

Marcos Antonio Ponce-Jara; Carlos Velásquez-Figueroa; David Tonato-Peralta;
George Paredes-Morillo

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Diseño de una estación meteorológica automática para registrar las variables solar y eólica

Design of an automatic meteorological station to record solar and wind variables

Marcos Antonio Ponce-Jara
marcos.ponce@uleam.edu.ec
Universidad Laica Eloy Alfaro de Manabí, Manta
Ecuador
<https://orcid.org/0000-0002-4450-4740>

Giselle Velásquez-Figueroa
giselle.velasquez@uleam.edu.ec
Universidad Laica Eloy Alfaro de Manabí
Ecuador
<https://orcid.org/0000-0002-4494-6784>

David Tonato-Peralta
ctonato@inamhi.gob.ec
Universidad Laica Eloy Alfaro de Manabí, Manta
Ecuador
<https://orcid.org/0000-0003-4188-5354>

George Paredes-Morillo
georgejoseph1615@gmail.com
Universidad Laica Eloy Alfaro de Manabí, Manta
Ecuador
<https://orcid.org/0000-0001-5298-0117>

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Marcos Antonio Ponce-Jara; Carlos Velásquez-Figueroa; David Tonato-Peralta;
George Paredes-Morillo

ABSTRACT

The objective of the research was to design an automatic meteorological station to record the solar and wind variables. It was developed from a descriptive documentary methodology with a non-experimental design, which, in a first phase, allowed analyzing weather data in order to diagnose the need to design a proposal for a meteorological station. It was observed that the radiation ranged between 5,000 and 7,000 Wh / (m²-day), even exceeding 8,000 Wh / (m²-day) in February, with some exceptions. Also, it was noteworthy that there were days with very low solar radiation due to the rains and heavy cloud cover. The designed automatic weather station showed a great advantage over conventional meteorological stations; this may be used in areas with little accessibility or in the absence of a power grid.

Descriptors: Weather; weather modification; bioclimatology. (Words taken from the UNESCO Thesaurus).

INTRODUCTION

The earth has experienced important climatic changes throughout its millions of years; for example, the last ice age that is recorded approximately 10,000 years ago. (Ureña-Elizondo, 2017). Meteorology is the interdisciplinary science focused on the physics of the atmosphere, which studies the weather, the atmospheric environment, the phenomena produced and the laws that govern it (Barriga, et al., 2015). This project proposes the study of meteorology with the construction of a meteorological station, in order to be able to take measurements and monitor the following atmospheric variables: solar radiation, wind speed, wind direction.

The meteorological measurement process is directly based on the implementation of a meteorological station, which seeks to have access to the installed sensors through a web page from anywhere in the world (Estévez, 2011). The measurement of meteorological variables is carried out by observing any geographical area, it is essentially a physical valuation, which is accomplished manually in the synoptic hours and the information is recorded in a meteorological card every day. Through electronic engineering and technology, the human observer may be partially or completely replaced by a machine in some cases, optimizing the measurement process of the

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different meteorological parameters (Ruiz-Ayala, et al., 2018).

In addition to the proposal previously described, the experience of the National Institute of Meteorology and Hydrology (INAMHI) was considered, with the purpose of having real-time information for meteorological surveillance systems and for early warning systems. In 2003, they began the first programs for the creation of an automatic meteorology network and in 2013; there were 91 automatic weather stations, which had satellite communication and General Packet Radio Service (GPRS) in real time to link with INAMHI servers (INAMHI, 2013).

In 2019, it was highlighted that there were only 5 enabled meteorological stations in Manabí, corresponding to stations, such as: M0168, M1217, M0162, M1208, M1233. Source: Vaca-Revelo & Ordóñez (2019).

Solar and Wind Potential in Manabí

According to data from the Solar and Wind Atlas (CONELEC, 2008), the province of Manabí has a high solar potential, and there are some areas of great interest where wind energy can be used through mini-wind technology and larger plants.

Solar potential

The province of Manabí has one of the highest levels of incident solar radiation in the country, with values that may reach around 4,700 Wh / m² / day (CONELEC, 2008). However, the behavior of this variable is not uniform and has variations throughout the geographical area of the province that are worthy to study in order to have a more accurate profile of such behavior. At the same time, despite being an abundant resource, its use in the province is limited to a 1 MW solar photovoltaic installation in the Jaramijó canton and 0.5 MW in Atacames. Source: Saltos Arauz, et al., (2017).

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Wind Potential

The highest wind potential in Ecuador is located in the Andean region, in the provinces of Carchi, Imbabura, Chimborazo, Cañar and Loja, where a potential of approximately 1,670 MW is estimated. Coastal regions such as the Santa Elena peninsula, El Aromo or parts of the Esmeraldas coasts have been located to a lesser extent (MEER, 2013). In addition, according to the Corporation for Energy Research (CER, 2017), there are two important areas for electricity generation through large-scale wind technology in Manabí, which are located in Aromo (Manta canton) and Montecristi hill (Montecristi canton). It was determined that the average velocities at an altitude of 80 m could reach 6.63 m / s and 5.88 m / s at these points, respectively.

Due to the above, the objective of the research was to design an automatic meteorological station to record the solar and wind variables.

METHOD

The research was developed from a documentary descriptive methodology with a non-experimental design, which, in a first phase, allowed the analysis for designing a proposal of a meteorological station in a second work phase. Thus, the structure was built in both hardware and software, to achieve the acquisition of solar and wind data, which were conditioned by the Raspberry Pi device, based on datalogger. It is important to highlight that this type of study has not been carried out locally with the depth or endorsement necessary for the development of it.

ANALYSIS OF THE RESULTS

In this respect, the data collected on solar radiation, wind speed and direction from February to April were analyzed.

With respect to the solar radiation data collected by the meteorological station, which was expressed in Wh / (m²-day), it was observed that the radiation ranged between 5,000 and 7,000 Wh / (m²-day), even exceeding 8,000 Wh / (m²-day) in February, with some

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exceptions. Also, it was noteworthy that there were days with very low solar radiation due to the rains and heavy cloud. See: <https://meteorologia.uleam.edu.ec/>

Besides, the solar radiation data referred to the month of March were evidenced on the page: <https://meteorologia.uleam.edu.ec/>. During this month, they obtained better results of solar radiation with respect to the previous one. It showed a more stable month with fewer fluctuations typical of the Ecuadorian coast vacation month. Most of the days ranged from 5,000 to a little more than 8,000 Wh / (m²-day), implied very good amount of energy that could be used.

On the other hand, on the indicated website, solar radiation data related to the month of April were shown. In general, this month ranged between 5,000 and 7,500 Wh / (m²-day), but it was observed that there were peaks greater than 9,000 Wh / (m²-day), being this month the highest in terms of solar radiation of those presented.

The average solar radiation measured during these months suggested the viability of using photovoltaic solar technology given the high incident solar radiation on this territory. Although there were very high peaks of Solar Radiation in April, March was the month that effectively generated more solar radiation.

Regarding the wind direction data, a radial graph was observed in order to better identify the frequency of wind direction between the months of February and April. The wind direction was predominant towards the south, where the greatest amount of data was found (between 276° and 289°); likewise, there was a considerable amount of data between 159° and 237°.

On the other hand, in terms of wind speed, there was a high correlation between more data and low speeds, and less data for speeds greater than 3 m / s. Source: <https://meteorologia.uleam.edu.ec/>

In general, in order to take advantage of wind energy through mini-wind technology, it was necessary to have speeds greater than 3 m / s; as a result, the data suggested that there was a good amount of wind energy that might be used to produce electric power using mini wind technology.

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PROPOSAL OF THE AUTOMATIC METEOROLOGICAL STATION (AMS)

Within these typologies, an automatic meteorological station (AMS) allows making and transmitting observations mechanically (OMM, 2017). Consequently, it includes a series of instruments for the collection and recording of meteorological variables according to their type, such as: climatic, synoptic or marine.

The measurements made with an AMS are read and recorded by a central data unit or “datalogger”, which may be processed by the device itself or externally. The main objective of these stations is to increase the number and reliability of surface observations, which is properly achieved (OMM, 2017).

For this purpose, through a collaboration agreement with INAMHI, both the sensors and the datalogger were calibrated and validated. The proposed design is composed of 3 sensors: Pyranometer, Anemometer and Vane. The signals from these sensors pass through an analog-digital converter (ADC) module to condition the signals before entering the central processing unit or datalogger. For this design, a Raspberry Pi was chosen. Each sensor is read at the same time; therefore, the reading process lasts one minute, where digital filters are executed and an average of the values is established. These are sent to both the INAMHI and ULEAM servers to be stored.

Then they are shown in a web application with free access to the university community in real time where changes with direction are easier to visualize (ULEAM, 2020). Besides, it has a photovoltaic solar system incorporated to control the weather station in the absence of a power grid.

Datalogger with Raspberry PI microcomputer for AMS

The datalogger is one of the most important devices in the installation and represents the central processing unit for the acquisition of data from the sensors and its conversion into a computer-readable format. It is also responsible for storing and sending information remotely by using specific algorithms for this purpose. In general, the prices of the devices in charge of these activities are very high. In this article, the

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use of a RaspBerry Pi 3B microcomputer like the datalogger is proposed as an alternative.

Sensors for the measurement of meteorological variables

A meteorological station must be able to measure analog and digital variables. For this design, it was equipped with analog and digital sensors to measure solar radiation, direction and wind speed. Solar radiation and wind direction is measured by analog sensors, which use an analog-digital (A / D) converter to adjust the signal before entering the RaspBerry Pi 3B. The converter communicates with the RaspBerry through the I2C communication protocol. On the other hand, the anemometer is a sensor that provides a digital signal that connects directly to the GPIO port of the RaspBerry Pi 3B.

Anemometer and weather vane

The sensor in charge of measuring wind speed is the NRG # 40GH anemometer, it is connected directly to one digital input of the GPIO port of the RaspBerry Pi3B. This sensor provides a digital signal in the form of a train of pulses, producing a pulse each time the circuit is closed for each generated turn. Internally, it has a tetrapolar magnet that induces a voltage of the sine wave in a coil, producing an output signal with the frequency proportional to the wind speed. The speed that is registered is proportional to the number of turns that is produced in a second, according to its data sheet, (NRG, 2015).

The wind direction is recorded by the NRG # 200P sensor, which is an analog sensor powered at 5 volts (5V) that provides a voltage proportional to the degrees of the vane. In order to condition the signal before being read by the RaspBerry Pi3B, it is necessary to use an A / D converter. The following formula defines the way the position is determined: $\text{Direction [degrees of rotation]} = V_{out} * 360^\circ / 5 \text{ (volts)}$.

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Pyranometer

The pyranometer is in charge of measuring the global incident solar radiation that reaches the earth's surface; it is a thermopile-based sensor that generates a signal in millivolts (mV) (0 - 50 mV), which may be measured directly on a datalogger without the need of an external power supply. For this sensor, it is necessary to use the A / D converter of minimum 16 bits speed, to condition the signal before entering the RaspBerry Pi3B. Once the electrical signal corresponding to solar radiation has been received, the formula used to determine solar radiation is: Solar Radiation $[W / m^2] = V_{out} * 2000 (w / m^2) / 0.05 (volts)$.

CONCLUSIONS

The automatic weather station designed, shows a great advantage over conventional weather stations. This may be used in areas with little accessibility or in the absence of an electrical network, which is why the design of a photovoltaic solar system is vital to ensure the energy supply for a long period.

In its operation, the datalogger is the most important element of an AMS, since it is in charge of collecting and processing the signals measured by the different meteorological sensors. In order to use this system, it is necessary to calibrate the measuring instruments; therefore, a parallel reading process was designed, that is, each sensor is read equally and in real time, to obtain reliable results.

The appearance of low-cost microcomputers such as the RaspBerry Pi3B, offers a good alternative to design a datalogger for use in the field of meteorology. It is composed of multiple communication ports (USB, Serial, SPI, I2C, HMI, Ethernet) which allow interacting with the device in a friendly and remote way; so it facilitates this station to be fully functional, it supports the expansion of more sensors and allows them to be read in real time, without the risk of losing data.

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Likewise, the use of web servers to store the measured information is of utmost importance to obtain a secure long-term backup. The test time determined the good performance of this prototype; however, they may be improved.

The information obtained on radiation, wind speed direction is not yet conclusive, but it gives an idea of the usefulness of this resource to generate energy projects and encourage the use of non-conventional renewable energies.

However, a technical-economic feasibility study is required, which uses the variables characterized in this project to justify the implementation of this type of technology.

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