ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ, АВТОМАТИЗАЦІЯ ТА ОБЧИСЛЮВАЛЬНА ТЕХНІКА В ТЕХНОЛОГІЧНИХ ПРОЦЕСАХ

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ARCHITECTURE OF SOLAR PANEL INTELLIGENT MONITORING SYSTEM BY MEANS OF INDUSTRIAL CONTROLLER

The paper is devoted to increasing the efficiency of real-time monitoring of the basic solar panel parameters. The main disadvantage of existing solar panel monitoring systems is the inability to troubleshoot a single solar panel of large power plants. This is due to the fact that modern inverters transmit voltage, current and power data of solar panel string. To determine which particular panel has bad parameters, it is necessary to disconnect all panels in the string and check their parameters separately. Another disadvantage of existing solar panel monitoring systems is the inability to measure the temperature of each panel individually, which significantly affects the solar panel performance. The solar panel intelligent monitoring system was developed and based on using the measuring sensors. The solar panel intelligent monitoring system is connected to the Internet via Wi-Fi. The solar panel intelligent monitoring system improves the measurement accuracy of the basic solar panels parameters. The solar panel intelligent monitoring system reduces the detection time of solar panels with bad parameters and characteristics.
Keywords: solar panel, intelligent monitoring system, solar panel string, detection time, parameters.

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АРХІТЕКТУРА ІНТЕЛЕКТИВНОЇ СИСТЕМИ МОНІТОРИНГУ СОНЯЧНОЇ ПАНЕЛІ ЗАСОБАМИ ПРОМИСЛОВОГО КОНТРОЛЕРУ

Стаття присвячена підвищенню ефективності моніторингу основних параметрів сонячної батареї в режимі реального часу. Основним недоліком існуючих систем моніторингу сонячних панелей є неможливість усунення неполадок однієї сонячної панелі великих електростанцій. Це пов'язано з тим, що сучасні інвертори передають дані напруги, струму та потужності сонячної батареї. Щоб визначити, яка конкретна панель має погані параметри, необхідно від'єднати всі панелі в рядку та перевірити їх параметри окремо. Ще одним недоліком існуючих систем моніторингу сонячних панелей є неможливість вимірювати температуру кожної панелі окремо, що суттєво впливає на продуктивність сонячної панелі. Інтелектуальна система моніторингу сонячних панелей була розроблена і базується на використанні вимірювальних датчиків. Інтелектуальна система моніторингу сонячних панелей підключена до Інтернету через Wi-Fi. Інтелектуальна система моніторингу сонячних панелей покращує точність вимірювання основних параметрів сонячних панелей. Інтелектуальна система моніторингу сонячних панелей зменшує час виявлення сонячних панелей з поганими параметрами та характеристиками.
Ключові слова: сонячна панель, інтелектуальна система моніторингу, рядок сонячних панелей, час виявлення, параметри.

Introduction. The trouble-free operation of solar panels and all elements of a solar power plant is a prerequisite for efficient electricity production and a profitable investment in a solar power plant. To ensure long trouble-free operation, periodic audits (diagnostics, defect recommendations) of all elements of a solar power plant are required.

Detecting defective and finding inefficient solar panels with reduced efficiency af-fects the level of electricity generation during the operation of a solar station. If the solar panels are connected in series, the failure of one of the elements can lead to partial or total loss of power of the entire solar power plant. In addition, due to the fact that solar panels are made up of a large number of semiconductor cells, the gen-eration of heat in a faulty element can lead to the destruction of neighboring elements, the problem will grow over time. Therefore, it is necessary to identify defective solar panels on time, which will allow them to be quickly replaced. This will maximize system life and maximize efficiency.

For timely detection of defective solar panels, it is necessary to continuously moni-tor the performance of the equipment, which allows timely detection of disturbances in the operation of solar panels, as well as control access to individual modules.

The solar monitoring system consists of modules that record the signals of current, voltage and temperature sensors of individual solar panels, as well as sensors of wind speed, position of the Sun, door sensors or sensors of unauthorized access to network inverters. The system modules are connected to a local controller, which in turn is connected to a higher level controller via a Modbus RS485 or CAN bus. Modular construction provides high configuration flexibility and system expansion. Thanks to this module they are suitable for use both in big power solar plants and in small power solar plants.

Monitoring is also important because during the day there may be a sharp drop in power, which may be due to various factors, such as shading the solar panel with certain objects or contamination of the solar panel surface (leaves, snow and dust).

By analyzing the solar panel monitoring systems, we can point out some draw-backs, such as the inability to measure the parameters of each solar panel separately, since most existing systems connect to the inverter and measure the main characteris-tics of the entire string, the high cost of such a system, and the inability to measure the temperature.

The renewable energy monitoring system (REMS) is proposed in [1]. The main advantages of REMS are the concept of an open source and low-cost data acquisition and transmission system using multi-user cloud remote monitoring. The REMS architecture is based on the Internet of Things (IoT) and Cloud computing principles. The REMS consists of three main parts San USB microcontroller, Raspberry Pi (Rpi) Embedded Linux System (ELS) and Online Web Monitor for real-time cloud monitoring.

Another solar monitoring system is designed with the help of Lab VIEW and DAQ card and presented in [2]. The solar panel is connected to the battery and then with sensors. The proposed system is connected by four sensors with Lab VIEW via DAQ hardware to acquire data. Lab VIEW has shown a high performance in communi-cating with several devices simultaneously and high capability of displaying several variables behavior at a time.

The solar monitoring system proposed in [3] is developed to get information on the defected solar panels for timely repair and maintenance. This system can be used up to 146 V and 15.5 A solar cell systems with an automatic selection of best resolu-tions.

Lab-VIEW based real-time interface system in paper [4] presents the detailed characterization of the performance and dynamic behavior of photovoltaic systems. They developed a software tool that integrates several types of instruments into a single system which can offer online measurements of all data sources and compare simulation results with monitored data in real-time. The proposed method provides a fast, secure and reliable system by making the system database-ready for performance analysis of the PV systems. The integration methodology of robust simulation and monitoring data in real-time can be used to study the fault diagnosis of a PV system.

To solve the current problem of monitoring photovoltaic (PV) systems especially for regions in developing countries or remote areas; an Arduino based open-source electronic platform data logger was developed [5]. This data logger meets the Interna-tional Electro technical Commission (IEC) standards requirements with a resolution of 18-bits, including 8 analog inputs for measuring up-to 8 PV modules. They men-tioned that these data logger can be customized for the specific needs of each project.

The remote intelligent monitoring system [6] is based on Tiny OS for monitoring and management for PV power generation. This system had implemented remote monitoring and reverse control by the host computer, ARM gateways, wireless sensor networks, and other components.

A simple sensor-based microcontroller data acquisition system for monitoring the temperature data in solar installations is presented in [7]. The system can easily change the date; time of experiment start and end, sampling rate and deals correctly with corruption such as power failure. The proposed data acquisition system can handle up to 16 sensors, has user interface system (4 buttons LCD screen), own stor-age systems such as flash memory or SD card; therefore, it doesn't require any ex-ternal computer to store the sensors data. This system automatically creates a new file on the SD card every day and records data on it and data can be handled and analyzed easily by any mathematical software such as Excel or MATLAB. The system monitors the sensors remotely by using the internet.

The Smart Remote monitoring system is presented in [8] which is using IOT that can monitor the Solar PV PCU and stores data in the cloud database through an easily manageable web interface. The proposed system has flexibility by using GPRS technology to interconnect the Solar PV Power Conditioning Unit to the Remote server.

Paper [9] presents the solar cell data acquisition system. The solar cell is character-ized by impedance which depends on environmental conditions. The solar cell data acquisition system is designed to measure the impedance of the solar cell. These im-pedance measurements are also used in the electrochemical capacitor quality control [10]. The experimental Nyquist plot was fitted by using the improved expression for impedance of the solar cell.

Solar panel intelligent monitoring system block diagram. The proposed solar panel intelligent monitoring system is based on the WiFi ESP8266 Development Board WEMOS D1. The WEMOS D1 board can be config-ured to work on Arduino environment using BOARDS MANAGER. The PAC1710 sensor is used to measure the voltage, current and power of the solar panel. This sen-sor measures the voltage developed across an external sense resistor to represent the high-value current of the solar panel. The PAC1710 also measures the voltage and calculates the average power over the integration period. The long integration time allows for solar panel intelligent monitoring system polling cycles without losing any power information.

The PAC1710 sensor is used because it`s maximum measured voltage is 40 V. Usually, the solar panel maximum voltage is less than 40 V. The main advantage of the PAC1710 sensor is capability to measure voltage, current and power of the solar panel without using additional current and power sensors. I2C bus is used to transmit the voltage, current and power data to the WEMOS D1 board.

The DS18B20 digital thermometer is used for the temperature measurements. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with WEMOS D1 board. The measured temper-ature range for the DS18B20 digital thermometer is from –55 °C to +125 °C. This temperature range corresponds to the solar panel operation temperature range. The solar panel intelligent monitoring system block diagram is shown in figure 1.

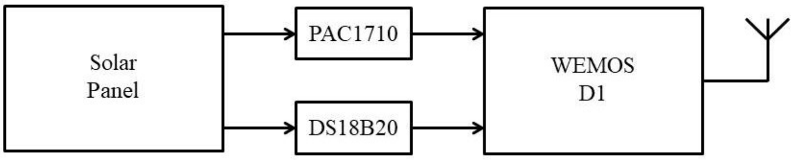

Fig. 1. Solar panel intelligent monitoring system block diagram

The solar panel intelligent monitoring system was designed as the prototype print-ed circuit board (PCB) with the PAC1710 sensor and the resistor shunt. The solar panel current passes through the resistor shunt and creates the voltage drop on it. The PCB is connected to the WEMOS D1 board and shown in figure 2.

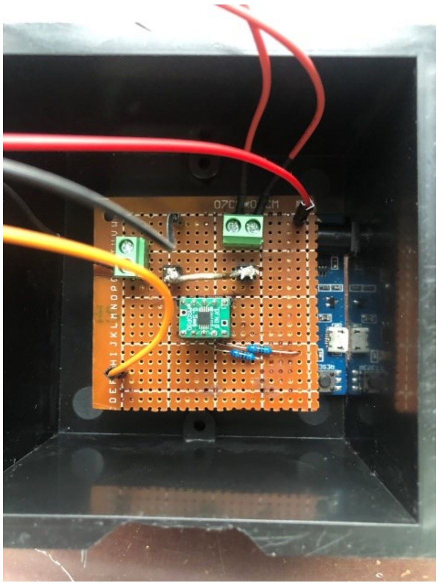

Fig. 2. Solar panel intelligent monitoring system PCB

The voltage, current, power and temperature data of the solar panel are sent via WiFi to the open Home Automation Bus (openHAB). OpenHAB is an open source, technology agnostic home automation platform which runs as the center of the smart home. The openHAB's strength is its ability to integrate a multitude of other devices and systems. Also openHAB includes other home automation systems, (smart) devic-es and other technologies in a single solution. OpenHAB provides a uniform user interface and a common approach to automation rules across the entire system, regardless of the number of manufacturers and sub-systems involved.

Solar panel intelligent monitoring system software algorithm. The solar panel intelligent monitoring system software algorithm consists of the following steps. The flowchart of the solar panel intelligent monitoring system soft-ware is shown in figure 3.

The first step is the declaration of variables and data input:

Tempr is temperature; Volt is the solar panel voltage; Curr is the solar panel cur-rent; WLAN_SSID is the WiFi network name; WLAN_PASS is the WiFi network password; MQTT_SERVER is the IP address of MQTT server; MQTT_SERVERPORT is the MQTT server port; MQTT_USERNAME is the name for authorization on MQTT server; MQTT_PASSWORD is the password for authori-zation on MQTT server; MQTT_TOPIC is the "topic" to which data will be trans-ferred; buttonPin is the Arduino pin that reads temperature. The Tempr, Volt, and Curr variables are used to exchange data between the WEMOS D1 board and Open-Hab.

The second step is the initialization of WEMOS D1 board ports for connection with the DS18B20 digital thermometer.

The third step is the initialization of the WEMOS D1 board on the WiFi network and its operation with OpenHAB.

The fourth step is the transfer procedure for the temperature, current, voltage and power data from the sensors to the WEMOS D1 board and to OpenHAB.

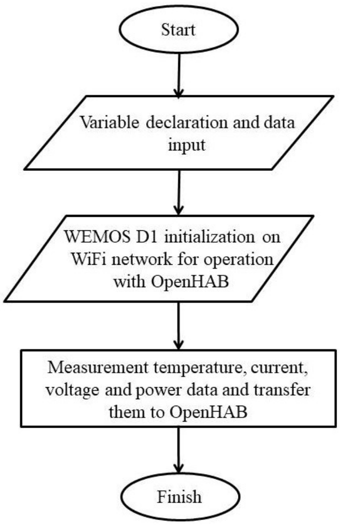

Fig. 3. Flowchart of the solar panel intelligent monitoring system algorithm

The main aim of the OpenHab website is to display the parameters of the solar panel such as temperature, voltage, current and power. These data are updated every 10 seconds. According to these data, graphs of parameters are plotted versus time. The OpenHAB website is shown in figure 4.

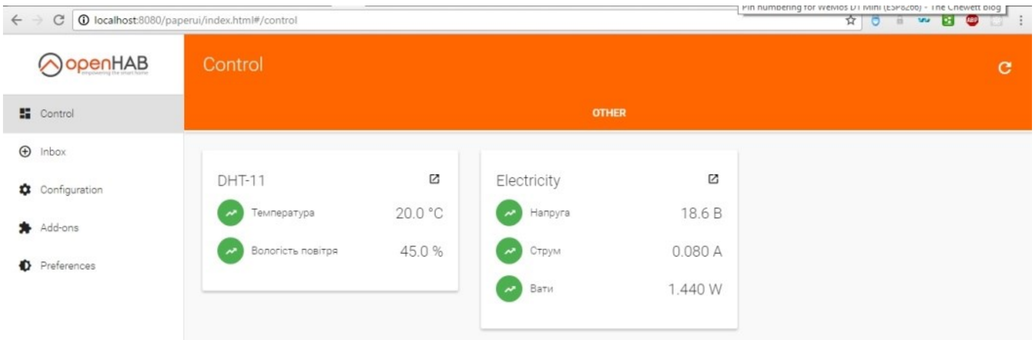

Fig. 4. OpenHab website

Experimental setup of solar panel intelligent monitoring system. The experimental setup of solar panel intelligent monitoring system is shown in figure 5.

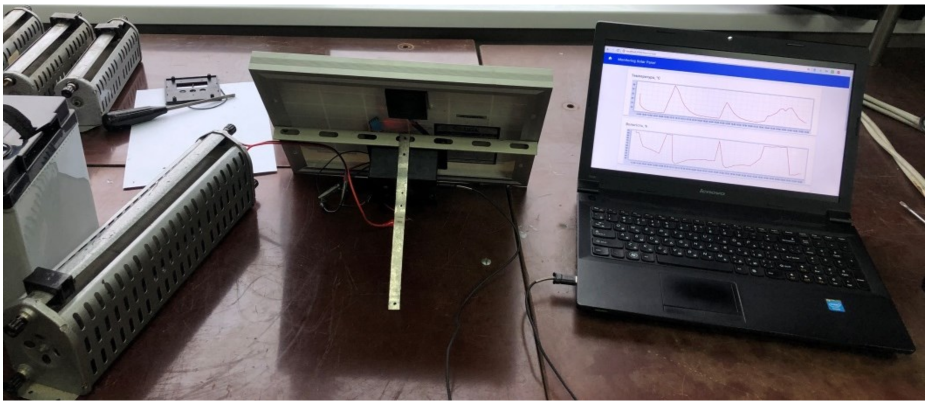

Fig. 5. Experimental setup of solar panel intelligent monitoring system

The experimental setup of solar panel intelligent monitoring system consists of the solar panel ALM-10M, the prototype printed PCB with the PAC1710 sensor and the resistor shunt, WEMOS D1 board, DS18B20 digital thermometer which are mounted on the reverse side of the solar panel. To confirm the operation of the solar panel intelligent monitoring system the rheostat was connected to the solar panel as load. By changing the rheostat resistance the operation of the solar panel intelligent monitoring system was confirmed. Figure 6 shows dependences of voltage, current and power versus time at the rheostat resistance change.

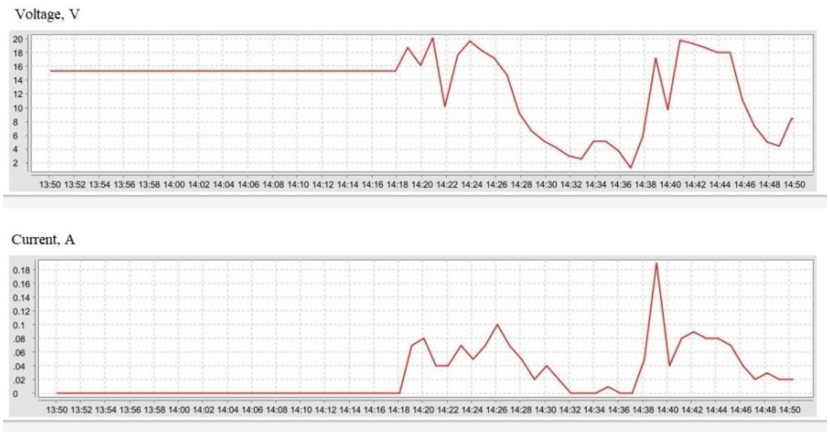

Fig. 6. Dependences of voltage, current and power versus time at the rheostat resistance change

Conclusions. The solar panel intelligent monitoring system was developed using OpenHab home automation technology platform. The solar panel intelligent monitoring system con-nects via Wi-Fi to track real-time energy generation from anywhere on the globe via a computer or smartphone connected to the Internet. By using the solar panel intelli-gent monitoring system the measurement accuracy of the solar panel parameters was increased. The solar panel intelligent monitoring system reduces the detection time of panels with bad parameters and characteristics.

To prepare data on the solar panel measurement parameters obtained from the WEMOS D1 board for sending from the operator's computer to the Web server and for further processing, it is necessary to establish a connection between these two nodes. In most cases, such tasks use a serial interface that is physically implemented using a USB-MicroUSB cable. The serial interface lets us send control signals from operator's computer to the WEMOS D1 board and retrieve process information backwards. In this way, the computer communicates with the WEMOS D1 board, which accordingly manages and receives the measurement parameters using the USB port. The developed software allows obtaining values of voltage, current and temperature produced by the solar panel.

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