ETFOS
FACULTY OF ELECTRICAL ENGINEERING
Josip Juraj Strossmayer University of Osijek

IEEE Hrvatska sekcija
Croatia Section

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SiP 2008

26th International Conference

SCIENCE IN PRACTICE

PROCEEDINGS

Osijek, May 5 – 7, 2008

Sponsored by

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Publisher
Faculty of Electrical Engineering
J.J. Strossmayer Univ. of Osijek

Editor-in-Chief
Radoslav Galić

Editors
Goran Martinović
Milan Ivanović

Design and Layout
Davor Vrandečić

Printing
Grafoplast - Osijek

CIP - Katalogizacija u publikaciji
GRADSKA I SVEUČILIŠNA KNJIŽNICA OSIJEK

UDK 621.313(063)
62-5:004.896>(063)

INTERNATIONAL conference Science to practice (26 ; 2008 ; Osijek)
26th scientific conference Science to practice, Osijek, May 5-7, 2008: Proceedings / <editors Goran Martinović, Milan Ivanović>. - Osijek : Faculty of Electrical Engineering, 2008.

Bibliografija.

ISBN 978-953-6032-62-4

1. Martinović, Goran
I. Električni strojevi -- Zbornik II. Robotika -- Zbornik III. Računarstvo -- Zbornik

120305036

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PREFACE

Hochschule Bremen, Fachbereich Elektrotechnik, Bremen (Germany) and Faculty of Electrical Engineering in Osijek (Croatia) started from 1984 year with organization a joint scientific colloquium every year. In 1996 Fachhochschule Wiirzburg-Schweinfurt from Germany as well as "Kando Kalman" Polytechnic - Budapest and "Pollack Mihaly" College of Engineering - Pecs from Hungary joined this scientific colloquium, in 2003 Polytechnic Engineering College of Subotica joined the group, too. The main topic of the conference was research, teaching and new technologies in electrical engineering and computer science. In 2008, new university partners joined us.

26th conference held in Osijek and organized by the Faculty of Electrical Engineering, J.J. Strossmayer University of Osijek. The conference provided a platform for researchers and practitioners interested in the theory and practice of electrical engineering, computer science, automation, robotics, as well as interdisciplinary research and applications of the mentioned disciplines with mathematics, physics, mechanical engineering, medicine, etc. Submitted and reviewed papers are fully developed results or on-going work. The general theme of SiP 2008 was “Modern Computer Systems in Engineering Applications”.

At the conference 72 authors, form seven countries, presented 35 papers in the following five sessions: (a) Research and project management, b) Power engineering and electrical drives, (c) Automation, robotics and industrial applications, (d) Computer systems and applications and (e) Computer systems and applications. With presented papers our faculties provided contributions to the development of new technologies and the knowledge economy in our countries which moves to the knowledge society - new civilizational and the development paradigm of European Union.

Osijek, September 2008

Editors

Application of a Solar Power Calculator in Power Engineering Education

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***Abstract* — Due to the need for a practical explanation of the solar energy exploitation, Solar Power Calculator has been created in this paper. Based upon measured results obtained by the Energy Institute Hrvoje Požar, the annual database for the year 2006. has been created for Split, Osijek, Zagreb and Rijeka. Using the created database, the algorithm and a user interface have been created for calculation of the total solar energy absorbed as well as direct financial benefit in the case of practical realization of the solar collector. A thorough application of the solar power calculator has been explained in this paper as well.**

***Keywords* — solar energy, solar cells, power, calculator**

I. INTRODUCTION

Due to the need for a practical explanation of solar energy exploitation, Solar Power Calculator has been created and described in this paper. Based upon measurement results obtained by the Energy Institute Hrvoje Požar, the annual database for the year 2006 has been created for Split, Osijek, Zagreb and Rijeka.

Using the created database, the algorithm and a user interface have been created for calculation of the total solar energy absorbed as well as direct financial benefit in the case of practical realization of the solar collector. A thorough application of the solar power calculator has been explained in this paper as well.

II. SOLAR POWER CALCULATOR APPLICATION IN EDUCATION

2.1. Input data

When the program starts, a dialog box opens up in which you select a year for which calculation is done or the data are saved in the database after measurements. After selecting the year, the data are read by clicking the mouse on the key *read* (Figure 1.). The database holds the data referring to total insolation for the four cities in the Republic of Croatia, i.e. Osijek, Zagreb, Rijeka and Split. The dialog box given in Figure 1. shows the insolation data referring to every single month and every city individually.

By selecting certain total insolation for a particular city we can see the total data for every day, interval and insolation value within the month (Figure 2.). The first, second, third, fourth and fifth column refer to year, month, day of the month, interval (in hours) and insolation value in W/m2 , respectively.

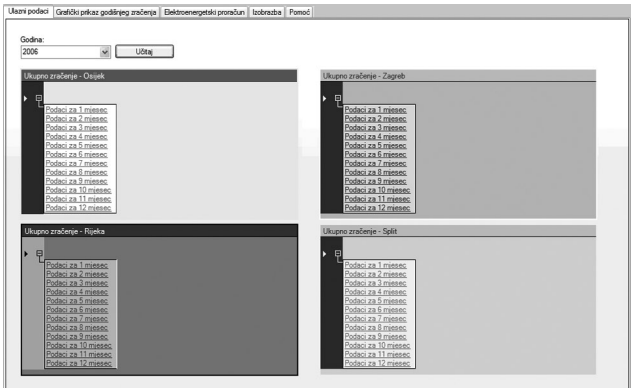

Figure 1. Reading data about total insolation per month

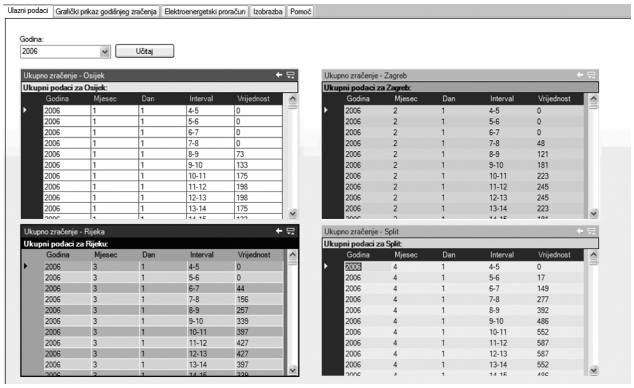

Figure 2. Total insolation for a particular city per months, days, hours and insolation values

2.2. Graphical representation of annual insolation

This dialog box represents graphically the data about the total insolation intensity during one year (per individual months) for the four cities in question (Figure 3.).

Below this graphical representation of annual insolation within the same dialog box there follow the data about mean monthly insolation intensity. By selecting a city, the data referring to average values of insolation intensity for every month are given (Figure 4.).

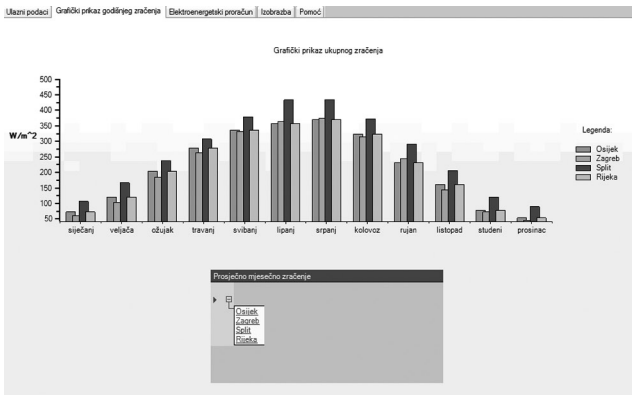

Figure 3. Graphical representation of annual insolation

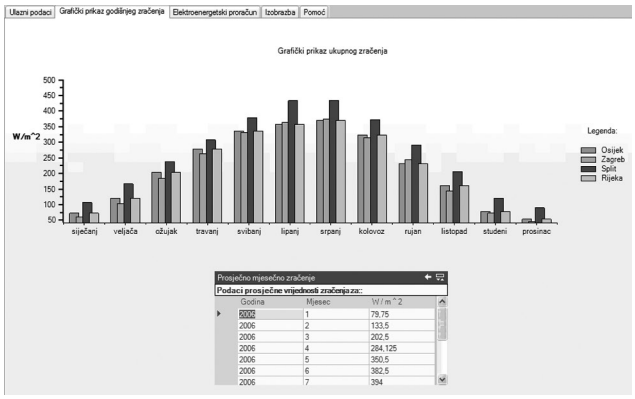

Figure 4. Data about mean insolation for every month

2.3. Solar cells

By selecting the Solar Cells menu on the menu bar, there appears a drop-down menu with the following options: Enter New Cell and Delete and Change Solar Cell (Figure 5.). If you want to enter a new cell, the option Enter New Cell must be selected, as shown in Figure 5. If you want to delete a certain cell that has already been entered, or change the saved cell, the option Delete and Change Solar Cell must be selected.

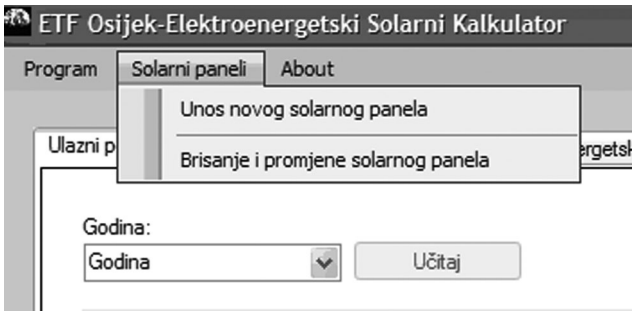

Figure 5. Solar cells

Data input for a certain solar cell of certain characteristics is done by selecting the Solar Cells menu. The following is to be entered: cell name, peak power, short-circuit current, open-circuit voltage, maximum power voltage, maximum power current, battery's rated voltage current, NOCT, voltage change due to temperature, wind power or surface pressure, hail resistance, operating temperature and storage temperature, maximum voltage of the system, dimensions and weight of the solar cell. When the necessary data are entered, they should be saved or in case we do not want to save them, they should be deleted.

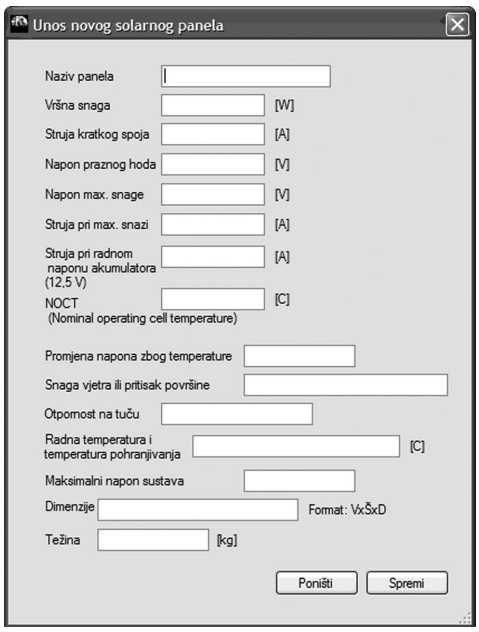

Figure 6. Input of a new solar cell

As can be seen from Figure 6., and based upon considerations outlined in previous theoretical sections, minimum requirements for the input of a new cell are as follows:

Cell name – cell name provided by the manufacturer

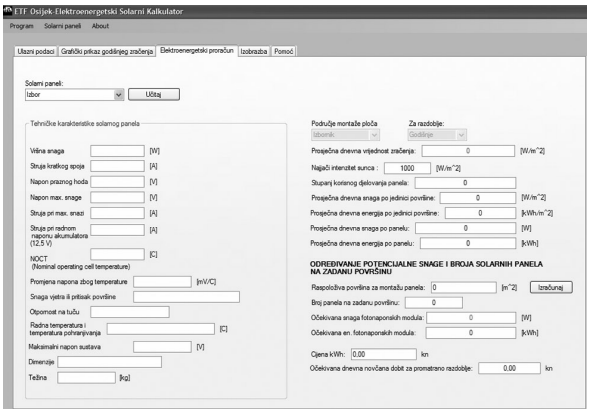

Figure 7. Power engineering calculation

- *Peak power* – cell power by maximum insolation [W]
- *Short-circuit current* – current that occurs at short-circuited cell terminals [A]
- *Open-circuit voltage* – cell terminal voltage in an unloaded condition [V]
- *Maximum power voltage* – cell terminal voltage by maximum power [V]
- *Maximum power current* – current along cell terminals by maximum power [A]
- *Battery's rated voltage current (12.5 V)* – current value that can be obtained if a battery is installed in the system [A]
- *NOCT* - nominal operating cell temperature [C]

- *Voltage change due to temperature* – voltage change at terminals due to temperature variation [mV/C]
- *Wind power or surface pressure* – cell resistance to pressure
- *Hail resistance* – maximum dimension and speed of hail a cell can stand
- *Operating temperature and storage temperature* – cell operating and storage temperature [C]
- *Maximum voltage of the system* – maximum cell breakdown voltage [V]
- *Dimensions* – cell dimensions (height, width, length) [mm]
- *Weight* – cell weight [kg]

2.4. Calculation of power and the number of solar cells on the given area from power engineering viewpoint

Selection of Power Engineering Calculation from the toolbar causes a dialog box to open in which a solar cell is first selected and then read. After that the area is selected in which the cell should be mounted (Osijek, Zagreb, Rijeka, Split). Then, by selecting the period (either annual or monthly) for which calculation should be done the program automatically shows the following: average daily insolation, highest sun intensity, level of cell efficiency, average daily power per unit of area, average daily energy per unit of area, average daily power per cell, and average energy per cell. Data that are subject to change i.e. that can be entered individually are the highest sun intensity (about 1353 W/m2) and the level of cell efficiency. A dialog box referring to power engineering calculation is presented in Figure 7.

- Area where the cell is mounted – geographical position, selection of the city with the cell
- *For period* – time interval for which calculation is done
- *Average daily insolation* – insolation value for a selected time interval
- *Highest sun intensity* – maximum insolation value
- *Level of cell efficiency* – percentage of transformation of solar energy into electrical energy
- *Average daily power per unit of area* - average daily power per unit of cell area expressed in W/m^2
- *Average daily energy per unit of area* - average daily energy per unit of cell area expressed in kWh/m^2
- *Average daily power per cell* - average daily power per cell expressed in W
- *Average daily energy per cell* - average daily energy per cell expressed in kWh
- *Available area for mounting a cell* – area that can be used for mounting a cell (roof, yard)
- *Number of cells per given area* – value obtained after entering the available area and pressing the key "Calculate", and it represents the maximum number of cells that can be installed
- *Expected power of a photovoltaic module* - expected power of a photovoltaic module for the given area
- *Expected energy of a photovoltaic module* - expected energy of a photovoltaic module for the given area
- *Price* – price on the basis of which financial gain is calculated. The required format is kuna+lipa.
- *Expected gain on a daily basis for the observed period* – financial gain expected on a daily basis for the given area, region and period.

The data about the area available for solar cells and the price for kWh are entered in the second part of the dialog box. After that, by clicking on the key *Calculate*, calculation is done. Calculation provides values referring to the number of cells on the given area, expected power of a photovoltaic module, expected energy of a photovoltaic module and the expected financial gain for the observed period (Figure 7.). Expected financial gain on a daily basis for the observed period is the product of the expected energy of a photovoltaic module and the market price of a kWh.

$$c_d = c_{kWh} \cdot W_p \qquad (1)$$

c_d - expected financial gain on a daily basis for the observed period [kn]

c_{kWh} – market price of a kWh [kn]

W_{pv} - expected energy of a photovoltaic module for the observed period [kWh]

2.5. Education, help and the toolbar

Dialog box Education contains explanations of necessary notions concerning solar energy and provides additional information regarding this renewable energy resource (Figure 8.).

Dialog box Help offers a graphical example explaining how to use a solar power calculator (Figure 9.).

On the toolbar there is a part giving an explanation of the program entitled Program. Solar cells and About give the data about the program and persons who helped creation of the program, respectively.

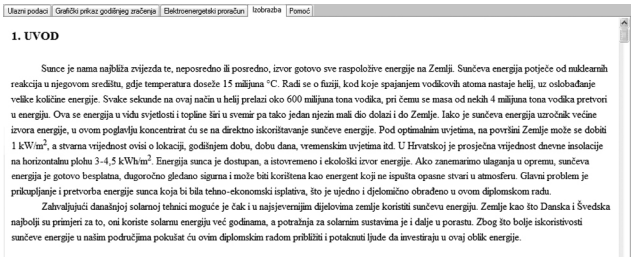

Figure 8. Education Menu

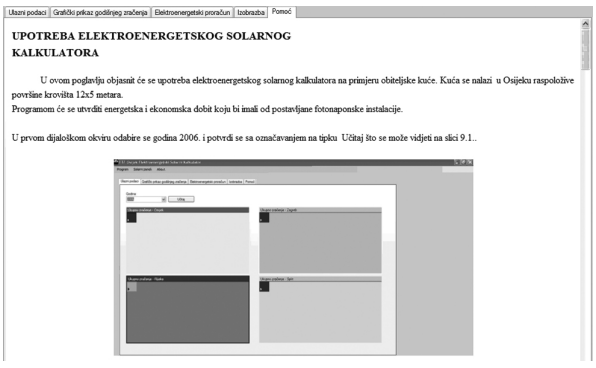

Figure 9. Help Menu

2.6. An example of using a solar power calculator

In this section we will explain usage of a solar power calculator on a family house. The house is located in Osijek, with available roofing area of 12x5 m2. The program will determine energy and economic gain that would be acquired if photovoltaic installations were installed.

In the first dialog box, year 2006 is selected and then confirmed. Read whatever can be seen in Figure 10.

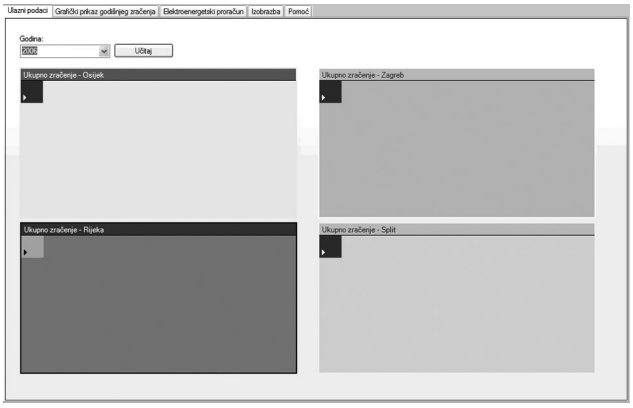

Figure 10. Help Menu

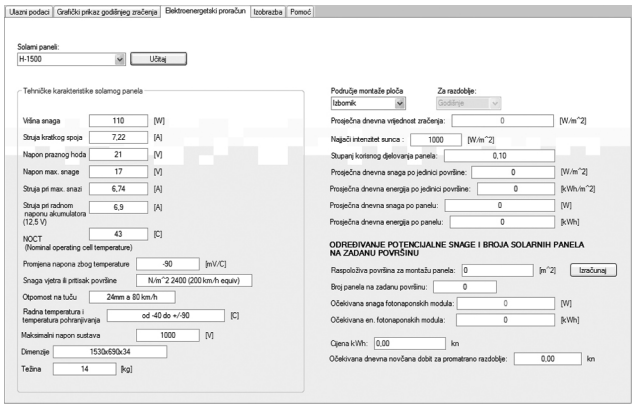

Figure 11. Dialog ox with cell reading

Then, the next dialog box named Power Engineering Calculation is opened, where it is possible to select a corresponding cell (H-1500), which is later on read (Figure 11.).

After that, the area is selected where the cell is to be mounted (Osijek) which is given by Figure 12. as well as the annual period shown by Figure 13.

We select the highest sun intensity that equals 1350 W/m2 and the level of cell efficiency. Then the data referring to the available roofing area of 12x5m (60 m2) is entered into the dialog box. As the last step in calculation, the price of a kWh of 0.61 kn is entered and calculation is confirmed.

A solar power calculator shows us an average daily insolation for the observed annual period which is 216.04 W/m2.

Figure 12 show total calculation results of the program referring to the annual period, the period for March, July and December, as well as calculation results for an available area of a family house of 60 m^2 (12x5m).

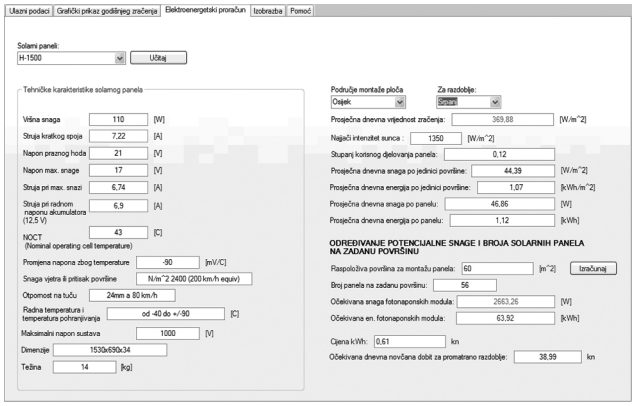

Figure 12. Dialog box with calculation for July

According to data explained in sections 2.3. and 2.4. the program has calculated the following:

TABLE I. Calculated data

Average daily power per unit of area	***25.92 W/m^2***
Average daily energy per unit of area	***0.62 kWh/m^2***
Average daily power per cell	***27.37 W***
Average daily energy per cell	***0.66 kWh***
Number of cells per given area	***56 pieces***
Expected power of a photovoltaic module	***1555.56 W***
Expected energy of a photovoltaic module	***37.33 kWh***
Expected financial gain for the observed period	***22.77 kn***

III. CONCLUSION

Solar Power Calculator proved to be very helpful when it comes to teaching and revision of issues concerning the usage of solar energy in the course Renewable Energy Resources. It is also used in other courses dealing with generation of energy to get a feeling of the financial benefit such investment of using the Sun's potential might result in. According to its abilities, the program is rather modest, but a feedback coming from users i.e. students makes it a valuable tool in studying solar energy, especially relative to energy and financial benefit it offers. Authors are proud of the fact that a particular product of a graduation paper has been used practically and that it will be useful to generations of students to come.

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ISBN 9536032-62-4