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MONITORING OF PHOTOVOLTAIC SYSTEMS PERFORMANCE

The easiest and most accurate way to determine the amount of incident solar energy is a measurement of the intensity of solar radiation in the given location. Necessary data on the availability of solar radiation and its energy can in principle be obtained by pyranometric measurements. An important prerequisite for results of measurements of solar radiation necessary to describe the actual relevancy of solar radiation on the site is that the measurements represent averages for a long time, as recorded by pyranometer with digital recording devices with the possibility to collect suitable number of samples in chosen time period. This work presents a system for monitoring parameters and working conditions of PV systems in real time with a perspective for monitoring of photovoltaic panels in real time application.

Keywords: intensity of solar radiation, pyranometer, open circuit voltage, realtime monitoring of FV systems performance

I. INTRODUCTION

Progress in the field of renewable energy sources is driven by the requirements of the times in terms of expectations of the inadequacy of exhaustible energy resources - oil, natural gas or uranium. With a virtually limitless source of semiconducting materials and their recycling at the end of life should more promote production of electricity from solar energy using photovoltaic devices.

The paper deals with the nature and essential characteristics of solar radiation and methods for monitoring performance of photovoltaic systems using Pyranometers in sunlight illumination in real working conditions. Basic characteristics and monitoring parameters of photovoltaic systems are the main theme of the contribution.

II. SHORT OVERVIEW ON MATERIALS FOR PV STRUCTURES

Achievement of products final properties is determined by the knowledge of technological processes and input material properties. In next we shortly describe the up to date state of the art in the field of materials for PV application.

The most widely used and longest used material for solar cells is silicon (Si) in various forms (monocrystalline, multicrystalline, polycrystalline, microcrystalline, amorphous). Silicon is a stable, nontoxic, and the second most widely used material of the earth's crust [5].

Elements used for photovoltaic applications are the elements of class III-V of the periodic table and their compounds (GaAs, CdTe, InP, $CuInSe_2$ and others). In the field of PV, cells based on GaAs have theoretical efficiency greater than silicon solar cells. Radiation resistance of III-V cells is better, but their prices are higher. A direct consequence is that the cells based on these are more or less prevalent in the semiconductor space applications. Properties of III-V semiconductors for photovoltaic are useful in the field of concentrator systems with multiple higher-intensity of light radiation, which can take advantage of their greater efficiency in compare to silicon structures [6].

The newest alternative is based on organic semiconductor materials - polymers, oligomers, dendrimers, pigments, dyes and others. Conditions for photovoltaic applications meet the dyes and polymers, substances such as chlorophyll, anthracene, tetrafenylopyrin, perylene pigment, C60, PPV, and many others [7]. Arise applications like silicon heterostructures, which use inorganic materials with organic. Manufacture of cells based on organic materials expected in the future available, cheap and environmentally demanding applications especially with high efficiency, flexibility, which is very advantageous in the production process and installations [8,9].

III. MEASUREMENT OF SOLAR RADIATION USING PYRANOMETER

Solar radiation is electromagnetic radiation with a wavelength of fractions from nanometers to hundreds of meters. Direct extraterrestrial solar radiation hitting the Earth's atmosphere is partly (about 30%) reflected back to space and the rest penetrates into the atmosphere. The part that penetrates the earth's atmosphere is partly absorbed by molecules and aerosols (water vapor, ozone, carbon dioxide and others) and partly dispersed, so that at ground level on a horizontal plane is available to direct sunlight and diffuse radiation. These two basic types of solar radiation are available at ground level. In determining the amount of solar radiation incident on a horizontal plane we distinguish total solar radiation, which consist of the direct and diffuse solar radiation and also of reflected radiation from the surrounding terrain, which reaches a given plane. The decisive factor, that affects the amount of sunlight reaching the earth's surface, is the intensity of the extraterrestrial solar radiation. This radiation, which average annual effort indicates the solar constant, as a result of its passage through the atmosphere, weakens and changes, so that at the surface turns out to only a part, which size is conditioned by various actors and factors. At present, the value of solar constant is set to 1367 Wm^{-2}. Spectral course of radiation is referred to as AM0 spectrum. Spectral course of radiation on the surface is again characterized by the AM1.5 spectrum [1].

The easiest and most accurate way to determine the amount of incident solar energy is a measurement of the intensity of solar radiation in the given location. Necessary data on the availability of solar radiation and its energy can in principle be obtained by pyranometric measurements. An important prerequisite for results of measurements of solar radiation, necessary to describe the actual relevancy of solar radiation on the site, is that the measurements represent averages for a long time [1], as recorded by pyranometer with digital recording devices with the possibility to collect suitable number of samples in chosen time period.

Pyranometer (Fig. 1) is the device based on the principle of energy measurement, which measures the intensity of global solar radiation at

Earth's surface. It can measure the reflected radiation and irradiated by the Earth's surface or diffuse solar radiation, when supplemented by additional technical equipment or method of installation. This type of pyranometer is in accordance with ISO 9060, according to which it is classified as first class pyranometer, with sixtyfour thermocouples (connected in series). These elements are covered with highly stable dark film, which guarantees excellent spectral absorption and long-term thermal stability [2].

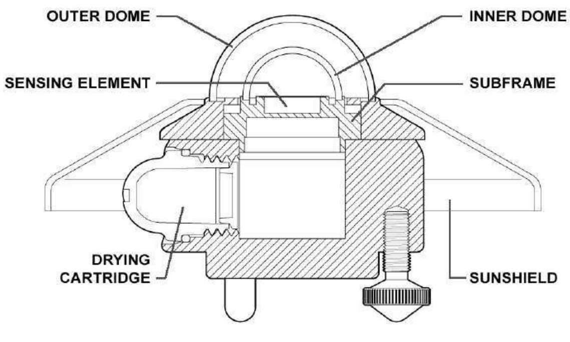

Fig. 1 Pyranometer Kipp&Zonen CMP 6 [3]

Pyranometer provides accurate and reliable measurement for monitoring of photovoltaic systems. When the pyranometer is mounted in the plane parallel to photovoltaic panel, the recorded values determine the effectiveness of these systems. It may indicate defective cells or panels with sudden decrease of their effectiveness, while gradually reducing their effectiveness indicates the need for cleaning the enclosures panels [4].

IV. EXPERIMENTAL PART

For adjustment of a property must be connected device Prolog using the serial port to a PC. Computer communicates with the device using terminal software (eg. HyperTerminal). Values of input signals are then converted to technical variables (temperature, radiation intensity, voltage, current and other) according to user configuration.

This is followed by the programming of parameters for measurement in datalogger - configuration of input channels and the conversion of input signals. Since open circuit output voltage of photovoltaic module, according to its parameters, is beyond the maximum permitted value for analog input (max. 2.5 V), it was necessary to use a resistive voltage divider. Subsequently, measurement was started.

Datalogger recorded the instantaneous values of solar radiation, voltage, current of illuminated module and voltage drop on Pt100 every second. In this article we show results of the output voltage tracking of unloaded photovoltaic module connected to the datalogger, along with measuring the intensity of solar radiation by pyranometer. Measured values were recorded on the memory card in real time. Illustration of measured intensity values is shown in Fig. 2. Data logger device provides the option of sending the measured values to e-mail address in selected time intervals. Figure 3 shows example of real-time evaluation of PV system performance and conditions, in this case the intensity of solar radiation and voltage produced on PV structure.

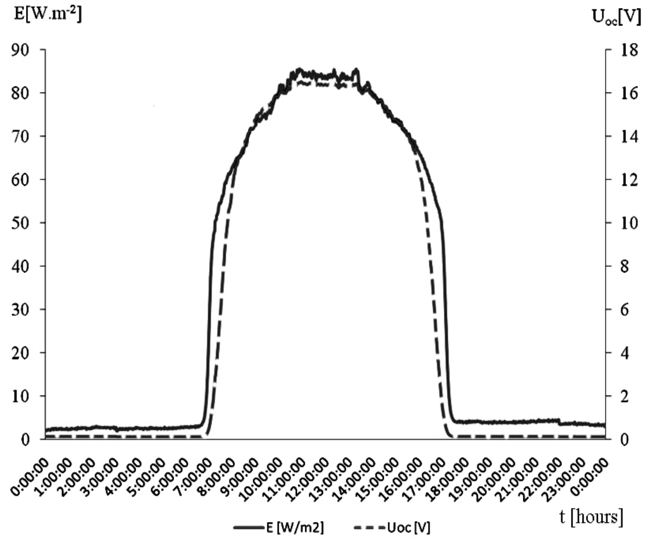

Fig. 3 One – day compare of measured intensity of solar radiation and open circuit voltage on PV structure

V. CONCLUSION

Achievement of products final properties is determined by the knowledge of technological processes and input material properties. The overall performance of PV systems is determined by knowledge of working conditions and their optimalization. Necessary data on the availability of solar radiation and its energy can in principle be obtained by pyranometric measurements. An important prerequisite for results of measurements of solar radiation necessary to describe the actual relevancy of solar radiation on the site is that the measurements represent averages for a long time, as recorded by

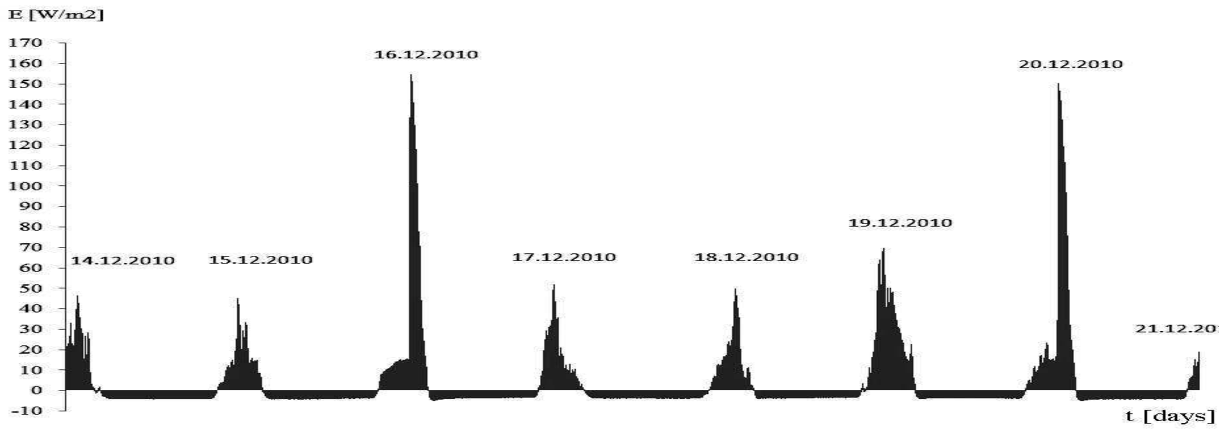

Fig. 2 One-week recording of solar radiation at SUT FEEIT Bratislava

pyranometer with digital recording devices with the possibility to collect suitable number of samples in chosen time period. In this work system for monitoring parameters and working conditions of PV systems in real time was introduced and some results illustrated the perspective application of this appliance for in-situ monitoring.

ACKNOWLEDGMENT

Partially, this work has been performed within the project VEGA 1/0443/10 supported by Scientific Grant Agency, Ministry of Education of the Slovak Republic.

This contribution is an outcome of a project entitled

"Finalization of Infrastructure
of the National Centre for Research and Application
of Renewable Energy Sources"
ITMS 26240120028

as part of the Operational Programme Research & Development
funded by the ERDF

Podporujeme výskumné aktivity na Slovensku/
Projekt je spolufinancovaný zo zdrojov EÚ

Európska únia

REFERENCES

[1] Kittler, R., Mikler, J.: Základy využívania slnečného žiarenia. VEDA, vydavateľstvo Slovenskej akadémie, Bratislava, 1986. SÚKK 1729/I-85, ISBN 71-013-I85,
[2] Internet side: *<www.kippzonen.com/?downloadcategory/551/Pyranometers.aspx>*
[3] Internet side: *<www.kippzonen.com/?downloadcategory/111/News+++Corporate.aspx>*
[4] Internet side: *<www.kippzonen.com/?news/48202/Improving+Photovoltaic+Efficiency.aspx>*
[5] Bube, R.H.: Photovoltaic materials: Imperial College Press, 1998, ISBN 1-86094-065-X.
[6] Internet side: < http://www.matdesign.sav.sk/data/long_files/saly.pdf>
[7] Nunzi, J.M.: Organic photovoltaic materials and devices. C. R. Acad. Sci. Paris, 2002.
[8] Goetzberger, A., et al.: Photovoltaic materials, history, status and outlook. Materials Science and Engineering, 2003 Report vol. 40, 1-46.
[9] Putala, M.: Materiálova chémia. Európsky sociálny fond. Internet side: *<158.195.47.144/clanky/chemia/Materialova_chemia.DOC>*

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