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Monitoring System for a Self-Consumption Photovoltaic System

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Abstract

Climatic conditions and temperature levels often affect the infrastructure of photovoltaic systems, causing the scheduled generation to not be as expected. The objective was to design a monitoring system for an experimental 3.4 kWp photovoltaic plant that is located on the terrace of building 1 of the Faculty of Engineering and Applied Sciences of the Technical University of Manabí. An automation process was developed to optimize the performance of the installation, using an innovative perspective, the study determinedly faces the initial challenges associated with the software previously used for the design of a data storage system when incorporated into the institutional geoportal. The successful implementation of the Oxley Solar mobile application and, consequently, of the PZM-0043 module, emerges as a comprehensive solution that ensures the continuity of monitoring and contributes significantly to improving the efficiency of the photovoltaic system. The Oxley Solar app overcomes previous limitations by enabling efficient data extraction via Bluetooth and subsequent transmission via Wi-Fi, facilitating more effective storage. The result was the introduction of the PZM-0043 module that adds a layer of automation to the system, guaranteeing continuous data transmission to the database to be stored in the geoportal.

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1 Introduction

Automation in obtaining information from a photovoltaic plant can involve various technologies and approaches. The automation of the control of photovoltaic plants through automated systems is an area of growing interest, with applications ranging from the protection of solar energy systems to advanced solar tracking programming using specialized software (Caballero, 2019). There are remote monitoring platforms that allow the acquisition, processing and visualization in real-time of detailed information on the operation and performance of isolated photovoltaic systems. These platforms enable continuous monitoring, data analysis and early detection of failures in solar installations (Guamán et al., 2017). The integration of these automation and remote monitoring technologies makes it possible to optimize the operation and maintenance of photovoltaic plants of any scale.

The 3.4 kWp photovoltaic system located on the terrace of building 1 of the Faculty of Engineering and Applied Sciences (FICA), suffered a prolonged period of inactivity due to the mistaken belief that serious and irreparable damage had occurred to the inverter. , an essential component that is responsible for transforming the direct current generated by the photovoltaic panels into alternating current usable by electrical loads. However, a technical inspection revealed that there was no damage to the inverter, but rather a meter connected to its output had failed. By removing this damaged element and connecting the photovoltaic system directly to the building's air conditioning system, the inverter resumed its normal operation (Mahian et al., 2013; Kenisarin & Mahkamov, 2007).

During this reactivation process, the possibility arose of implementing a monitoring system that would allow extracting and recording information in real-time about the electrical generation of the photovoltaic system through the inverter. We worked on an innovative low-cost solution to reactivate and monitor the performance of the photovoltaic system taking advantage of the existing infrastructure (Kannan & Vakeesan, 2016).

Through an exhaustive investigation of the system components, detailed information on the inverter was collected, which led to a thorough analysis of its characteristics, communication and assembly. These specifications were largely documented in the user manual provided by the manufacturer, providing a solid foundation to fully understand the operation of the inverter and its capabilities. Although the manual recommended the use of the Sunny Explorer software (SMA, 2023) to extract data, this solution was identified as not efficient due to the limitation of the connection via Bluetooth, and the lack of data storage if no device was connected.

Faced with the challenge of the range of the connection, innovation was promoted, the search focused on a mobile application that worked similarly to the Sunny Explorer, allowing the extraction of information through Bluetooth and its subsequent sending through Wi-Fi. The main objective was to send and view this information in real-time in the UTM GeoPortal (geoportal.utm.edu.ec, 2018) (Gungor & Lambert, 2006). After extensive analysis, the most suitable option was identified as the Oxley Solar mobile application.

A system was launched that, through the use of the PZM-0043 module, allowed the information to be extracted and sent to the geoportal database. This solution not only overcomes the initial connection limitation but establishes an efficient and continuous solution for PV system monitoring and data storage. The integration of this technology strengthens the monitoring capacity, accessing precise, real-time monitoring of power generation and overall system performance. This advance represents a significant step towards efficiency and automation in the monitoring of photovoltaic installations (Oesterreich & Teuteberg, 2016).

2 Materials and Methods

The present study focused on the revitalization and optimization of the 3.4 kWp photovoltaic system located on the terrace of FICA building 1, emphasizing the crucial role of automation in obtaining information. To carry out this task, initial inspection and diagnosis were used, performing a detailed visual inspection of all components of the photovoltaic system, visually identifying possible problems, wear or apparent damage, and focusing on the apparent problem of the inverter.

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3 Results and Discussions

To achieve the desired results, the resolution of the problems was proposed, the damaged meter that affected the inverter was removed and the photovoltaic system was connected to the building's air conditioning system to restore the proper functioning of the inverter. A meticulous investigation of the system components was carried out, with a primary focus on the inverter, detailed data was collected on the inverter features, communication and mounting. Image 1 shows the characteristics table of the university investor.

Figure 1. Inverter Characteristics Table

Using the nameplate, it was possible to determine that the inverter model is Sunny Boy, which "transforms the direct current of the photovoltaic generator into alternating current and injects it into the public electrical grid" (SUNNY BOY 2500/3000 solar inverter Installation instructions, page 7) and the user manual for this inverter model was easily located.

Revision of the user manual

During this stage, the manual provided by the manufacturer was carefully reviewed, to obtain precise and detailed technical information about the inverter. This allowed essential data to be collected, including maximum input currents and voltages, maximum input power and consumption requirements for optimal operation. Likewise, details were extracted about general aspects and accessories associated with the investor. With this information, the type of communication of the inverter with other devices to obtain data related to the generation of the photovoltaic system was determined (Veliz et al., 2021).

The free software supplied by the company SMA, responsible for the manufacture of the system inverter, was used. The tool used was Sunny Explorer Version 2.01.21.R (www.sma.de, 2020), this software allowed the connection of the inverter with another device using Bluetooth technology. The software interface connected to the inverter, which shows the generation recorded on 02/16/2023, is illustrated in Figure 2, this process is decisive for obtaining and displaying key data related to the generation of the photovoltaic system.

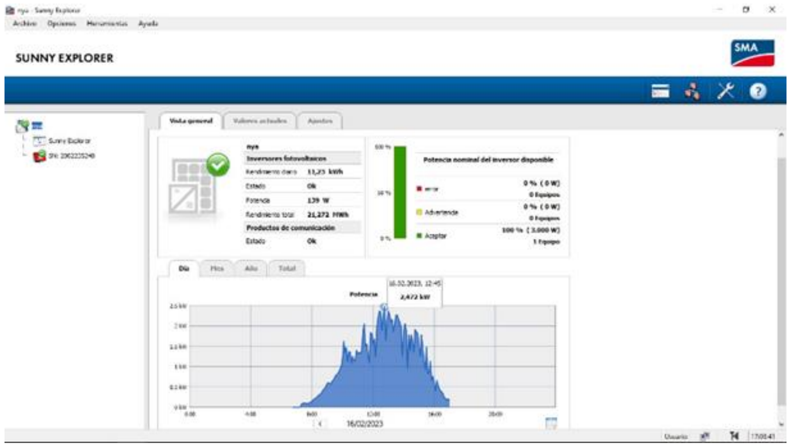

Figure 2. Generation information for 02/16/2023

Sunny explorer software evaluation

Figure 2 presents a graph and a detailed table that reflect the photovoltaic generation of the system in question for 02/16/2023; However, when trying to access the information corresponding to previous days, a significant limitation was evident in the Sunny Explorer software. This system did not store information for days in which no device was connected to the inverter, resulting in a lack of data for those periods. The inefficiency of this methodology was aggravated by the existence of days during which data was not recorded due to the absence of connections.

Innovation and search for alternatives

Given the limitations identified in the Sunny Explorer software, particularly the inability to store data in the absence of connected devices, a strategic decision was made to improve the efficiency of monitoring data generation more consistently. To overcome these limitations and move towards a more robust monitoring system, a search for alternatives was undertaken in the form of more advanced and versatile software. The strategy consisted of identifying solutions that could effectively replace Sunny Explorer, allowing efficient data extraction (Massie et al., 2004; Hameed et al., 2009).

The long-term objective of this initiative was to implement an automated system that not only overcomes the observed limitations but also guarantees continuous and uninterrupted monitoring of the photovoltaic system generation. The active search for more advanced and suitable software was considered decisive to ensure an effective transition towards an optimized monitoring system in line with the most recent standards in photovoltaic technology (Salas, et al., 2006). In the search carried out, we found the Oxley Solar (solar, 2023) mobile application.

The selection of the Oxley Solar Mobile Application and implementation allowed for an innovative system for obtaining data, after an exhaustive analysis, it was chosen as the optimal solution due to its ability to extract data via Bluetooth and transmit it via Wi-Fi. This versatile Android app stands out by supporting Bluetooth connections to SMA Sunny Boy inverters and Wi-Fi connections to the pvoutput.org system (Oxley Web Services, 2023), making it an ideal choice for various setups and use cases, also effectively addresses previous limitations, providing a comprehensive and adaptable solution for photovoltaic system monitoring (Reisi et al., 2013; Sharma & Chandel, 2013).

A phone specifically configured with the Oxley Solar app was initially installed at the inverter location. The uniqueness of this device lies in its constant connection to the inverter, ensuring that the information generated is captured without interruptions. Notably, this phone does not require a battery, allowing it to be continuously connected to a power outlet using an adapter, thus avoiding possible failures due to lack of power. In Figure 3 you can see in (A) the graph of the generation presented and in (B) the image of the phone that is connected to the inverter

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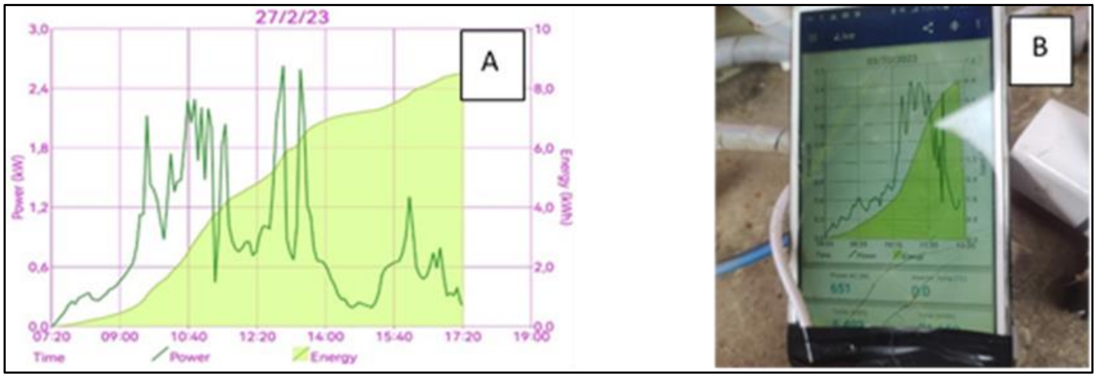

Figure 3. Generation graph presented by Oxley Solar (A), image of the phone that is connected to the inverter

As seen, a clear visual representation of how Oxley Solar presents generation data is offered, highlighting its similarity to the interface of the previously used software, Sunny Explorer. This visual consistency not only makes transitioning between platforms easier but also cements the Oxley Solar app as an ideal alternative. Because the software sends information via Wi-Fi, in collaboration with the FECA, the installation of a Wi-Fi access point was achieved on the terrace, home of the photovoltaic system, to provide connectivity to the connected phone, thus allowing efficient transfer of data to specific destinations. Figure 4 (A) shows the connection of the inverter with the phone and the router, while (B) shows the installation of the Wi-Fi point.

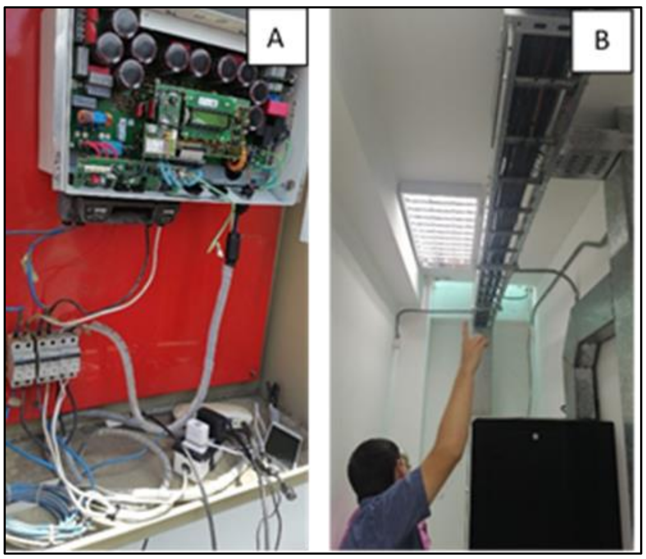

Figure 4. Inverter with phone and router (A), Wi-Fi point installation (B)

The temporary solution of keeping the phone constantly connected represented a short-term measure; however, it was recognized that it was not the optimal long-term option.

Implementation of the data extraction system with Module PZM-0043

The choice of this module was based on the need to overcome previous limitations. The PZEM-004T module is a multifunction meter that allows measuring voltage, current, active power and energy in devices connected to a 110/220V single-phase line. With communication capabilities UART, this module is versatile, being able to send data to microcontrollers, PC, WiFi modules or PLC. (Ssdielect, 2022).

The PZM-0043 module connects to the inverter to obtain the data and send it directly to an ESP8266 WiFi module. The ESP8266 WiFi module is a wireless communication device based on the Tensilica Xtensa L106 processor, compatible with the TCP/IP protocol and designed to provide Internet access to any microcontroller. Through the ESP8266 module, the data collected by the PZM-0043 module is sent to the database. This approach not only overcomes previous limitations but also establishes a system for continuous monitoring and data storage of the PV system.

Establishing an effective connection between the modules and the inverter is crucial to ensure correct data transmission in the system. Figure 5 clearly illustrates the layout and connection of the modules to the inverter, highlighting the importance of this configuration for the efficient sending of information. This strategic step ensures fluid communication between components, facilitating the exchange of essential data for effective monitoring and control of the photovoltaic system.

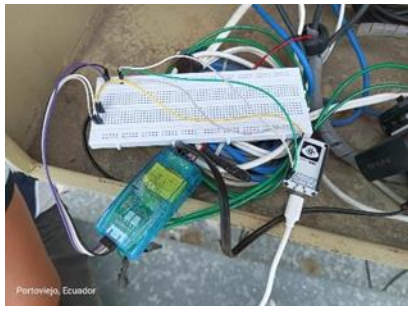

Figure 5. Connection of the modules to the inverter for data sending

The process of implementation and improvement of the photovoltaic system at the Technical University of Manabí has yielded significant results, marking considerable progress in terms of monitoring and energy efficiency. Below is a detailed analysis of the results obtained:

Inspection of the initial problem in the inverter revealed that the problem resided in a meter connected to the inverter. By removing this component and connecting the photovoltaic system to the building's air conditioning system, it was possible to efficiently reactivate the system, highlighting the importance of an accurate diagnosis.

Initial use of the Sunny Explorer software demonstrated limitations, especially the lack of data storage when no devices were connected. The search for innovative solutions led to the choice of the Oxley Solar mobile app, which offered an efficient way to extract information using Bluetooth and send it over Wi-Fi. This transition resulted in a more dynamic and adaptable system.

The inconvenience of constantly keeping a mobile phone connected was overcome by implementing a PZM-0043 module which allows overcoming connection restrictions and guaranteeing continuous monitoring. This multifunction device, with UART communication capabilities, allowed efficient data extraction and subsequent sending via a PZM-0043 module to the database. This integration represented a significant step forward towards automation and improvement of the monitoring system.

The introduction of modern information and communication technologies has been essential to enhance efficiency in data capture and its intelligent use. Not only does it provide direct and up-to-date access to valuable information, but it also consolidates solid data management that can be essential for analyzing the performance of the photovoltaic system and implementing specific optimization strategies.

The innovative automation system implemented has transformed the photovoltaic plant into a more agile and adaptable installation, with the capacity to respond efficiently to variations in energy demand. This visionary approach, in addition to successfully overcoming initial technical challenges, sets a valuable precedent to drive continuous improvements and disruptive innovations in photovoltaic technology.

The experience and knowledge acquired in this pioneering project stand as an exemplary guide, easily extrapolated to other generation plants, thus contributing to the incessant advancement of photovoltaic technology and its integration into more intelligent, efficient and sustainable electrical networks. This progress is not only an achievement for the specific facility but also illuminates the path toward a cleaner, more self-sufficient energy future.

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4 Conclusion

The automation system of the 3.4 kWp photovoltaic plants was implemented, this is positioned as a necessary element to increase the efficiency, performance and reliability of the renewable energy generation installation. Automatic extraction and registration of operational data was achieved, allowing its integration both with the geographic information system and with the SCADA supervision and control platform.

Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The author(s) have approved the final article.

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