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Design and Implementation of a Real-Time Monitoring Platform for Solar PV Panels Using PLC

Abstract. Solar panels play a significant role in the renewable energy sector. However, performance monitoring of photovoltaic (PV) panels is challenging in PV systems. Moreover, solar panel testing equipment is not available everywhere and is an expensive device. So, this paper presents a method for measuring and monitoring the PV panel parameters based on a Programmable Logic Controller (PLC) with a simple design. Terminal voltage, load current, the power dissipated, temperature, and intensity of light were measured and displayed both locally on the digital display unit of the PLC and remotely on a smartphone. The proposed system has good stability, reliability, and broad application prospects.

Streszczenie. *Panele słoneczne odgrywają znaczącą rolę w sektorze energii odnawialnej. Jednak monitorowanie wydajności paneli fotowoltaicznych (PV) jest wyzwaniem w systemach PV. Co więcej, sprzęt do testowania paneli słonecznych nie jest dostępny wszędzie i jest drogim urządzeniem. W tym artykule przedstawiono metodę pomiaru i monitorowania parametrów panelu fotowoltaicznego opartą na programowalnym sterowniku logicznym (PLC) o prostej konstrukcji. Napięcie końcowe, prąd obciążenia, rozpraszana moc, temperatura i natężenie światła były mierzone i wyświetlane zarówno lokalnie na cyfrowym wyświetlaczu PLC, jak i zdalnie na smartfonie. Proponowany system ma dobrą stabilność, niezawodność i szerokie perspektywy zastosowań. (**Projekt i wdrożenie platformy monitorowania w czasie rzeczywistym dla paneli fotowoltaicznych z wykorzystaniem PLC**)*

Keywords: Renewable energy, PV Panels, Remote monitoring system, Ethernet integrated webserver.
Słowa kluczowe: Energia odnawialna, panele fotowoltaiczne, system zdalnego monitorowania, zintegrowany serwer sieciowy Ethernet.

Introduction

Photovoltaics is now one of the world's fastest-rising energy sectors.The major problem facing the world is increasing the efficiency of PV systems, as most solar cells can only convert about 15% to 25% of obtainable energy into electrical energy [1, 2]. Since the efficiency of PV is highly sensitive to optimal performance, periodic monitoring is required to assess the operation of solar power [3, 4, and 5]. Adequate measures must be taken during installation to increase a PV system's total energy output. However, because PV systems are typically installed in distant or high locations, there is still the possibility of failures or maintenance issues throughout the operation. Manual examination and remote wired monitoring are the most common monitoring methods. However, these approaches have drawbacks, such as time and wiring complexity [6]. Recently, a wireless platform was added to the solar PV monitoring system. This makes it possible to collect data from different sensors and nodes and send it wirelessly. However, several challenges, such as extensive data management, signal interference, long-range data transmission, and security, could influence the performance of solar PV monitoring [7].

Several studies have used Arduino [8, 9] and Raspberry-Pi [10, 11] technology to monitor PV systems.

Newly, the artificial intelligence techniques are also used for calibrating and monitoring industrial sensors like gas concentration sensors, force sensors, humidity sensors, and thermocouples [12 ,13]. Although these solutions are low-cost, open-source, and extensible, they should not be considered a replacement for PLC technology. The PLCs are designed for industrial applications; they have the required approvals and environmental specifications; and they are robust, scalable, and extensible [14], [15], [16]. So, the PLC technology can be considered a better choice for monitoring the PV system. Therefore, this work tries to design and implement the use of the embedded Ethernet-web server property of the LOGO! 8 PLC in the real-time monitoring of PV systems remotely on any standard web browser. In addition, it is locally displayed at its display unit.

Proposed Monitoring System:

The proposed monitoring system collects the required data from a PV panel via sensors and transmits it to the control center. The general block diagram of a proposed solar panel measurement system is shown in Fig. 1. Four measurement sensors are used to collect the data from the PV panel and its environment and transmit it to the PLC unit. A voltage divider is used to measure the terminal voltage (VPV). A Hall-Effect sensor is used to measure load current (IPV). A temperature sensor is used to measure the temperature (TPV). A Light Dependent Resistor (LDR) measures a percentage of the light intensity (LPV). Power consumption (PPV) was calculated by the product of measured current and voltage. A LOGO! 8 PLCs are linked to the router via an Ethernet cable.

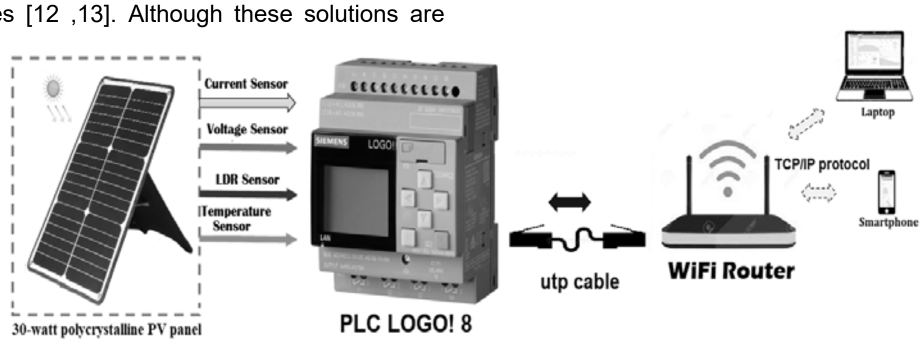


Fig. 1. The whole system block-diagram

The key elements that make up this system are interfacing the sensors to a PLC, which contains Ethernet property, and a WIFI Router for transmission of data wirelessly to the server. The PV system's hosting of the integrated web server page facilitates operators' view and monitoring of all parameters of the PV system on a smartphone, tablet, or PC via a web browser. The hardware units of the work have the following specifications:

- The panel used in this work is "SOLAR PANEL MSX 120" from BP MSX. It has a Nominal Maximum Power (Pmax) of 120 W, a Voltage at Pmax of 33.7 V, and a load current at Pmax of 3.56 A.
- A voltage divider is used to split and reduce the measurement voltage into a 10V range (i.e., give a voltage within the range of the PLC input and read it from the input). So, the solar PV terminal voltage was sensed using a voltage divider circuit.
- The Hall-type sensor's operation is through the Hall Effect [17]. It is used to measure the load current when the magnetic field is perpendicular to the conductor, generating a voltage difference proportional to the current that passes through it.
- The temperature of the panel was measured using a temperature transducer sensor.
- LDR is a light-controlled variable resistor used to measure the intensity of sunlight exposure to the panel. LDR has a very high resistance (≈1 MW) in the dark but drops to a few kW once it receives light since its resistance is inversely proportional to the amount of light that strikes it. Changes in resistance can be easily measured by converting them into voltage.
- The LOGO! 24CE 0BA8 PLC unit is employed in this work. It contains 8 Digital Inputs (DI), 4 Analog Inputs (AI), 4 Relay Digital Outputs (DO), 12/24 DCV power supply, the memory of 400 blocks, user-defined web pages, and a standard micro-SD card. In addition, the LOGO! 8 PLC has full communication options via the Ethernet interface, and it is compatible with the integrated webserver. This functionality will enable the operators to have access to all the functions of the controller from the level of the web browser. This means that if a WiFi router is connected to the network, the operator will have access to the controller, e.g., using a smartphone.

Software Implementation of the Monitoring System:

The flowchart of the proposed system is shown in Fig. 2. For PLC software, functional diagram language is consumed to achieve the proposed software package using LOGO! Soft Comfort Version 8.3 as presented in Fig. 3.

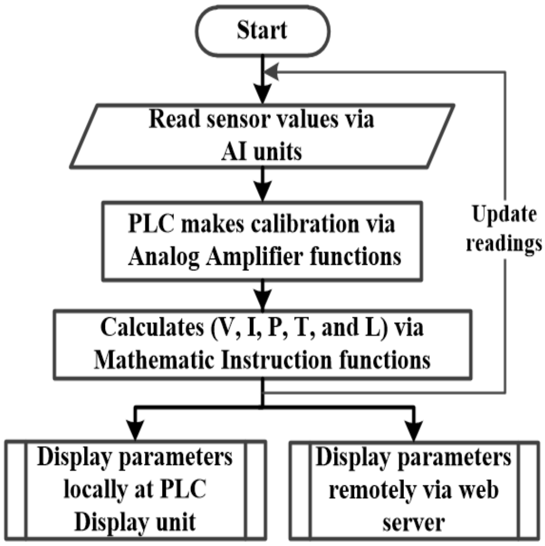


Fig. 2. Flowchart of the proposed PV monitoring system

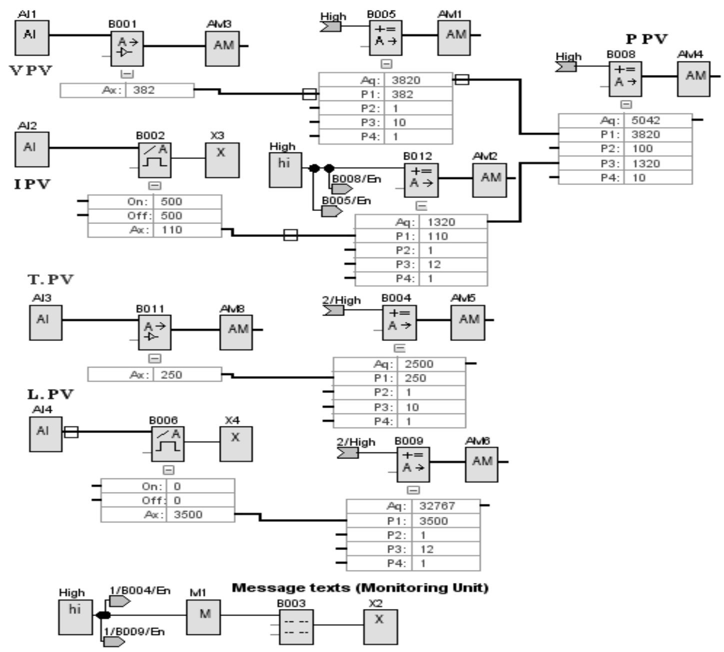
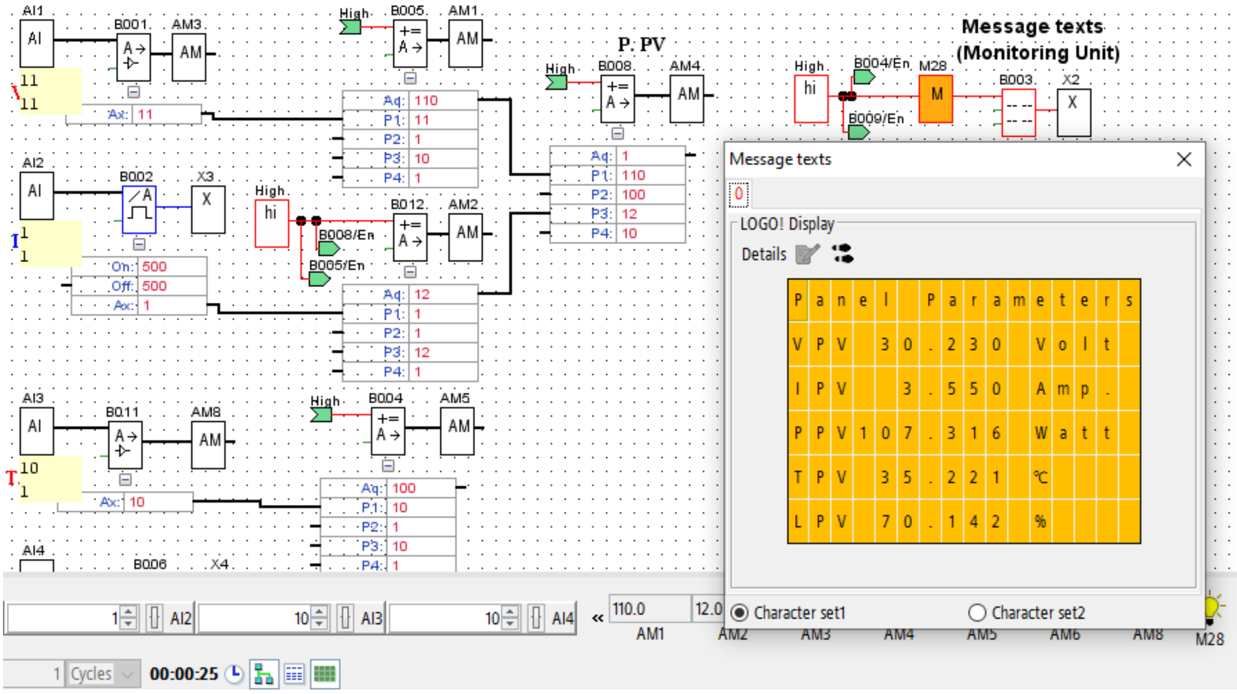


Fig. 3. Functional program of the monitoring system

The functioning of the program is as follows:

- The output signal of the voltage divider is connected to the first analogue input pin of the PLC (AI1-which corresponds to input terminal I7). The Analog Amplifier unit (B001) amplifies an analog input value from AI1 and returns it (scaled) to the analog output for the PV panel. Instead of B005. Mathematic instruction B005 is used to calibrate the PV voltage signal to the real value of the PV voltage by taking the transformation via voltage divider into consideration.

- The output signal Hall-effect transducer is connected to the second analogue input pin of the PLC (AI2-which corresponds to input terminal I8). Mathematic instruction B012 is used to calibrate the load current signal to the real value of the load current by considering the transformation of the hall-effect sensor.
- Mathematic instruction B008 is used to calculate the value of the consumption power by multiplying the value of the PV voltage (B005) by the value of the load current (B012).
- The output signal of the temperature sensor is connected to the third analogue input pin of the PLC (AI3-which corresponds to input terminal I1). Then, the Analog Amplifier unit B011 is used to calibrate the temperature signal to the actual value.
- The output signal of the light sensor is connected to the fourth analogue input pin of the PLC (AI4-which corresponds to input terminal I2). Then, the Analog Amplifier unit B006 is used to calibrate the LDR signal to the real value of the light intensity.
- Message text B007 displays the output values of the mathematical instructions (B005, B012, B008, B004, andB009) units, representing the system parameters: PV voltage, load current, consumption power, temperature, and light intensity, respectively.
- The used PLC's display unit, which shows the "Message text B007" information, features a six-line display with 16 characters per line, allowing for precise text formulation. It has fewer abbreviations and provides more detailed operator information. In addition, it can change the color of the backlighting.
- PLC LOGO! 8 Includes an integrated webserver to monitor and control PLCs via WLAN and the Internet, is easy to set up, and requires no knowledge of HTML programming. Therefore, this is done by entering the IP address of the PLC into the webserver editor page using a web browser. It is password protected and suitable for all traditional browsers. It can be played via smartphone, tablet, or PC.



• Results & Discussion

The proposed functional diagram language program was tested using the LOGO! Soft Comfort Simulation property before being downloaded to the LOGO! 8, See Fig.4.

The communication processor based on the Ethernet interface was facilitated in transferring the proposed control program wirelessly to the LOGO! 8 PLC, with only a LOGO! 8-router connection required via standard Ethernet cable.

The instantaneous date of the PV panel system parameters displayed in the message text is shown in the PLC display unit. Also, the integrated webserver page makes it easy to show this data on both the smartphone and the PC at the same time (see Fig. 5 & 6).

The results show that the proposed monitoring system could be a good way for an industrial solar PV system to be monitored remotely and in real-time.

Fig. 5: Experimental Results: Message text on the PLC display unit, smartphone, and PC

Fig. 6: Experimental Results: Message text on the PLC display unit, and smartphone.

Conclusion:

Compared to traditional methods, the proposed work provides one of the simplest ways of measuring and monitoring (locally and remotely). Other advantages of the proposed design include cost-effectiveness, robustness, high durability, and higher precision in measurements.

This study can be useful in analyzing the performance characteristics of the PV system and estimating its efficiency, localizing the abnormal PV panels and detecting the causes that might lower energy production, which enables easy repair and maintenance; designing an accurate solar tracking system and an appropriate maximum power point tracking system.

The proposed design can be easily modified and expanded to be compatible with any solar system. In this work, the webserver was hosted locally, and in future work, cloud computing technology could be used for the same purpose. In addition to the monitoring function, it is possible to modify this work in the future to implement a two-axis sun tracking system and maximum power point tracking with a DC-DC converter for maximum power extraction from the PV system.

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