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# EXPERIMENTAL DETERMINING OF ENERGY EFFICIENCY OF PV SOLAR POWER PLANT AT THE FACULTY OF SCIENCES AND MATHEMATICS IN NIŠ

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**Abstract:** This paper presents basic information on a 2 kW solar power plant at the Faculty of Sciences and Mathematics in Niš and the equipment for its energy efficiency determination depending on the real meteorological conditions (inverter, communication system, sensor, etc.). Additionally, the results are shown of experimental determination of energy efficiency of the solar power plant at the Faculty of Science and Mathematics in Niš from June 1, 2013 to September 1, 2013 (energy of the Sun radiation, ambient temperature, wind velocity, generated electrical energy, etc.).

**Keywords:** solar energy, PV solar power plant, PV solar power plant energy efficiency.

## 1. INTRODUCTION

Photovoltaic (PV) solar system is a system that uses the radiation of the Sun to generate electrical energy and to supply it to the consumers. A PV solar system can operate independently of the power grid (off-grid PV system) or it can be connected to it (on-grid PV system). On-grid PV solar systems are comprised of solar modules, an inverter which converts the direct current (DC) output of a photovoltaic (PV) solar module into a utility frequency alternating current (AC), monitoring system, a transformer through which the generated electrical energy is sent to the power grid and power lines for the connection of PV solar system to the power grid. In these systems total amount of generated electrical energy is sent to the power grid. These systems comprise large power solar plants installed on the ground and small power plants installed in private households, residential and other objects [1−4].

## 2. SOLAR POWER PLANT AT THE FSM IN NIŠ

Solar power plant at the Faculty of Science and Mathematics (FSM) in Niš is comprised of 10 serial connected solar modules made of monocrystalline silicon with single power of 200 W (*SST-200WM, Shenzhen Sunco Solar Technology Co.*). Solar modules are located on a metal stainless steel base inclined at 32º towards the south. By means of adequate conductors solar modules are connected with DC distribution board (RO-DC), single phase inverter (Sunny Boy 2000 HF, power of 2 kW), AC distribution board (RO-AC) and the city power grid. At the output of AC distribution board there is a single phase alternating voltage of 230V, 50Hz. The information about the amount of electrical energy, generated by the solar power plant and the energy of the Sun radiation incident on the solar power plant is acquired by Sunny WEBBOX which is connected, by Bluetooth, to the inverter and *Sunny SensorBox* sensor inclined at a 32° angle in relation to the horizontal plane [5]. A 2 kW solar power plant on the roof of FSM in Niš is shown in Figure 1, while a part of the interior of the *Solar energy laboratory* at FSM in Niš with the inverter and additional equipment for monitoring and acquisition of data for 2 kW solar power plant is shown in Figure 2.

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*Figure 1. Solar power plant power of 2 kW on the roof of FSM in Niš*

*Figure 2. Part of the interior of the Solar energy laboratory at FSM in Niš with an inverter and additional equipment for monitoring and acquisition of data for 2 kW solar power plant*

## 3. EXPERIMENT AND CALCULATION OF ENERGY EFFICIENCY OF SOLAR POWER PLANT

### *3.1. Measurement of meteorological parameters*

For the measurement of meteorological parameters (intensity of the Sun radiation falling on a square meter of the surface oriented at a 32° angle in relation to the horizontal plane, wind velocity and ambient temperature), at the FSM in Niš, a *Sunny SENSORBox* sensor was used. Sunny SENSORBox is connected with Sunny WEBBox through *SMA Power Injector* with integrated *Bluetooth*. The measurement of parameters, storage and measured data processing along with their visualization is performed by *Sunny Portal*. Measured values are stored in tables in *CSV* or *XML* format to enable their numeric and graphic processing [6].

### *3.2. Measurement of the amount of electrical energy obtained from solar power plant*

The information about electrical parameters of solar power plant at the FSM in Niš is obtained through WEBBOX. The data obtained from the solar power plant are registered each 5 minutes in WEBBOX which performs their acquisition and processing. Measurement of the parameters, storage and processing of the measured data is performed by means of *Sunny Portal*, so the computer gives numerical data on daily, monthly and annual amounts of generated electrical energy (kWh), maximal power (kW), financial gains obtained by selling electrical energy (Euro) and reduction of $CO_2$ (kg) emission by utilizing solar power plant. Apart from this, the computer can give daily, monthly and annual graphic presentation of the changes in maximal power and the amount of electrical energy generated by solar power plant [7].

### *3.3. Calculation of energy efficiency of the solar power plant*

The Energy efficiency of a solar power plant implies the ratio of electrical energy generated in a time interval by the solar power plant and the Sun radiation energy falling on solar modules of the plant during the same time interval. Having this in mind we distinguish hourly, daily, monthly and annual energy efficiency of the solar power plant. Monthly energy efficiency of the solar power plant is calculated by the following expression [8,9]:

$$\eta_M = \frac{\sum_{i=1}^{n}(E_D)_i}{S \cdot \sum_{i=1}^{n}(E_S)_i} \qquad (1)$$

where $n$ – is a number of days in the month, $E_D$ – is the total amount of electrical energy generated during the day by the solar power plant (Wh), $E_S$ – is the total amount of the energy of global Sun radiation reaching the solar modules (Wh/m$^2$) during the day and $S$ – is the total surface of solar modules (m$^2$).

Experimental determination of energy efficiency of the solar power plant is performed by including in the expression (1) the measured data on daily amount of electrical energy generated by the solar power plant and the Sun radiation energy falling on the solar power plant. The values of the energy of global Sun radiation reaching solar power plant are obtained by performing measurements through *Sunny SENSORBox*.

## 4. RESULTS AND DISSCUSION

Graphic presentation of the experimental results of the measurements of monthly values for the global Sun radiation $E_{sopt}$ reaching, during the day, a square meter of the solar modules oriented at a 32° angle in relation to the horizontal plane in Niš and monthly amount of the electrical energy $E_e$ generated by 2 kW solar power plant on the roof of the FSM in Niš from June 1, 2013 to September 1, 2013 is given in Figure 3.

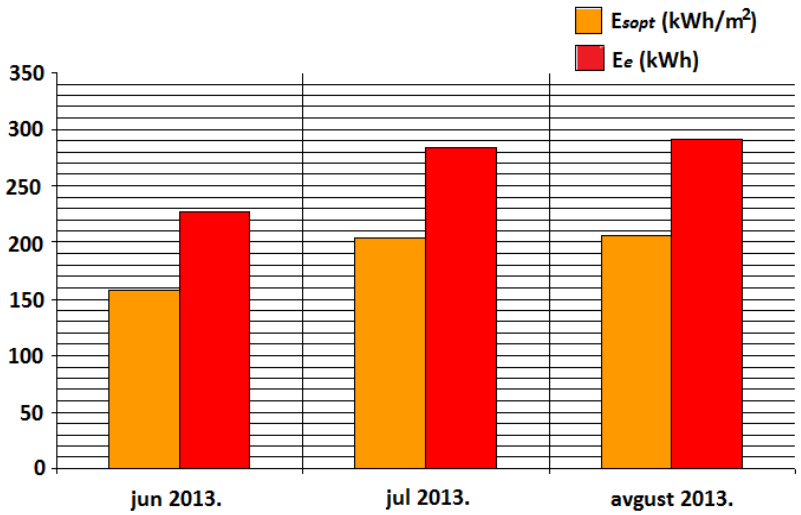


*Figure 3. Graphic presentation of experimental results of measuring monthly values for the global Sun radiation $E_{sopt}$ reaching, during the day, a square meter of solar modules oriented at a 32° angle in relation to the horizontal plane in Niš and the monthly amount of electrical energy $E_e$ generated by 2 kW solar power plant on the roof of FSM in Niš from June 1, 2013 to September 1, 2013*

Figure 3 shows that from June 1, 2013 to September 1, 2013 the experimental results of the measurements of monthly values for the global Sun radiation reaching, during the day, a square meter of the solar modules oriented at a 32° angle in relation to the horizontal plane in Niš, range from 157,57 – 206,19 kWh/m$^2$ and that the monthly amount of the electrical energy generated by 2 kW solar power plant on the roof of the FSM in Niš range from 226,36 – 291,5 kWh.

Graphic presentation of experimental values of the energy efficiency ($\eta_M$) of 2 kW solar power plant on the roof of the FSM in Niš from June 1, 2013 to September 1, 2013 is given in Figure 4.

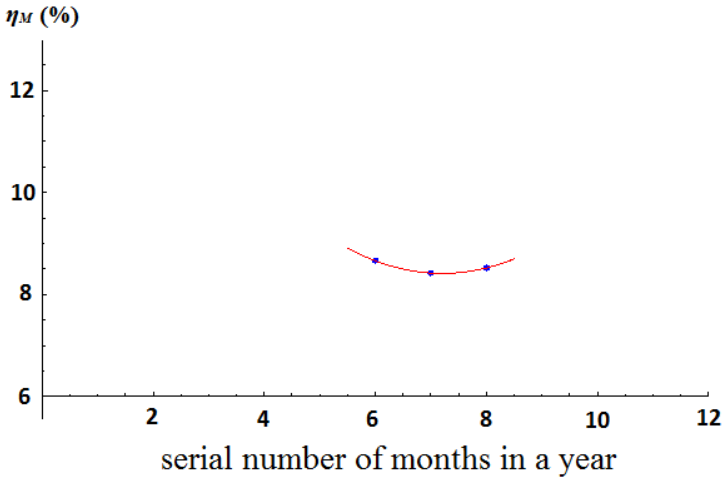


*Figure 4. Graphic presentation of experimental values of the energy efficiency ($\eta_M$) of the solar power plant of 2 kW on the roof of the FSM in Niš from June 1, 2013 until September 1, 2013.*

Figure 4 shows that the experimental energy efficiency ($\eta_M$) of 2 kW solar power plant on the roof of the FSM in Niš ranges from 8,42 – 8,66%, from June 1, 2013 until September 1, 2013.

Graphic presentation of the dependence of the energy efficiency ($\eta_M$) of 2 kW solar power plant on the roof of the FSM in Niš on the ambient temperature ($T_{amb}$) and the wind velocity ($v$) from June 1, 2013 until September 1, 2013 is given in Figure 5.

Figure 5 shows that with an increase of the ambient temperature there is a decrease of experimental energy efficiency of a 2 kW solar power plant on the roof of the FSM in Niš. With an increase in ambient temperature there is an increase in thermal vibrations of atoms of crystal material mesh which constitute solar cells thus impeding directed motion of freecharger carriers, bringing about voltage decrease of the open circuit and diminishing the power of the solar cells. On the other hand, with an increase in wind velocity there is an increase in the energy efficiency of the solar power plant due to the cooling of the solar modules under the influence of the wind.

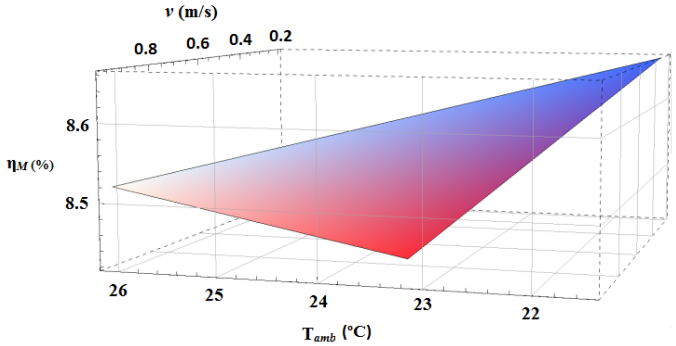


*Figure 5. Graphic presentation of the dependence of energy efficiency ($\eta_M$) of 2 kW solar power plant on the roof of the FSM in Niš on the ambient temperature ($T_{amb}$) and wind velocity (v) from June 1, 2013 until September 1, 2013*

## 5. CONCLUSION

Based on all above mentioned one can conclude that the energy efficiency of a 2 kW solar power plant on the roof of the FSM in Niš ranges from 8,42 – 8,66%, from June 1, 2013 to September 1, 2013. It was found that an increase in ambient temperature brings about a decrease of the experimental energy efficiency of the solar power plant during the summer months. This is a consequence of an increase in solar modules temperature and an absence of stronger air flow.

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ЕКСПЕРИМЕНТАЛНО ОДРЕЂИВАЊЕ ЕНЕРГЕТСКЕ ЕФИКАСНОСТИ СОЛАРНЕ ФН ЕЛЕКТРАНЕ НА ПРИРОДНО-МАТЕМАТИЧКОМ ФАКУЛТЕТУ У НИШУ

**Сажетак:** У овом раду приказани су основни подаци о соларној електрани од 2 kW на Природно-математичком факултету у Нишу, као и опрема за одређивање њене енергетске ефикасности у зависности од стварних метеоролошких услова (инвертер, комуникациони систем, сензори, итд.). Осим тога, приказани су резултати експерименталног одређивања енергетске ефикасности соларне електране на Природно-математичком факултету у Нишу у периоду од 1. јуна 2013. до 1. септембра 2013. год. (енергија сунчевог зрачења, собна температура, брзина вјетра, произведена електрична енергија, итд.).

**Кључне ријечи:** соларна енергија, соларна ФН електрана, енергетска ефикасност соларне ФН електране.