Article

Journal of Technical Invention
June 2022 Vol.6 No.17 22-28

Two Axis Solar Tracker Monitoring

Monitoreo de Seguidor Solar de Dos Ejes Tipo Monoposte

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DOI: 10.35429/JOTI.2022.17.6.22.28 Received January 12, 2022; Accepted June 24, 2022

Resumen

Los seguidores solares han surgido como una alternativa para una mayor captación de energía solar para los paneles solares. Sin embargo, los seguidores solares pueden llegar a fallar o tener cambios repentinos en su seguimiento, por lo que se requiere conocer las variables del seguidor solar en todo momento. Esto se puede lograr a través de una comunicación tipo IoT, esta consiste en emplear microcontroladores, computadoras de placa reducida y una comunicación que envie los datos a algún servidor. Este trabajo propone un esquema de monitoreo para los seguidores solares de dos ejes tipo monoposte. A diferencia de los trabajos publicados en el estado del arte, este tiene mayores funcionalidades y flexibilidad, utilizando una comunicación Wifi con la Raspberry PI 4B. El esquema de monitoreo se ha validado experimentalmente, implementando en los motores para un seguidor solar de dos ejes tipo monoposte, proporcionando un excelente desempeño a lo largo de sus trayectorias.

Monitoreo, Seguidor solar, Paneles solares

Abstract

Solar trackers have emerged as an alternative for increased solar energy collection for photovoltaic panels (PV). However, PV trackers could eventually fail or have unexpected changes during tracking, requiring continuous knowledge of the solar tracker parameters at any time. It is possible to accomplish with IoT communication, which consists of implementing microcontrollers, embedded computers and network communication to transmit the information to a server. This paper presents a monitoring scheme for two-axis single pole solar trackers. In contrast to the published papers in the state of the art, it has more functionality and greater flexibility, employing a Wi-Fi connection with the Raspberry PI 4B. This monitoring scheme has been experimentally tested using the motors for a two-axis single pole solar tracker, resulting in an excellent performance along their trajectories.

Monitoring, Solar tracker, Solar panels

Citation: SANTANA-CRUZ, Rene Francisco, OLIVO-FLORES, Marco Antonio, OCAMPO-MARTÍNEZ, Rafael and SOTELO-MATÍNEZ, Samuel. Two Axis Solar Tracker Monitoring. Journal of Technical Invention. 2022. 6-17: 22-28

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I. Introduction

In recent years, there has been a growing interest in producing electricity in a more environmentally friendly way, while seeking to maximize electricity production in order to stop producing electricity by polluting means. Solar panel technology is very important on a global scale for the production of clean electrical energy [1],[2]. However, there are complications in the collection of solar energy, as a consequence it is necessary to use solar tracking systems [3,5]. The literature mentions that there are two types of trackers according to the type of movement: one-dimensional or two-dimensional. The two-dimensional can change in two axes and according to their support they are known as carousel or monopost.

The two-axis monopole type solar trackers need to know the altitude and azimuthal angle of the sun, both of which change constantly throughout the day. Two-axis tracking captures more solar energy compared to single-axis tracking. The most commonly used method is polar tracking better known as altitude-azimuthal tracking. The principle of operation is to track the polar axis, which is parallel to the Earth's rotation axis. The other axis is perpendicular to the polar axis, called the declination axis. When the two-axis monopole type solar tracker is in operation, it rotates at the same speed as the Earth's rotation but the direction of rotation is opposite.

The performance of the solar tracking action is by consuming the least electrical energy, which implies a balance between generation and tracking. In addition to solar tracking, it is essential to implement a monitoring system to view the tracking variables in real time. In [6-13] the Arduino Uno platform is used for monitoring the solar energy parameters and the factors affecting its deficiencies along with the ThingSpeak platform interfaced with Wemos.

The system developed in [14] uses an ESP32 IoT board and a web application. This was designed with HTML, CSS and JavaScript. Other works employ the connection between Arduino and Pi Raspberry Pi [15],[16]. Their IoT application was open-sourced as an API and ThingSpeak [15,17].

On the other hand, monitoring systems have been designed with ESP32 Wi-Fi modules. The ESP8266 Wi-Fi module is based on ESP8266 to transmit sensor data with an ESP 32 microcontroller and a local Thinger.IO server [18]. In [19] the Arduino Mega was used for data transfer to the Cayenne API using an additional Ethernet board and RJ45 cable.

Modbus communication has also been employed in the energy management monitoring and the information is sent through a Modbus to Ethernet converter, thereby sending the solar radiation information with an IoT board. The board uses an Intel Atom quad-core 2.4 GHz processor and a Broadcom BCM 2837 64-bit quad-core 1.2 GHz CPU [20].

In this work, we propose to use an Arduino Mega to read the 1024 PPR (Pulse Per Revolution) encoders of the motors of a two-axis monopole type solar tracker. The Arduino collects the PPR data at a sampling rate of 15s. Simultaneously, the PPR data is sent to a small board computer (Raspberry PI 4B), via SPI (Serial Peripherical Interface) communication.

The Raspberry does a conversion of the PPRs to zenith and azimuthal degrees of inclination in order to send them to a web page via IOT communication. Such IOT communication is carried out from the Raspberry in a WiFi environment, addressing the ThingSpeak server. Within ThingSpeak a system called SCADA has been designed using the DIN EN ISO 924 standard that allows to better interpret the data in simple graphs.

The data acquired daily are stored in matrices within ThingSpeak that allow to have a backup and to generate histograms in off-line conditions, thus maintaining a backup system in case of eventual anomalies.

This paper is divided into 5 sections. Section II presents the monitoring system of the two-axis monopole solar tracker and a description of its components. Section III shows the complete monitoring scheme of the two-axis monopole solar tracker through a block diagram. Finally, sections IV and V show the experimental results and the corresponding conclusions.

II. Monitoring system of the two-axis monopole type solar tracker

The remote monitoring of the variables is achieved through platforms that allow the transmission of data to any point where the user in question is located and without the need to move to the site where the process is being carried out. An indispensable part is that the data can be observed in real time, in order to know the status of the process at a given moment.

Figure 1 shows the approach of this work. First, data acquisition is performed on the Arduino (Figure 1.a) and transferred via SPI to a Raspberry Pi (Figure 1.b). After processing the information, the Raspberry Pi sends this data via WiFi to the ThingSpeak platform using a generated API key (Figure 1.c). With this platform it is possible to receive the information and then display it graphically in a SCADA system, which has diagrams and graphs describing the trajectory of the motor axes. The ThingSpeak system has a sampling time of 15 seconds in the free version. Thus, the data is sent in intervals of this time period.

III. Monitoring algorithm for the two-axis monopole type solar tracker

In the solar tracker monitoring is done in conjunction between an Arduino Mega and Raspberry Pi 4B. Both platforms are low cost and allow acquiring the measurements from the encoders, which are embedded in the motor shafts. The motors are DC and permanent magnet, have a reduction gear and dual shaft drives to generate the rotary motion for the two-axis monopole type solar tracker. Both motors are electronically managed by two H-type full bridges, achieving the adjustment of the motion according to the pulse width modulation.

Figure 2 presents the monitoring algorithm of the two-axis monopost type solar tracker. According to this figure it can be seen that the arduino is in a lower level, because it is in charge of the pulse width modulation, using modulation frequency is 1 kHz and the duty cycle changes between 80% to 92%.

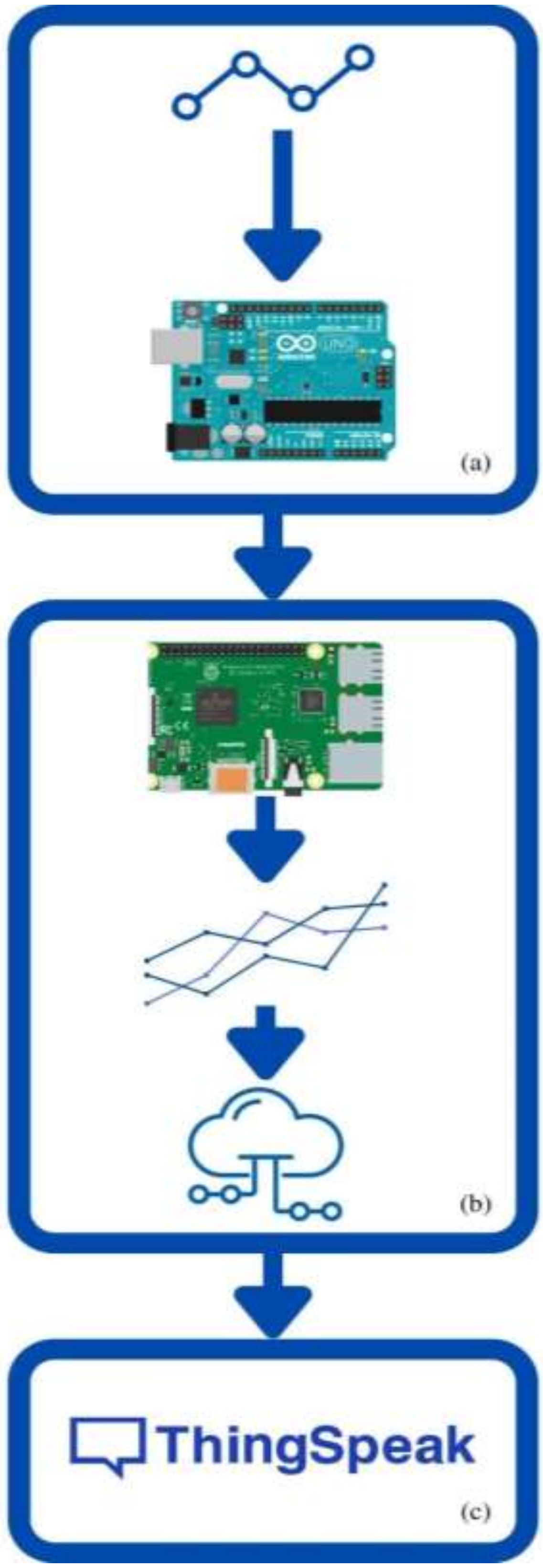

Figure 1 Development of the monitoring of a solar tracking system considering the stages: (a) Data acquisition using Arduino. (b) Data reception, conditioning and sending using Raspberry Pi. (c) Data monitoring using the ThingSpeak platform.

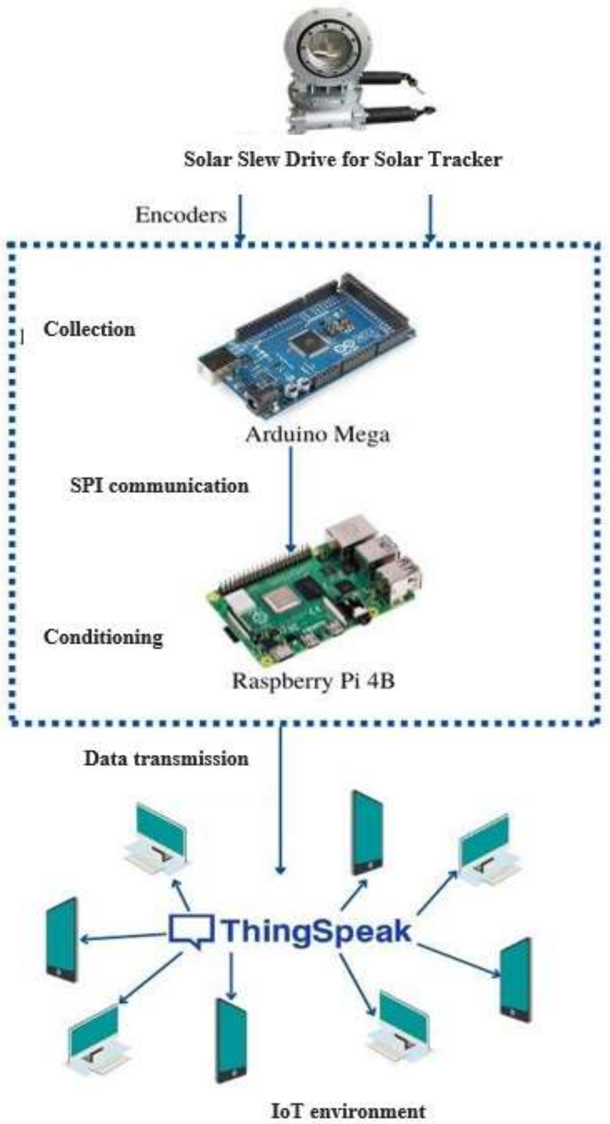

Figure 2 Schematic used for solar tracking monitoring using IoT tools (Raspberry Pi and ThingSpeak)

In addition to changing the duty cycle, the Arduino (slave) is in charge of sending the data from the encoders via SPI communication to the Raspberry. The Raspberry acts as the master because it interrupts the Arduino every 15s to send it the PPRs data. The Raspberry interprets the PPRs and converts them into degrees of zenith and azimuthal tilt, which correspond to each axis of the motor.

This information aggregation action is known as tracker data acquisition, the Raspberry sends the data set via WiFi. At this point, an API Key address is used. The API is the access key to the ThingSpeak IoT platform site. On the ThingSpeak platform, the information is routed to the server. Here the data is queried for display in the SCADA system (Figure 2). The SCADA system provides the opportunity to remotely access any device with access to the platform.

Finally, the ThingSpeak program allows the information sent by the Raspberry during each sampling period to be stored in a database. This database is used for the history of the azimuthal and zenithal axis positions within the SCADA system.

IV. Results

The information obtained with this monitoring system for solar tracking is shown in the SCADA system graph (Figure 3 and Figure 4). Figure 3 displays the azimuthal axis trajectory and the final degree of the trajectory which was 362.20°. Figure 4 displays the azimuthal axis trajectory and the final degree of the trajectory which was 367.55°.

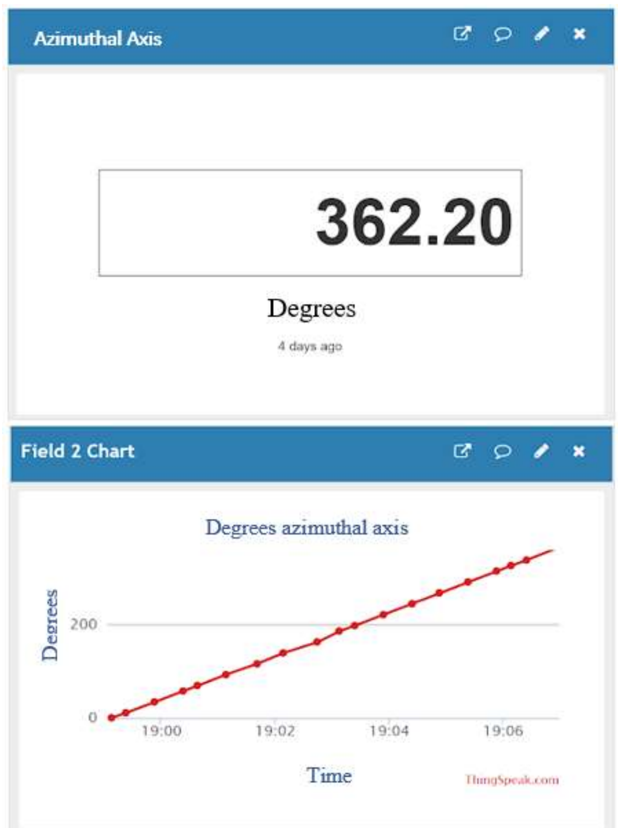

Figure 3 Design of the azimuthal axis motion monitoring in ThingSpeak, showing the most recent value and a plot against time

The platform shows, on the one hand, the position in degrees of the respective axis of the last data string received. In parallel, from the database generated with the historical information, a graph of the movement generated by each motor is displayed.

In order to check the operation of this system, both motors are energized at full voltage to generate a sequence of progressive data.

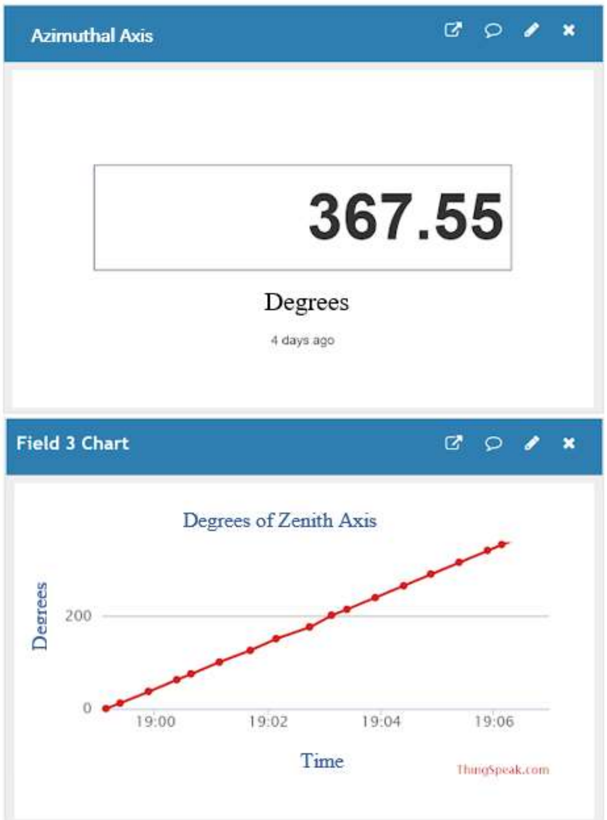

Figure 4 Graphical design of the zenith axis motion monitoring in ThingSpeak, showing the most recent value and a plot with respect to time

Figures 5 and 6 show the differences between the data sent to the ThingSpeak platform and the expected behavior of the azimuthal and zenith axes for each sampling time, resulting in a total of 19 iterations to achieve a 360º turn.

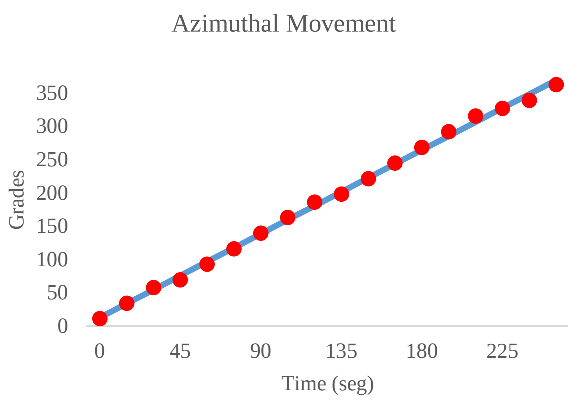

Figure 5 Comparative plot between the expected data (Blue) and those obtained in ThingSpeak (Red) on the azimuthal axis

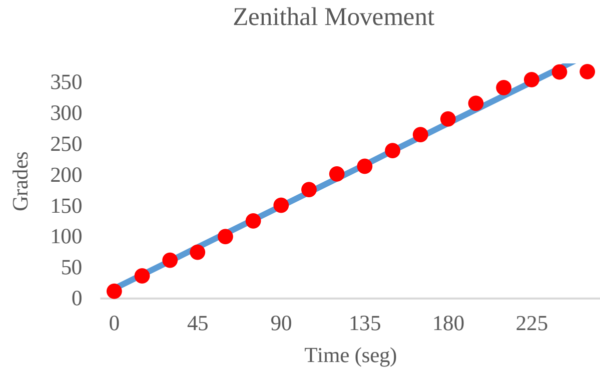

Figure 6 Comparative graph between the expected data (Blue) and those obtained in ThingSpeak (Red) in the zenith axis

In order to check the effectiveness of this system, the relative error obtained between the obtained data and the expected data was calculated according to the formula

$$e_r = \frac{\sum_0^n \left|\frac{x_i - x_v}{x_v}\right|}{n} \quad (1)$$

where
n = total number of data
x_i = value acquired in each iteration
x_v = expected value

The relative error is 0.0304 and 0.0432 for the azimuthal and zenithal axes respectively, which shows that the proposed system has a sampling accuracy between 96% and 97%.

Acknowledgement

The Universidad Tecnológica de San Juan del Río is grateful to CONCYTEQ and the LEIISA laboratory.

MORENO-GUZMÁN, Martín. PhD. Full-time Professor. Universidad Tecnológica de San Juan del Río.

TREJO-ZÚÑIGA, Iván. PhD. Full time professor. Universidad Tecnológica de San Juan del Río.

Funding

The project has been partially funded by CONCYTEQ [Collaboration/36/2021].

Conclusions

This paper shows the implementation of a monitoring system on the variables of interest related to two-axis monopole type solar trackers.

The monitoring scheme is deployed in a SCADA system, which was designed based on the DIN EN ISO 924 standard that allows better interpretation of the data in simple graphs.

The data collection system was structured with an Arduino Mega and a Raspberry in a WiFi environment, addressing the ThingSpeak server. The proposed monitoring system ensures the sending of the data in a sampling frequency of 15s, in addition to the storage in a database for query in histograms. In addition, the tracking of trajectories in the zenith-azimuthal engines was demonstrated and the effectiveness of this system was verified. Through the calculation of the relative error between the obtained data and the expected data, yielding a value of 0.0304 and 0.0432 for the azimuthal and zenithal axes, respectively. Demonstrating that the proposed system has a sampling accuracy between 96% and 97%.

The analytical and experimental evaluations confirm that the proposed monitoring system has a correct operation on the ThingSpeak platform, where the variables of the respective axis degrees are displayed. It was proved that the proposed monitoring system allows knowing the related variables of the two-axis monopost type solar tracker, being able to migrate this system to any type of solar tracker.

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