1-kWp photovoltaic system at the Technical University of Łódź

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The paper presents the advanced measurement system being developed for the 1 kWp photovoltaic generator installed at the Technical University of Łódź, at the Department of Microelectronics and Computer Science, in the city centre. The main aim of research is verification of feasibility of photovoltaic generator in polluted environment and influence of I–V characteristics mismatch on long-term performance.

The photovoltaic system is equipped with comprehensive monitoring system which collects climatic data and I–V characteristics of all PV modules under operation of PV generator. The monitoring system is based on the custom-made microprocessor board, designed with view of reliability of the data collection. The key module of the system is advanced I–V characteristics scanner with a switching matrix.

Keywords: PV measurements, I–V characteristics, performance evaluation.

1. Introduction

Nowadays, the environment pollution in the city centres is a real problem, both to the human health and technical infrastructure. The remedy to this problem is, among others, the use of clean energy sources. The presented photovoltaic installation focuses on these issues: education and promotion of renewable energy and monitoring of pollution influence on photovoltaic devices.

The system is designed to provide detailed data on each aspect of system operation for a long time, including the I–V characteristics of every PV-module within the generator. This required a specific controller to satisfy the stated objectives, i.e., great number of analogue sensors, fast characteristics scanner, and a switching matrix. The used controller, based on Motorola MC68331, was developed and built at the Department of Microelectronics and Computer Science. Apart from the measurement of electrical parameters, a number of climatic parameters are stored as well.

A detailed performance evaluation of any photovoltaic module and system requires the knowledge of its I–V characteristics [1,2]. The collected data will provide the material for the research on the pollution influence on the degradation of photovoltaic devices in the long term and improvement in a system performance under partial shadowing and rapidly varying insolation in short terms.

2. Monitoring system construction

The photovoltaic installation is located on the roof of the 8-floor university building in the city centre, in the neighbourhood of the coal heat and power plant. The installation comprises of 20 multicrystalline silicon modules SF52A from Solar Fabrik of 50 Wp each (see Fig. 1). The modules are arranged in two south-oriented rows with 30° inclination. The PV-array consists of 5 parallel branches, each containing 4 modules connected in series. The system will be connected to public utility grid with a commercial string inverter, with no battery storage.

The overall construction of the monitoring system is summarised in Fig. 2. The central unit – MC86331 microcontroller based-coordinates all measurement processes. At the specified time intervals, it initiates the measurement of the I–V characteristics of a PV-module selected with the switching matrix. The data from the scanner are collected and buffered for the transmission to the PCs. In the same measurement cycle, the controller sends request and receives the data from the sensors from the climatic module. Additional electrical parameters (bus DC currents and voltages) and are also collected. The climatic module is a separate device, capable of reading data from temperature, radiation, atmospheric pressure, and humidity sensors.
All the data are transmitted to two PCs online, but in a case of any PC malfunction, the non-volatile RAM buffer provides temporary data storage for about one hour.

The main data storage is realised as an SQL database, duplicated on the second PC for the reliability sake. The access to the database will be provided with WWW interface, both for acquiring data for research purpose and also for online visualization of system operation.

3. I–V characteristics scanner

The scanner of I–V characteristics of PV-modules together with the switching matrix is the most advanced and challenging part of the monitoring system.

The electrical configuration of the PV-generator is realised as a switching matrix, allowing for instant disconnecting of any module in order to measure its characteristics (Fig. 3). Since electrical configuration of the generator is 5x4, the rapid disconnection of any modules would disturb the power level by 20%, but the use of the fast bypass diode (Fig. 3) will provide the current flow in the affected branch, minimising the power drop even more. The global working point will slightly change, but such an effect is comparable to rapid insolation or shadowing changes and is not harmful to the inverter.

The use of mechanical relays instead of semiconductor switches simplifies the problem of control and drastically lowers the costs. They can withstand millions of cycles without increase in their contact resistance. Since there is virtually no inductance in the load circuit, there is no danger of shortening their lifetime.

The resistance of relays in the range of 100 mΩ will introduce a small measurement error, especially near short-circuit conditions of PV module. Since the purpose of the measurement system is to study the dynamics of modules characteristics under operation, the highest accuracy is not the most important objective.

The control signals come from the control unit through the electrical isolation. The PVn terminals are connected to the common, for all the modules, measurement bus, but only one module can be scanned at the given moment due to the current limitation of the variable load $R_L$ (Fig. 4).

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The selected PV-module is connected to a typical measurement system (Fig. 4) [3,4]. The major points of this system are: variable load $R_L$, A/D and D/A converters for controlling the load and taking the measurements of voltages and currents.

The current measurement is realised with the use of a shunt resistance $R_S$ whereas the voltage can be measured directly on the module output. Both signals with the proper range adjustments are passed through the multiplexer to the A/D converter.

The measurement of an I–V curve of a PV–module consists in driving the operating point along the whole curve with the use of a variable load resistance. The load is a high-speed MOS-transistor with low channel resistance, in order to minimise the power dissipation and increase the accuracy near ISC point of the characteristics.

The whole analogue part is electrically isolated from the digital part of the microcontroller. In order to avoid the wide connection buses, the fast DAC and ACD with serial interface (SPI) were used, which provided limiting of the electrical isolation to several signals only. The 5-to-21 decoder is used to provide control signals to the switching matrix, was implemented in CPLD device and electrically isolated from the microcontroller part.

The digital part (Fig. 5) is based on microcontroller MC68331 equipped with a powerful peripheral subsystem. It supports in-system programming and debugging through BDM interface. Software development is possible in C language. The processor works with 512 kB ROM Flash memory and 256 kB RAM. The external devices, coupled to the microcontroller are: nonvolatile 2 MB RAM memory, used as a data buffer, real time clock, LCD and keyboard panel and communication chips, supporting quad UART and USB ports. The generation of CS signal for external devices and switching matrix signals is realized with CPLD device.

The monitoring system is still under development. The monitoring will provide very detailed information about all the modules within the generator, including their I–V characteristics and their mutual influence.

The performed experiments show that the shortest characteristics scanning time is about 0.5 s and for faster measurements cycles a hysteresis in the characteristics can be observed. Figure 6 presents the family of one-module characteristics taken at 1 s time intervals, under rapidly varying insolation (2 minutes measurement time – 5/02/2004).

The system allows for a long-term performance analysis as well as study of dynamic behaviour of PV-generator under partial shadowing and rapidly varying insolation in short terms. The polluted environment, in which the installation operates, is already noticeable as a dust and dirt deposition on solar modules.

The system electronic construction uses fast integrated circuits with reconfigurable hardware which gives a great amount of flexibility for future modifications. The high level of reliability is ensured with the presence of additional RAM buffer and duplicated database.

References

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