Solar Energy Potential and its Spectral Distribution under Different Climate Conditions

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Abstract

At the Department of Physics and Process Control, Faculty of Mechanical Engineering, Szent István University, Gödöllő, Hungary various solar applications were installed for educational, demonstrational and research purposes, such as PV and solar thermal units, transparent insulation wall and solar dryer unit. During studying the performance of the equipment, large amount of energy production data were collected and compared to the meteorological (solar irradiation, ambient temperature, etc.) data. During the analysis of the main factors the spectral and temperature dependence were identified. This paper presents some results of the analysis of the comparison of the energy and spectral data in a given time period, focusing mainly on the 10 kWp PV system at the campus.

1. Introduction

From the solar applications of the Department the performance of the 10 kWp PV system (detailed description in the next chapter) and the comparison of a vacuum rube and a flat plain collector was targeted. The efficiency of flat plate and vacuum tube collectors is different, caused by several reasons e.g. different convective heat loss, different shape (useful surface), different spectral sensitivity, etc. The collating of the operation of these collectors (a flat plate collector was installed about ten years before and a vacuum tube collector was installed in 2009 in the Department of Physics and Process Control Szent István University) has set questions about the importance of the different influence effects.

In the framework of a common project between the Vienna University of Natural Resources and Applied Life Sciences Institute (BOKU) and the Szent István University, Gödöllő (SZIUG) a spectrometer of the BOKU was installed in Gödöllő for two months. The type of the spectrometer was MS-710. Several literatures describe similar problems indicated in this paper (Stuart et al., 2009).

2. System description

On the campus of the Szent István University, Gödöllő, Hungary a 10 kWp photovoltaic system was constructed. The system was installed (on 8th October, 2005) on the flat roof of a student hostel building of the campus. The azimuth angle is 5° to East and the tilt angle is 30°, which is a good yearly average value for the site. The system has three different subsystems, two identical parts of 3,1 kWp from amorphous silicon DS40 modules (Dunasolar Ltd.), and a 3,5 kW part of ASE100 modules from polycrystalline (RWE Solar Gmbh) technology shown in Fig.1. Every subsystem uses a separate inverter (Sunpower SP3100/600 and SP2800/550), through which the produced energy is converted to the 230 V, 50 Hz electrical grid.

Fig.1. Polycrystalline (back) and amorphous silicon (in front) PV modules.

This set up was the largest PV installation (the total power is 9,6 kW) in the country at the time of installation until the last year. It was designed for at least 25-30 year life time (for example the solar panels have 20-year power warranty).

The estimated annual amount of energy produced is about 10 000 kWh, depending on the weather. During first four year of operation this value was 40 119 kWh. As the system has three (but two identical) subsystems, an important question was how the system energy production is shared among the different subsystems (Seres and Farkas, 2007).

The four year of operation produced fairly enough data for the comparison of the subsystems. From the literature it can be known, that the modules with different technologies are working in different way under various meteorological (mainly on radiation and temperature) conditions. The quantities measured are the irradiation (in the panel plane by a silicon reference sensor, and the total radiation by a pyranometer), the temperature (environmental and module temperatures, for each type, by Pt100 sensors), PV array (DC) voltage, current and power and the AC voltage, current, power and energy supplied to the electrical grid. The measurement of the key quantities was carried out by a PC based data logging system. The connection of the analogue input signal channels with the description of the measured quantities are shown in details in Fig. 2 (Seres et al., 2009).

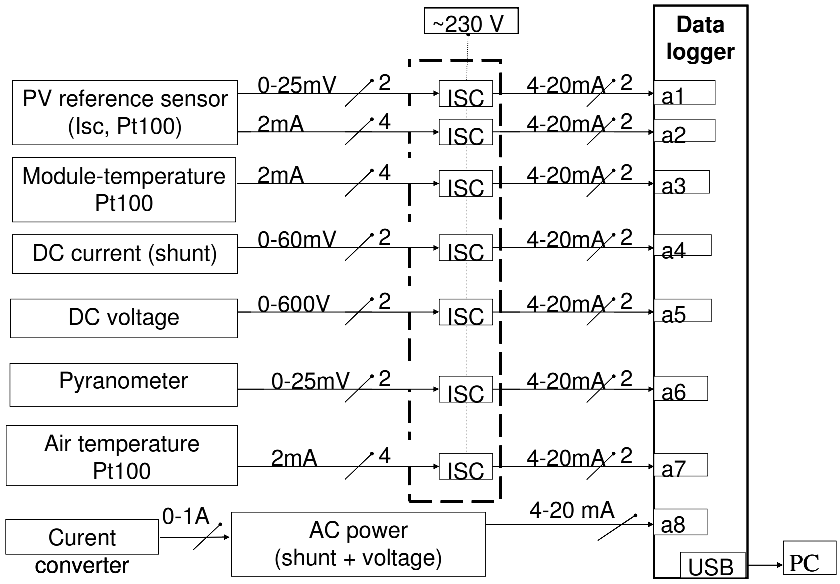

Fig. 2. The input quantities of the data logger system.

Because of the big distance between the data logger computer, and the measurement points (inverter room and sensor connection boxes), signal converters were installed to the system in order to serve as an amplifier. The signal converters (ISC – isolated signal converter) transform all different output signals of the sensors (e.g. different voltage levels) to 4-20 mA signal, what is sent to the AD converter unit of the data logger PC.

3. Comparison of the subsystems

As it is shown in Fig. 3 the nominal power of the polycrystalline subsystem is about 20 percent higher than the two other ones. The deviation of the energy production between each subsystem was under control continuously. From the graph it can be seen, that the second and the third subsystems are working nearly the same way, and the power of subsystem 1 is squarely higher.

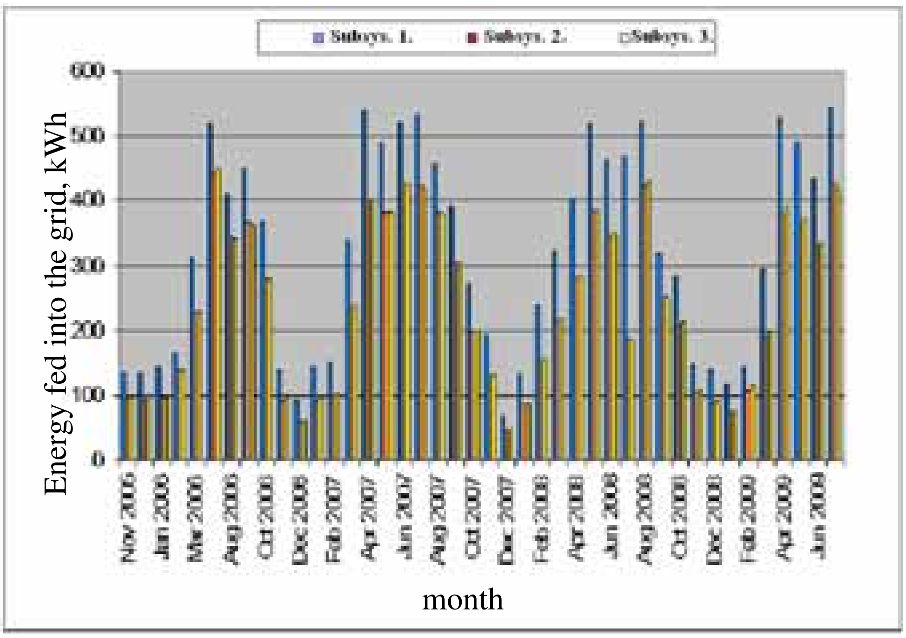

Fig. 3. Comparison of the energy production of the subsystems.

It can be seen from Fig. 3 that each DS40 module fields are producing almost exactly the same energy, as it was planned but for the better comparison of the two DS subsystems a graph was drawn to shown the rate of their energy production (Fig. 4). From this graph a decided differences can be seen approximately 4%. That difference has a flavour what is a seasonal profile. The cause for this effect is under investigation yet, and it is thought to have some practical reasons (bigger shading for one DS40 subsystem during winter, when low radiation inclination angle occurs), as the DS40 modules showed quite homogenous behaviour during the producer test.

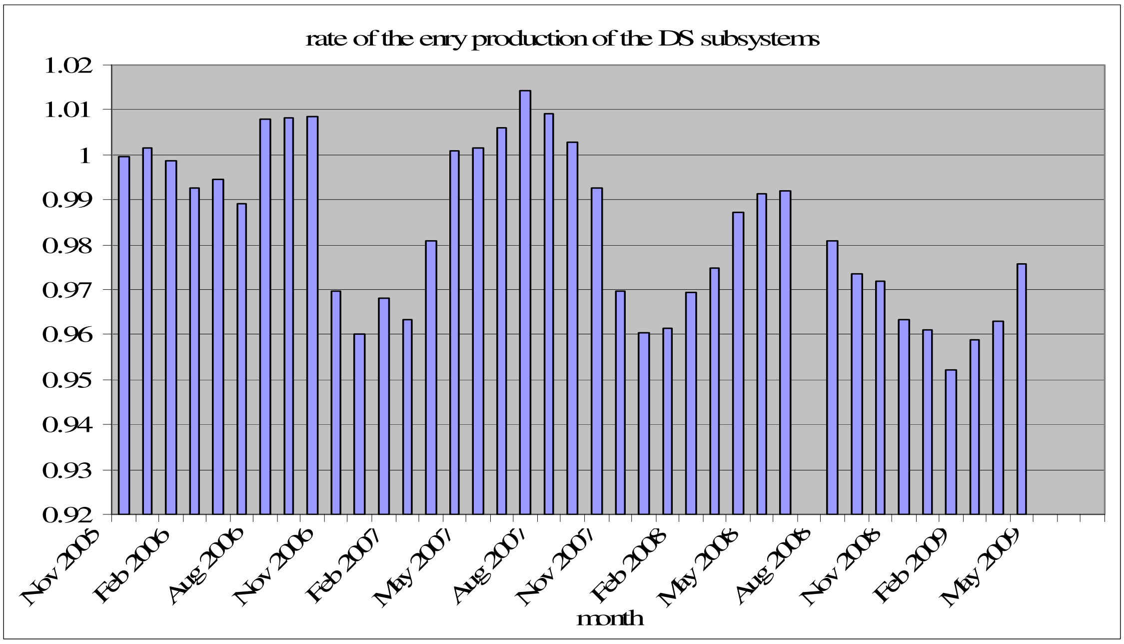

Fig. 4. The comparison of the energy production of the DS subsystems.

The rate of the energy production of the ASE and DS subsystems has a distinction. The ASE subsystem produced about 30% more energy than the DS, and the difference is higher in the winter time and lower in the summer time.

3.1. General specifications

Beside the energy production of the total system the production of the subsystems were also measured continuously and separately.

From the daily power distribution of the different subsystems it can be seen, that DS subsystems are working almost exactly the same way, and the power of the ASE subsystem is higher. From these data the comparison of the energy production of the different module technologies under different meteorological conditions were investigated. During the numerical analysis the normalized energy production data (the energy production values divided by the nominal power – so the energy production of a 1 kWp unit) was used because of the different nominal power of the subsystems.

The measurements show a seasonal effect in the rate of the polycrystalline versus the amorphous subsystems normalized energy production. During winter period is about 20% higher than in summer period (Fig. 5).

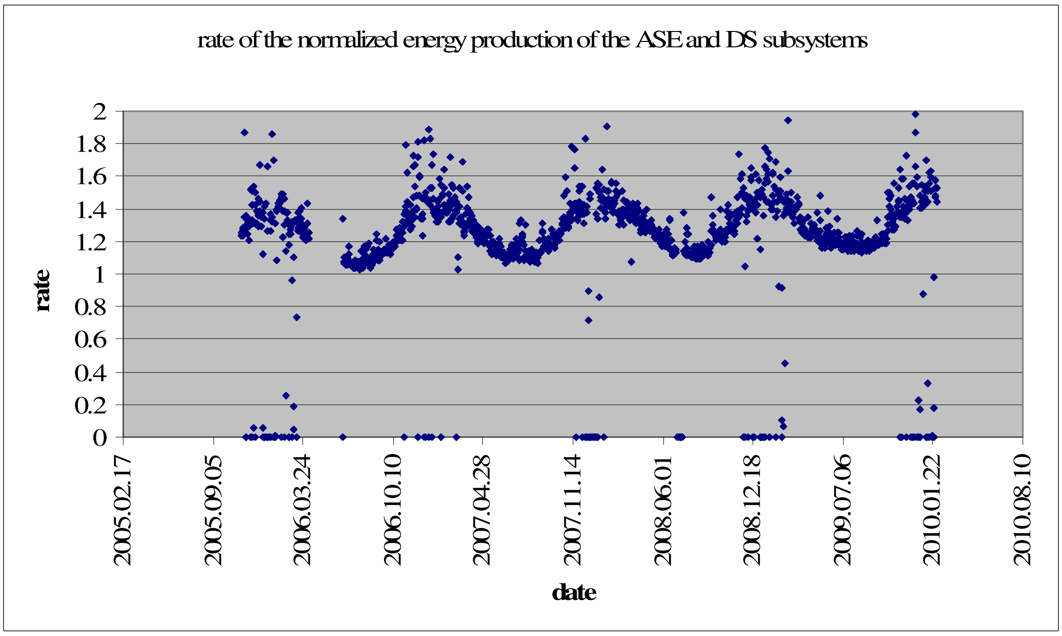

Fig. 5. Rate of energy production of polycrystalline vs amorphous.

3.2. Spectral measurements

Based on these measurements analysis was carried out to determine the rate of the red and IR (infrared) radiation – which is the most important spectral range for the collectors – in the incoming power. It was investigated how this rate is influenced by the different meteorological conditions (mainly cloudiness).

The used spectrometer saved the data of the incoming radiation in every minute from September to the beginning of November. A measured spectra is shown in Fig. 6.

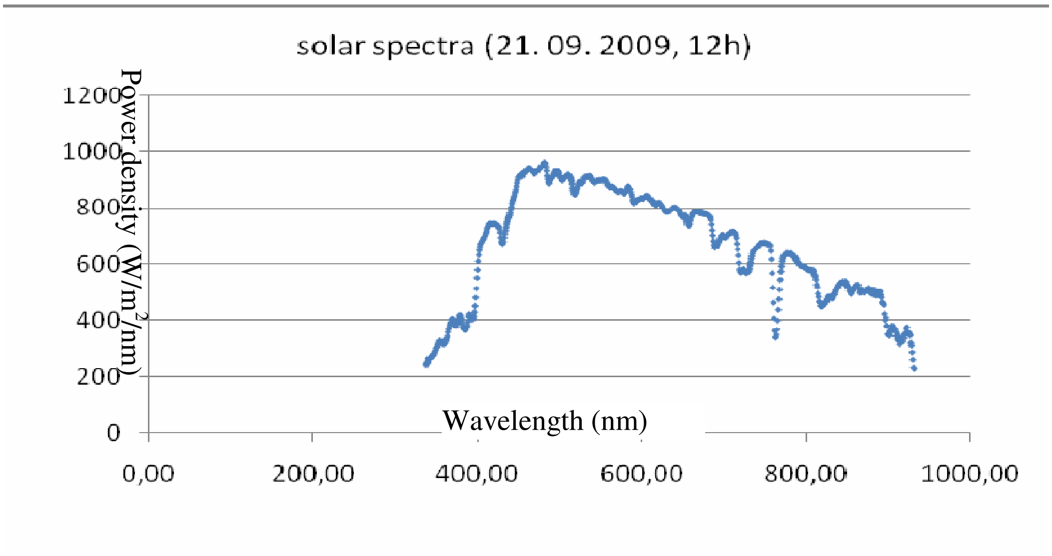

Fig. 6. Spectral measurement (21. 09. 2009).

To separate the useful range of the spectra of the incoming radiation classification was used based on the traditional physical wavelength ranges. The used classification can be seen in Table 1 as follows.

Table 1. The used spectral ranges.

Range	Wavelength
Infrared	above 780 nm
Red	640 - 780 nm
Orange	600 - 640 nm
Yellow	570 - 600 nm
Green	490 - 570 nm
Blue	430 - 490 nm
Violet	380 - 430 nm
Ultraviolet	below 380 nm

To conceivable the solar radiation spectra distribution it is shown an example a sunny day in Fig. 7. The ranges are differentiated with the suitable colours.

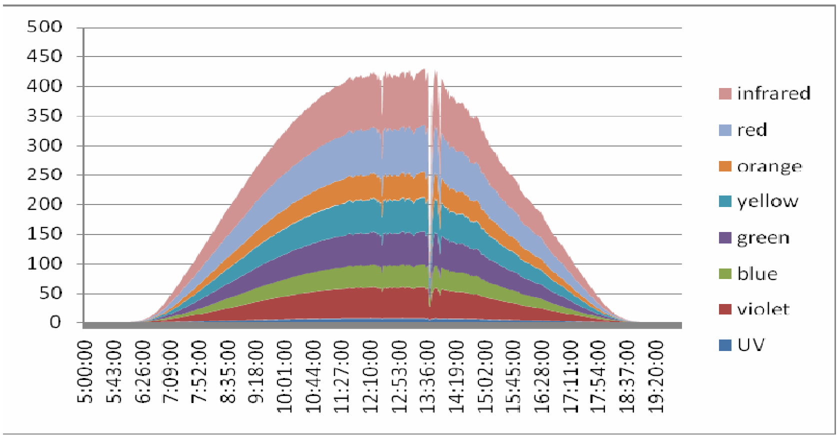

Fig. 7. Classification of the incoming solar radiation (21. 09. 2009).

The measurements were performed by time serial, and as the rate of red and IR radiations have an effect on the efficiency of collectors, a calculation was done to get this rate, as it is shown in Fig. 8.

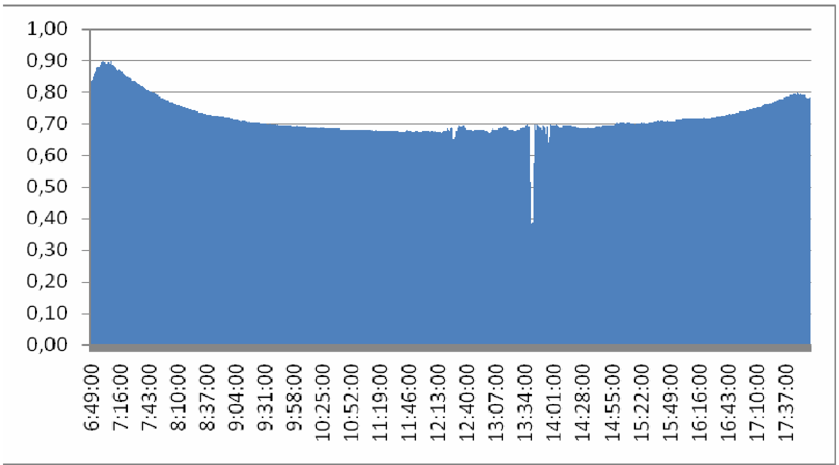

Fig. 8. The rate of the red + IR range to the rest of the spectra (21. 09. 2009).

In the result the higher range if the red + IR can be determined in the morning and evening hours. During the analysis it was presumed, that the red and infrared range of the solar radiation is more important than the rest. In order to verify it, the rate of the power of the red and infrared radiations compared to the other ranges was determined for every minute, and it was averaged to 10 minute time intervals (as the energy data were available for 10 minutes averages, as well). For clear days the rate of the red and infrared radiations was compared to the rate of the different PV modules (ASE/DS) normalized energy production for what an observable relation was determined, as it can be seen in Fig. 9.

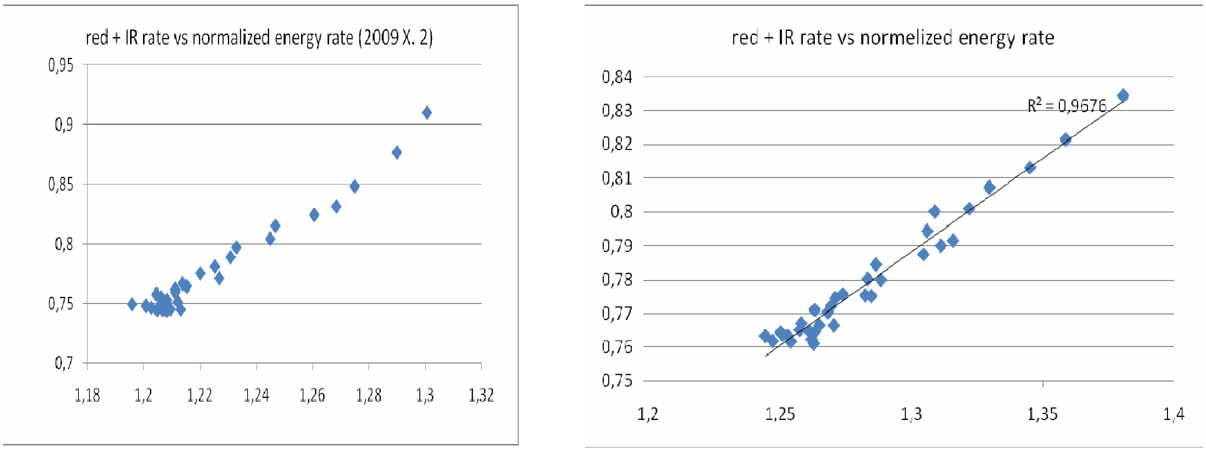

Fig. 9. Comparison of red and infrared radiation rate to ASE/DS normalized energy production rate for different days.

From the graph it can be seen that higher ASE/DS rate occurs for higher red and infrared rate in the solar radiation. To check the stability of the effect more days were analyzed the same way. The analysis was performed separately for the sunny, partly sunny and cloudy days. From the graphs in Fig. 10 the data of the sunny and partly sunny days can be seen. Each dot represents a daily average data for the period of 11 – 13 hours (earlier and later – mainly in November – the radiation data were quite low to cause higher measurement errors). For the dark cloudy and for the morning –evening periods the data did not show reliable relation.

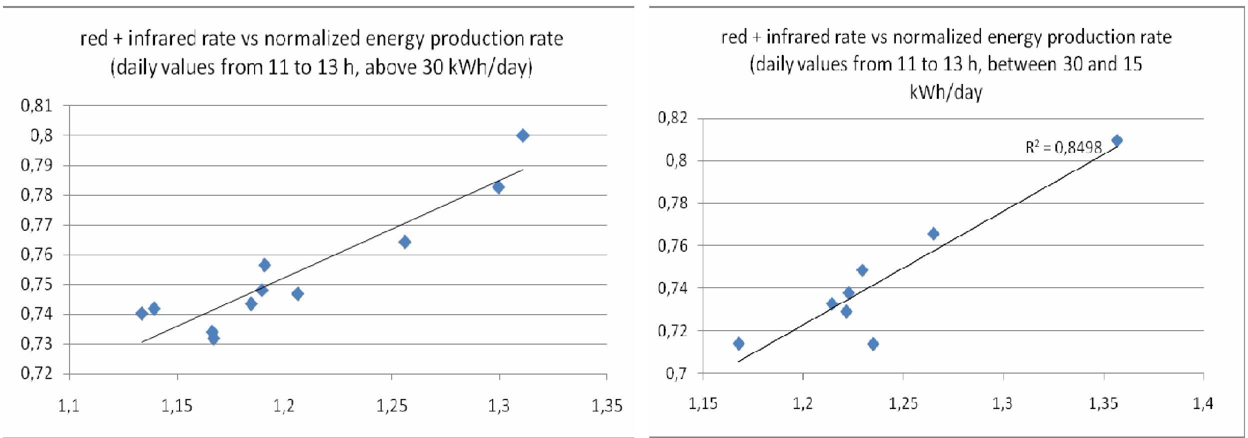

Fig. 10. Comparison of red and infrared radiation rates to ASE/DS normalized energy production rate for clear days.

4. Conclusion

From the analysis it can be concluded, that the different type of PV modules give different responses to the changing of the solar spectra. Te rate of the normalized energy production of the polycrystalline and amorphous silicon photovoltaic modules is proportional to the red and infrared rates of the solar radiation. Further measurements under controlled conditions (artificial lighting) are planned to set up for improving the elaborated model.

5. Acknowledgement

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6. References

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