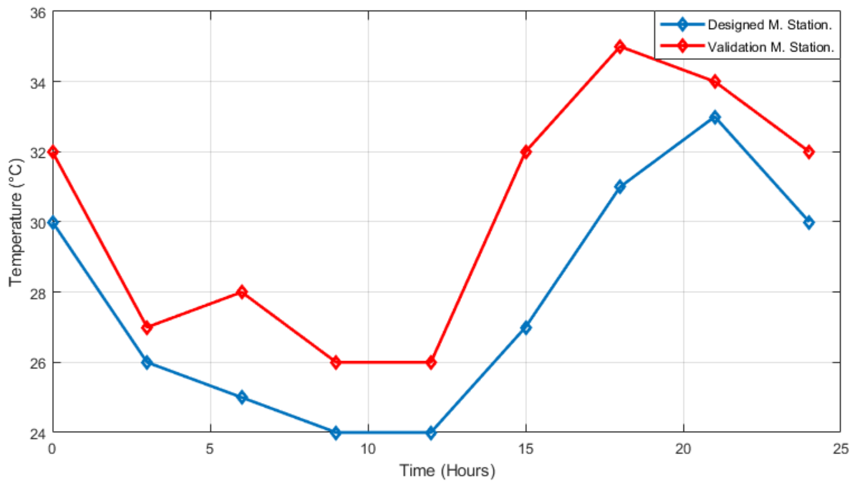

Figure-10. Ambient temperature measurements taken from the designed meteorological station and the validation station, on 10/28/2020.

In Figure-11, we can see the comparison between the measurements recorded by the meteorological station and the station taken for its validation [36]. We can see that in the worst case the difference is approximately 4° C. In the statistical analysis performed, we obtained an absolute imprecision of 0.3246 [37].

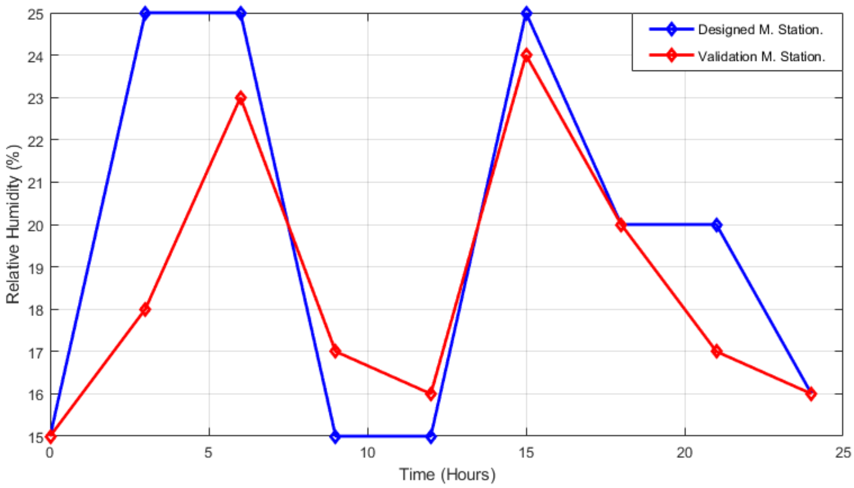

Figure-11. Relative air humidity taken from the designed meteorological station and the validation station, on 10/28/2020.

In Figure-11, we can see the comparison between the relative air humidity measurements recorded by the meteorological station and the station taken for its validation [38]. We can see that in the worst case the difference is approximately 7%. In the statistical analysis carried out, we obtained an absolute imprecision of 0.475 [39]. The absolute error is an indicator of the imprecision of a given mean. The standard deviation present in the sample obtained was 3.906 and a variance of 14.4843 [40].

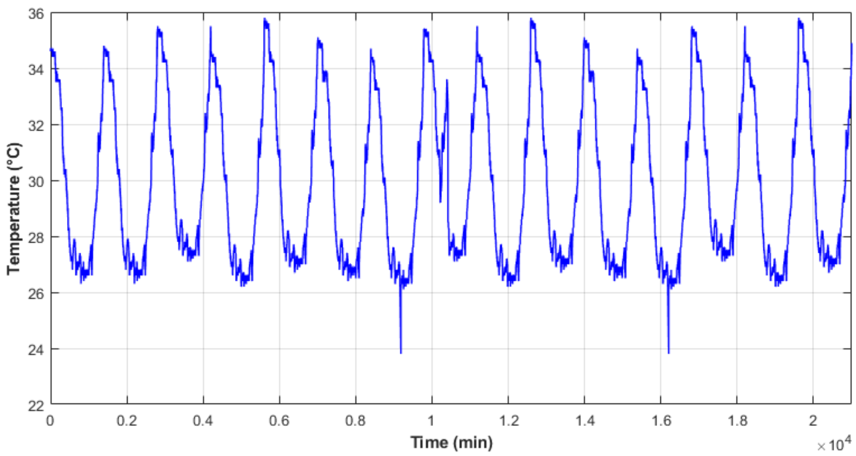

Figure-12. Record of the relative humidity of the soil with the weather station designed.

In Figure-12, we can observe the records of the soil temperature with the weather station for a period of 15 days after the calibration. Likewise, in Figure-13 we can observe the records of the relative humidity of the soil for the same period of 15 days.

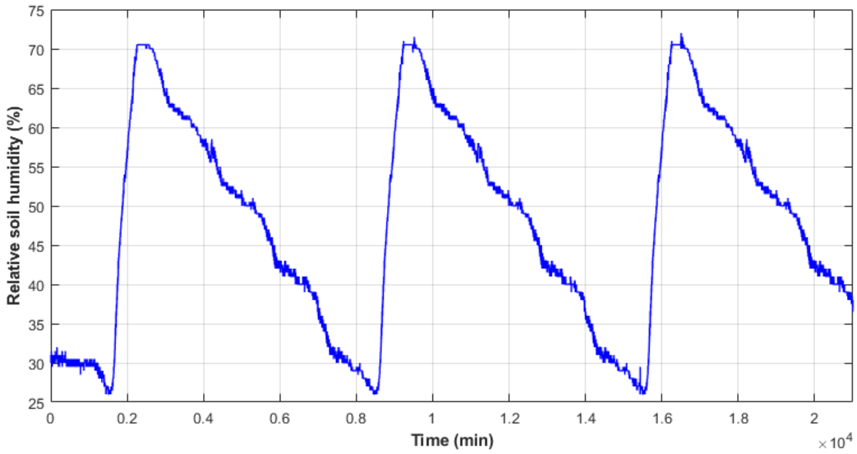

Figure-13. Record the soil temperature with the designed weather station.

CONCLUSIONS

The original objective of the research was to develop a low-cost weather station with technology and to conduct a proof of concept for its implementation in applications for monitoring environmental variables and remote data acquisition systems, such as for the commercial weather station industry.

The wireless data acquisition system based on GPRS technology is used for data transmission in different commercial systems to not only measure and transmit the meteorological parameters, but also to collect data on system performance for evaluation purposes.

Validation of the data obtained with the built meteorological station was carried out, giving errors of 5%, which after the corresponding calibration of the same decreased to be almost zero in some variables such as temperature and wind speed.

In this article, we have focused on the development of a wireless data acquisition system (SADW) by using the Arduino Mega 256 board and a Nextion TDT LDC to display the information. The proposed SADW is based on a precision electronic circuit, data processing and transmission. Once the data were acquired, they were processed through Labview to carry out the corresponding calibration.

CONFLICTING INTERESTS

The authors declare that there are no conflicts of interest regarding the publication of this document.

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