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# CHARACTERISTICS OF SOLAR RADIATION IN REGION CLOSE TO TIMISOARA

**Abstract:** *This paper presents a study on the solar potential in the south-west part of Romania based on measurements carried out and published by the Department of Physical Foundations of Engineering and values provided by the Station of monitoring the solar radiation at the Faculty of Physics from West University. Annual thermal potential is 1247 kWh/m$^2$/year horizontal surface. Potential thermal optimum on a tilted surface is 1456 kWh/m$^2$/year. Quantity of heat produced in one year by 1 m$^2$ inclined under the optimum angle; is 1094 kWh/m² / year.*

**Key words:** irradiation, radiation, solar potential, pyranometer.

## INTRODUCTION

Proper design of solar energy systems requires accurate knowledge about the solar radiation obtainable at particular locations.

The best radiation information of a place is obtained from experimental measurements of the global and diffuse components of the solar insolation at that place [1].

Design and implementation of modern equipment for efficient conversion of solar energy into other forms of energy requires knowledge of the solar potential of the location where the solar system is used and weather conditions that affect the performance of the energy chain. Heatstroke a place of its meteorological factors are uncontrollable variables to which knowledge necessary detailed measurements carried out over longer time, usually tens of years [2].

For long periods of time (a month, a year), the amount of useful energy of the solar installation depends on the total radiation but also on the solar potential because for lower intensities than the average intensity, the facility is inefficient. The total irradiation that exceeds the critical line depends on the global radiation and on the fraction of insolation.

Some solar radiation measurements using pyranometers have been performed since 1976 at Politehnica University of Timisoara [1,2].

This paper presents a study on the solar potential in region close to Timisoara, based on measurements carried out and published by the Department Physical Foundations of Engineering and values provided by the Monitoring Station of solar radiation at the Faculty of Physics from West University of Timisoara.

## EXPERIMENTAL SETUP AND DATABASE

### Pyranometer

The pyranometer is designed to measure the global radiant flux G [Wm$^{-2}$] in horizontal plan, but also for measuring the diffuse radiation. The sensor is shown in next figure (see Fig. 1).

**Figure 1.** *Pyranometer*

### Wattmeter

The SOLARIS 1 wattmeter measures solar radiation intensity in the plan of the solar collector and has been designed to equip the BFI department users to be able to calculate the efficiency of solar installations. Sensitivity error is ± 1W/m$^2$.

### Experimental setup

The experimental setup is installed on the roof of Faculty of Electronics and Telecommunication at coordinates 45°44´49,65´´N, 21°13´33,92´´E. The site consists of a weather station for the measurement of temperature, direction and speed of the wind and atmospheric pressure (Fig. 2), a pyranometer for measuring the global radiation, and one for measuring the difuse radiation. The sensors of the setup have been integrated into a data acquisition system based on National Instruments PXI Platform, including a PXI-6259 data acquisition board optimized for high accuracy [2].

**Figure 2.** *Measurement system, location: Politehnica University*

The system sensors have an input/output range of 0÷2000 W/m$^2$ and 4÷20mA respectively, and a time constant of 28 seconds [2, 3].

The LabView software components process the measured values every 15 sec and store them in an SQL database. Figure 3 presents the architecture of the software.

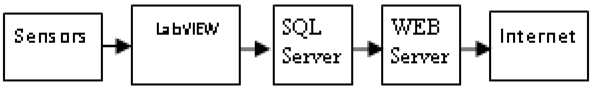


**Figure 3** *Software components of the measurement system*

The LabView software also provides the time values for every day, month, year, hour, minute and second and this is besides the instantaneous measured values.

Also, online data is provided by the project web page http://solar.physics.uvt.ro/srms which displays the instantaneous solar radiation values on the horizontal unit surface, or inclined in different directions, together with other climate parameters [8].

The „online data" that exists uses an SQL program that displays graphically the hourly average energy for the current and previous days. The SQL database uses a two-server configuration for data redundancy and fault-tolerance.

## MEASURED VARIABLES. STATISTICAL AVERAGES

### Irradiance in horizontal plan

Was measured hourly over several years and denoted by Ga , m, d, h where: a - number of the year, m - month, m∈(1,12), d - day of the month, d∈(1,31), h - measurement time zone (hour), h∈(1,14)[9,10].

In order to characterize the average days of the month, averages were calculated for each hour with the formula:

$$G_{m,h} = \frac{1}{D}\sum_{1}^{d=D} G_{a,m,d,h} \quad (1)$$

where D is the total number of measurements at h hour of the calendar month; D=31·a. Average irradiance for a given month was calculated with the formula

$$G_m = \frac{1}{H}\sum_{1}^{h=H} G_{m,h} \quad (2)$$

where H is the total number of measurements (hours ) of data related to the average day of the given month. Annual average irradiance was calculated using the formula

$$G_{year} = \frac{1}{M}\sum_{1}^{m=M} G_m \quad (3)$$

(W/m$^2$) where M is the number of months, M = 12 .

*Irradiation* for 1 hour of the average day of the month was calculated with the formula

$$H_{m,h} = 3600 \cdot G_{m,h} \quad (4)$$

(J/m2/h). Irradiation daytime for the average day of a month was calculated by formula 8:

$$H_{m,h} = 3600 \cdot \sum G_{m,h} \quad (5)$$

(J/m2/h). Irradiation for the average day of the year is calculated by formula 9 (J/m2/h):

$$H_{year(d)} = \frac{1}{M}\sum_{1}^{m=M} H_m \quad (6)$$

*Energy* ( solar potential ). The average solar potential per time unit which permeates through the horizontal surface with area of 1 m2, at the ground, within 1 year is given by the formula:

$$Q_{horizontal} = N \cdot H_{year(d)} \quad (7)$$

(J/m$^2$/h), where N is the number of days .

## EXPERIMENTAL DATA

### Global Irradiation of the solar flux. BFI measurements

For the 45 ° parallel the ratio between the average solar energy on the collection surface inclined under the optimum angle and the average solar energy in the horizontal plane is *r*= 1.17. For Timisoara the optimal angle of the plan solar collector is 50°. So the solar potential for optimum inclination angle is:

$$Qoptim = r \cdot Q \quad (8)$$

The average optical efficiency of the thermal collectors is:

$$\eta_{optic} = 0.75 \quad (9)$$

So the maximum amount of heat (solar thermal potential) that is produced in one year by the collecting area of 1m$^2$, tilted at the optimum angle is

$$Q_{thermal} = \eta_{optim} \cdot r \cdot Q_{optim} \quad (10)$$

On the results shown below it is visible that the highest values are in June, more than 800W/m$^2$ [1,6,7].

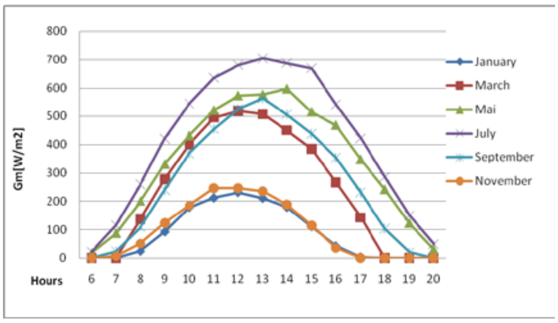


**Figure 3**. *Hourly distribution of solar radiation for average days for even months, year 2012*

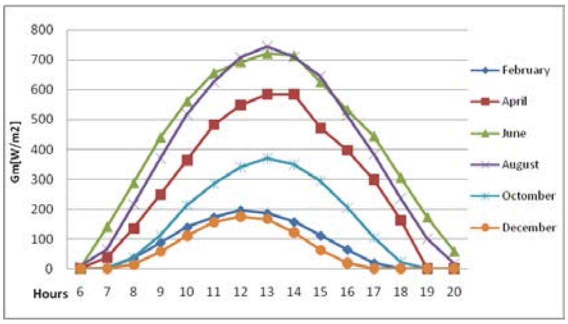


**Figure 4**. *Hourly distribution of solar radiation for average days for odd months, year 2012*

On tables below (table 1 and table 2) results are shown computing data registered from starting from year 2010, 2011 and 2012.

**Table 1.** *Global solar irradiation of the average day* $G_{m,h}$*(W/m²), BFI measurements*

| Month / Hour | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 0 | 0 | 0 | 0 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 39 | 118 | 142 | 145 | 94 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 105 | 114 | 265 | 343 | 358 | 267 | 159 | 62 | 0 | 0 |
| 9 | 73 | 106 | 190 | 330 | 480 | 590 | 475 | 416 | 312 | 183 | 97 | 0 |
| 10 | 102 | 169 | 286 | 374 | 580 | 704 | 681 | 612 | 414 | 276 | 163 | 94 |
| 11 | 154 | 247 | 336 | 508 | 610 | 745 | 771 | 691 | 487 | 334 | 231 | 137 |
| 12 | 188 | 291 | 384 | 512 | 615 | 807 | 801 | 704 | 538 | 364 | 261 | 158 |
| 13 | 190 | 282 | 380 | 470 | 605 | 810 | 778 | 701 | 543 | 367 | 252 | 146 |
| 14 | 174 | 210 | 345 | 412 | 590 | 720 | 693 | 646 | 476 | 315 | 182 | 107 |
| 15 | 104 | 165 | 293 | 352 | 512 | 629 | 602 | 538 | 413 | 273 | 116 | 82 |
| 16 | 36 | 84 | 214 | 280 | 384 | 431 | 504 | 426 | 279 | 127 | 44 | 0 |
| 17 | 0 | 0 | 126 | 237 | 317 | 417 | 395 | 298 | 158 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 142 | 176 | 264 | 189 | 68 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 92 | 0 | 0 | 0 | 0 | 0 | 0 |
| $G_m$ [W/m²] | 128 | 194 | 266 | 314 | 438 | 481 | 533 | 455 | 378 | 256 | 168 | 121 |
| $G_{year}$ [W/m²] | 311 | | | | | | | | | | | |
| $H_{m(d)}$ | 3.67 | 5.59 | 9.57 | 13.57 | 18.91 | 24.25 | 23.01 | 19.66 | 13.60 | 8.28 | 4.84 | 2.61 |
| $H_{year(d)}$ | 12.30 MJ/m² per day | | | | | | | | | | | |
| $Q_{horiz}$ | 4490 MJ/m² per year=1247 kWh/m² per year | | | | | | | | | | | |
| $Q_{optim}$ | 1456 | | | | | | | | | | | |
| $Q_{thermal}$ | 1094kWh/m² per year | | | | | | | | | | | |

## Global solar irradiance flux in WestUniversity determination [2,4,5]

At the West University of Timisoara, solar radiation is measured with Kipp&Zonen pyranometers belonging to the solar radiation monitoring station.

This monitoring station has DeltaOHM LP PYRA first class pyranometers.

The station was carried out under a grant from the Department of Physics in collaboration with the Department of Measurements and Optical Electronics MEO-UPT, funded by the Minister of Research [2,3,4].

**Table2**. *Global solar irradiance of the average day Gm,h(W/m²), West University measurements*

| Month / Hour | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 0 | 0 | 15 | 3 | 19 | 31 | 23 | 7 | 0 | 0 | 0 | 0 |
| 7 | 0 | 5 | 71 | 38 | 94 | 136 | 112 | 64 | 20 | 4 | 8 | 0 |
| 8 | 19 | 41 | 178 | 134 | 204 | 263 | 243 | 208 | 98 | 47 | 57 | 14 |
| 9 | 71 | 101 | 285 | 247 | 324 | 406 | 384 | 357 | 217 | 144 | 140 | 67 |
| 10 | 133 | 167 | 376 | 374 | 427 | 526 | 494 | 504 | 338 | 249 | 209 | 119 |
| 11 | 175 | 206 | 441 | 485 | 507 | 615 | 589 | 620 | 425 | 332 | 260 | 135 |
| 12 | 197 | 231 | 454 | 545 | 570 | 657 | 632 | 685 | 484 | 384 | 262 | 145 |
| 13 | 190 | 216 | 424 | 562 | 589 | 680 | 644 | 694 | 506 | 399 | 246 | 129 |
| 14 | 153 | 173 | 363 | 550 | 566 | 652 | 630 | 671 | 486 | 360 | 189 | 95 |
| 15 | 95 | 126 | 276 | 464 | 497 | 576 | 574 | 606 | 426 | 296 | 109 | 52 |
| 16 | 38 | 72 | 175 | 386 | 442 | 477 | 485 | 499 | 327 | 197 | 33 | 13 |
| 17 | 4 | 20 | 80 | 275 | 311 | 376 | 381 | 364 | 204 | 98 | 1 | 0 |
| 18 | 0 | 0 | 19 | 160 | 197 | 258 | 259 | 220 | 94 | 21 | 0 | 0 |
| 19 | 0 | 0 | 3 | 55 | 98 | 143 | 134 | 91 | 19 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 4 | 24 | 47 | 41 | 14 | 0 | 0 | 0 | 0 |
| $G_m$ [W/m²] | 87 | 113 | 236 | 286 | 343 | 390 | 375 | 374 | 254 | 195 | 127 | 66 |
| $G_{year}$ [W/m²] | 237 | | | | | | | | | | | |
| $H_{m(d)}$ | 3.87 | 4,89 | 11,38 | 15,42 | 17,53 | 21,03 | 20,25 | 20,17 | 13,12 | 9,11 | 5,45 | 2,77 |
| $H_{year(d)}$ | 12,08 MJ/m² per day | | | | | | | | | | | |
| $Q_{horiz}$ | 4410 MJ/m² per an = 1225 kWh/m² per year | | | | | | | | | | | |
| $Q_{optim}$ | 1433 | | | | | | | | | | | |
| $Q_{thermal}$ | 1074 kWh/m² per year | | | | | | | | | | | |

## COMPARATIVE ANALYSIS

Results for both laboratories for solar radiation-solar potential are shown in next table. In these table values of the solar potential, the averages, absolute and relative errors are shown.

**Table 4**. *Thermal solar potential*

| | $Q_{thermal,BFI}$ [kWh/m² /year] | $Q_{thermal,UVT}$ [kWh/m² /year] |
|---|---|---|
| | 1094 | 1074 |
| $Q_{thermal,}$ [kWh/m²/year] | 1084 | |
| $\Delta Q_{thermal,}$ [kWh/m²/year] | -10 | 10 |
| $\varepsilon$ (%) | 0.91 | 0.93 |

## CONCLUSIONS

We can conclude that these measurements made by the two laboratories are in very good agreement.In agreement with BFI determination, we conclude the following:

- In the summer months (June, July, August) global solar radiation flux density in the horizontal plane at noon varies between 615-810 W/m$^2$;
- In the months pass season - spring and autumn (March, April, May, September, October, November) global solar radiation flux density in the horizontal plane at noon varies between 261-384 W/m$^2$;
- In winter months (December, January, February), global solar radiation flux density in the horizontal plane at noon varies between 158-291 W/m$^2$;
- The amount of incident solar energy per year per unit on the horizontal surface is 1247 kWh/m$^2$/year;
- The amount of incident solar energy per year per unit surface with optimum tilt is 1456 kWh/m$^2$/year.

The average amount of BFI and UVT measurements on the surface of the heat produced annual by the optimum tilt unit is 1094 kWh/m$^2$ year.

## ACKNOWLEDGEMENTS

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## REFERENCES

[1] I. Luminosu, A. De Sabata, S. Ilie, “Comparative analysis of the solar potential in west region of Romania”, AIIR conference, 22nd edition, pp. 147-155 Timisoara (2013) (in Romanian).

[2] T. Jurca, E. Tulcan-Paulescu, C. Dughir, M. Lascu, P. Gavrilă, A. De Sabata, I. Luminosu, C. De Sabata, M. Paulescu, “Global solar irradiation modeling and measurements in Timisoara”, Proceeding of Physics Conference (Tim-10) Nov -2010, Timisoara, vol. 1837, published (2011).

[3] I. Luminosu, C. De Sabata, A. De Sabata, „Research in solar energy at Politehnica University of Timişoara: studies on solar radiation and solar collectors”, Int. Journal of Thermal Sciences, 14(1), pp. 157-169 (2010)

[4] Marius Paulescu, Ciprian Dughir, Eugenia Tulcan-Paulescu, Mihaela Lascu, Paul Gravila, Traian Jurca, "Solar Radiation Modeling and Measurements in Timisoara, Romania: Data and Model Quality", Environmental Engineering and Management Journal (EEMJ) Vol.9, No.8, pp.1089 (2010).

[5] M. Paulescu, A. Neculae, E. Tulcan-Paulescu, „Measurements and estimation of solar radiation. West Universiy Publishing (2008)(in Romanian)

[6] C. De Sabata, I. Luminosu, A. De Sabata, „Tradition and perspectives in solar energy at Politehnica University of Timisoara”,. Excelsior Art (2010)(in Romanian)

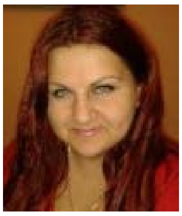
[7] I. Damian,I. Luminosu, M. Costache, M. Cristea, „Application of a simple model for the daily global solar irradiation”, Scientific Bulletin of Politehnica Timisoara, pp. 50-55, (2008)

[8] http://solar.physics.uvt.ro/srms

[9] O. P. Singh, s. K. Srivastava and a. Gaur. “Empirical relationship to estimate global radiation from hours of sunshine”. Energy Laboratory, Department of Applied Sciences, Institute of Engineering and Technology, Lucknow, 226 021, Uttar Pradesh, India.

[10] O. P. Singh, S. K. Srivastava and A. Gaur, “Empirical relationship to estimate global radiation from hours of sunshine”, Energy Convers. Mgrnt Vol. 37, No. 4, pp. 501-504, 1996.

## BIOGRAPHY



**Simona Ilie** was born in Timisoara, Romania, on March 11, 1987. She received a MSc degree in Engineering and Competitiviness Management from „Politehnica” University of Timisoara in 2011, a MSc degree in „Enterpreneurship and business creation” from ISCTE University from Lisbon, Portugal in 2011 and she is a PhD student since 2012 at „Politehnica” University of Timisoara. Her scientific work is related to photovoltaics, fresnel lens, optimal design of photovoltaic power plants and also molecular physics, radiation, electrical engineering, energetics.

# KARAKTERISTIKE SUNČEVOG ZRAČENJA U OKOLINI TEMIŠVARA

*Ioan Luminosu, Aldo De Sabata, Simona Ilie, Dejan Jovanović, Dejan Krstić*

**Rezime:** *U ovom radu je predstavljena studija solarnog potencijala u južno- zapadnom delu Rumunije koja se zasniva na merenju izvršenom i objavljenom od strane laboratorije za fiziku i inženjerstvo. Rezultati su dobijeni u stanici za monitoring sunčevog zračenja koja se nalazi na fakultetu fizike iz zapadnog univerziteta. Godišnji termalni potencijal na horizontalnoj površini je 1247 kWh/m$^2$/godini dok optimalni termalni potencijal na površini postavljenoj pod uglom iznosi 1456 kWh/m$^2$/godini. Količina toplote proizvedene u jednoj godini na površini od 1 m$^2$ pod optimalnim uglom je 1094 kWh/m² /godini.*

**Ključne reči:** zračenje, solarni potencijal, piranometar.