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Monitoring system for photovoltaic cells

Sistema de monitoreo para celdas fotovoltaicas

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Abstract

Efficiency control in photovoltaic cells can establish whether or not such technology is feasible in certain sectors of industry. This fact can determine the partial or total change to these sustainable energies. For this reason, this paper proposes a wireless photovoltaic cell monitoring system, which can be integrated by an industrial communication network in order to establish a better efficiency of this type of technology. The system is based on a master-slave architecture and consists of two main communication devices, of which one of them (slave) registered voltage and resistance for monitoring solar power generation, while the second (master) collects the information to process such data. This system is compared with other devices in the resistance readings, in addition, through the proposed system the voltage drop of a photovoltaic cell during the day is identified.

Communication, Microcontroller, Measurement, Radio frequency, Monitoring

Resumen

El control de la eficiencia en celdas fotovoltaicas puede establecer si es viable o no dicha tecnología en ciertos sectores de la industria. Este hecho puede determinar el cambio parcial o total a estas energías sustentables. Por este motivo en el presente trabajo se propone un sistema de supervisión de celdas fotovoltaicas inalámbrico, que puede ser integrado por una red de comunicación industrial con la finalidad de establecer una mejor eficiencia de este tipo de tecnología. El sistema está basado en una arquitectura maestro-esclavo y consta de dos dispositivos de comunicación principales, del cual uno de ellos (esclavo) censa voltaje y resistencia para el monitoreo de la generación de energía solar, mientras que el segundo (maestro) recopila la información para procesar dichos datos. Se compara este sistema con otros dispositivos en las lecturas de resistencias, además, a través del sistema propuesto se identifica la caída de tención de una celda fotovoltaica durante el día.

Comunicación, Microcontrolador, Medición, Radio frecuencia, Monitoreo

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Introducción

There are various monitoring and control methods for supervising critical equipment in the industry (Chacon, 2001-2002) . One of the most relevant are automated systems (Pérez, 2015). The characteristic of these is based on remote monitoring of the production process. The way these systems communicate is defined by various communication protocols (Pardo, s/f). The most used are: PROFINET, PROFIBUS, AS-I, HART among others. These protocols are supported by the OSI model (Balchunas, 2014). This model consists of 7 layers: physical, link state, network, transport, session, presentation and application as shown in figure 1.

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data-link
1	Physical

Figure 1 Layers that make up the OSI model

The modernized control of any system today is based on the pyramid of automation (Pardo, s/f), this consists of 5 levels, the first refers to the field network. This section defines the devices needed to measure and execute any process in the factory. The second level establishes a control network, this layer manipulates the instruments for production, the third monitors layers 1 and 2 through SCADA and HMI systems. The fourth inspects the production of a factory in a general way, and in the last one statistical information is established for one or more production plants. Its main function of these systems is to optimize the processes of product generation. The development of this technology can be used in other areas such as energy, specifically in sustainable energies such as solar. This type of technology is subject to weather conditions, which limits the efficiency of it. Another restriction that these photovoltaic systems have is the loss of power due to their use (Cepeda, s/f).

These characteristics condition an in-depth study of the climatic conditions and uses that these devices have, so that through automation systems a better efficiency can be established in the generation of energy through sunlight. One of the most relevant studies on the monitoring of the conditions in which photovoltaic cells are found over time was carried out by Amira (Shahieda, 2020) where she proposes a system that monitors dust on solar panels, her system determines the thickness of it in photovoltaic cells. Another outstanding system in the last decade was proposed by Devi which proposes a system to monitor the solar energy delivered by solar panels through IOT technology, this system is based on Arduino technology and Rasberry equipment. However, these methodologies although they guarantee a constant monitoring of the conditions of a photovoltaic cell, there is still no communication network between panels for the monitoring of them as in which the automation pyramid is defined, therefore, these studies are limited to a single photovoltaic cell and not a network of the same, Consequently, the malfunction of each cell cannot be identified. For this reason, a wireless monitoring system is proposed to monitor the efficiency of a photovoltaic cell network and its correct operation.

Methodology

The operation of the system consists of five blocks as shown in figure 3. From these blocks two main aspects are derived. The first establishes the reading and transmission of information, Figure 2-A. While in the second it receives this information and processes it, figure 2-B. The first block performs voltage and current readings in accordance with Cat standards [8]. The second through a digital analog converter, transform the analog signals of the photovoltaic cells to digital, so that later in the third stage, by means of FSK modulation, the data is transmitted to the master reading equipment. The master system interprets the origin of the information, where it is determined what type of device sends it. The information from it is processed and stored in an Excel workbook (Microsoft, 2021) and displayed on an LCD display.

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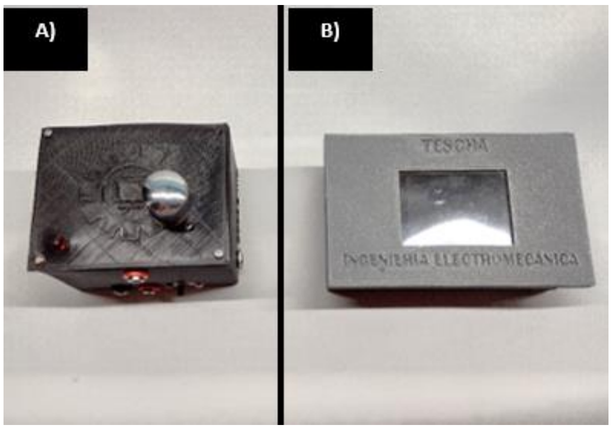

Figure 2 Wirelees multifuncional measuring device

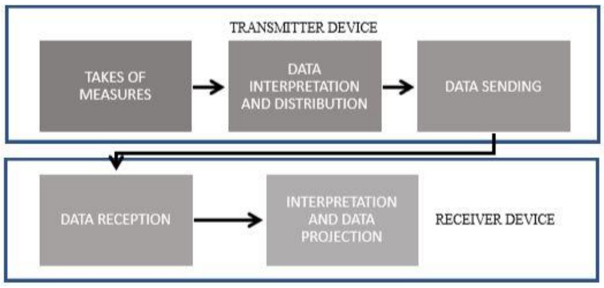

Figure 3 Operation wirelees muntifuncional device

To determine the correct operation of the system, electrical impedance and potential tests were performed, for the first stage the resistance of a copper wire was calculated by means of equation 1 (Boylestad, 2004), with a resistance factor (ρ) of $1.68_{x10^{-8}}$ Ω*m, , with 0.12 mm diameter (A) and 21.5m length (l) and resistivity readings were compared with different brands of multimeters, including: FLUKE 115 with accuracy of ±0.5% at a resolution of $1_{x10^{-1}}$ volts (FLUKE, s.f.) and TRUPER MUT-33 with accuracy of ±0.5% at a resolution of $100_{x10^{-3}}$ volts (TRUPER, s.f.). In addition, different measurements of commercial resistances were made with a resistivity error of ±5%

$$R = \frac{\rho l}{A} \quad (1)$$

In the second stage, the reading of electrical potentials of a solar cell was carried out at different times within the eastern zone of the state of Mexico, in the Tecnológico de Estudios Superiores de Chalco, in a period that includes from 01:00 pm to 05:30 pm at intervals of 15 min from the start time of the reading. Measurement readings were saved via Microsoft Data Streamer.

Results

Voltage readings which the measurements were, this is due to the decrease in sunlight in the course of the day.

Figure 4 System coupled to a photovoltaic cell

Time	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)
01:00	20.86	02:45	20.43	04:30	19.14
01:00	20.86	02:45	20.43	04:30	19.14
01:15	20.96	03:00	20.48	04:45	18.93
01:15	20.91	03:00	20.48	04:45	18.98
01:30	20.86	03:15	20.48	05:00	19.03
01:30	20.86	03:15	20.48	05:00	19.03
01:45	20.86	03:30	20.05	05:15	18.87
01:45	20.86	03:30	20.05	05:15	18.87
02:00	20.75	03:45	19.78	05:30	18.44
02:00	20.75	03:45	19.78	05:30	18.44
02:15	20.59	04:00	19.73		
02:15	20.59	04:00	19.73		
02:30	20.59	04:15	19.57		
02:30	20.59	04:15	19.62		

Table 1 Record of electric potential in photovoltaic cell

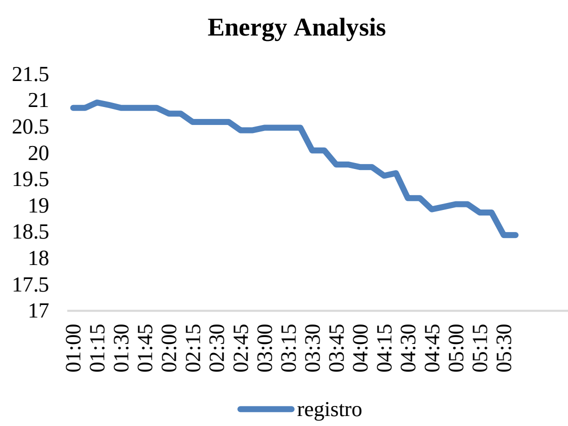

Figure 5 Energy analysis

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Resistance

The tests performed in which the resistance reading is taken are shown in Table 2. The values obtained by the system are in column four. The first row of the table refers to a wire whose resistance in calculation by equation 1, the remaining rows, are equivalent to commercial resistive values.

RESISTIVE VALUE (Ω)	TOLERANCE	RANK(Ω)	MEASURED VALUE DMMI(Ω)	MEASURED VALUE FLUKE 115(Ω)	MEASURED VALUE MUT-33(Ω)
31.93			32.4	31.3	31.2
56	±5%	[53.2-58.8]	51.39	55.5	55.1
100	±5%	[95-105]	100	98.6	97.7
156	±5%	[148.2-163.8]	150.73	154	152.5
180	±5%	[171-189]	173.11	176.8	175
220	±5%	[209-231]	213.52	217.1	215
400	±5%	[380-420]	391.84	393.8	390.0
460	±5%	[437-483]	467.62	469.5	465
680	±5%	[646-714]	690.91	685.0	680
820	±5%	[779-861]	810.62	812	804
1000	±5%	[950-1050]	974.90	976	968

Thanks

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Conclusions

The voltage data of the photovoltaic cell mark a decreasing trend that is equivalent to the amount of light perceived by the same cell, the values that stand out the most are between 20 to 21 volts, these values fall into the ranges in which the manufacturer indicates. In terms of the resistances measured in the proposed equipment, all readings are within the ranges established by the resistor factories, therefore, the reading error is less than 5%. Consequently, the system can continuously monitor a network of photovoltaic cells.

Discussion

Sustainable energy generation such as solar has been a compromising alternative due to the low costs that have been presented in recent decades (IRENA, 2020). However, the efficiency of these is still low. This largely refers to the separation of electrons in the semiconductor, which are only presented by high evoked frequencies in most cases by UV rays (Pacheco, 2018). This fact limits effective power generation to a time range of the day when sunlight can best be harnessed.

However, this range is conditioned by the climatic conditions and those of photovoltaic cells, this fact derives the importance of continuously measuring the amount of energy that enters a network of photovoltaic cells, so that with this the necessary means are obtained to better perform the efficiency in the generation of energy of this technology. An interesting study in which it could be highlighted through this proposed system, is to predict in certain seasons of the year, what type of inclination is optimal for a better efficiency of these devices, in addition to predicting automatically in which time intervals this equipment should be changed or have a certain maintenance. Another advantage to highlight in the proposed system are the timely establishments of failures in the system. This is because the system can be coupled with automated systems such as ERP (FAEDIS, s.f), dedicated to storing and reporting control parameters in production factories.

References

Balchunas, A. (2014). *OSI Reference Model v1.31*. Obtenido de Guides: http://www.routeralley.com/guides.html

Boylestad, R. L. (2004). *Análisis introductorio de circuitos.* Pearson educación.

Cepeda, J. (s/f). *Aspectos que afectan la eficiencia en los paneles.* Bocotá: Universidad Santo Tomás.

Chacon, D. (2001-2002). *Supervición y control de procesos.* EUPVG-UPC.

FAEDIS. (s.f). *Sistemas ERP y CRM.* Universidad Militar Nueva Granada.

FLUKE. (s.f.). *Multímetro digital Fluke 115*. Obtenido de Multimetros digitales: https://www.fluke.com/es-mx/producto/comprobacion-electrica/multimetros-digitales/fluke-115

IRENA. (2020). *COSTOS DE GENERACIÓN DE ENERGÍA RENOVABLE EN 2020.*

Microsoft. (2021). *¿Qué Transmisor de datos?* Obtenido de https://learn.microsoft.com/es-es/microsoft-365/education/data-streamer/how-it-works

ISSN: 2523-6806

Pacheco, S. T. (2018). Eficiencia en paneles solares. *Revista del Diseño Innovativo*, 9-21.

Pardo, G. (s/f). *Protocolos de comunicación industrial.* Bogotá .

Pérez, E. (2015). Los sistemas SCADA en la automatizacion industrial. *Tecnología en Marcha*, 3-14.

Rajendran, V. D. (2019). Solar energy monitoring system by IOT. *IJANA*.

Shahieda, A. (2020). *Solar panel dust monitoring system.* Engineering Heritage Journal (GWK).

TRUPER. (s.f.). *Multimetro digital junior*. Obtenido de Mut-33: https://www.truper.com/ficha_tecnica/Multimetro-digital-junior-3953.html

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