ACTA TECHNICA CORVINIENSIS
BULLETIN OF ENGINEERING

[1.] CRISTIAN P. CHIONCEL, [2.] DIETER KOHAKE, [3.] LADISLAU AUGUSTINOV,
[4.] PETRU CHIONCEL, [5.] GELU OVIDIU TIRIAN

YIELD FACTORS OF A PHOTOVOLTAIC PLANT

Abstract:

The paper gives the definition of the main yield factors that characterizes the performances of a photovoltaic plant. This are analyzed for a grid connected photovoltaic plant at the University in Resita, in use since spring 2008, were the main climatic and technique parameters of the photovoltaic plant are monitoriesed and heaped in an data base for further analysis.

Keywords:

yield factors, photovoltaic plant, photovoltaic system

INTRODUCTION

Accurate and consistent evaluations of photovoltaic (PV) system performance are critical for the continuing development of the PV industry. These performance parameters allow the detection of operational problems; facilitate the comparison of systems that differ with respect to design, technology or geographic locations.

SPECIFIC YIELD FOR SOLAR PHOTOVOLTAIC PLANTS

Parameters describing energy quantities for the PV system and its components have been established by the International Energy Agency (IEA) Photovoltaic power System Program and are described in the IEC standard [1]. The generally definition of yield factors of power plants, expressed in simplified terms, describes how many times energy generated during plant operation covers the energy used for constructing the plant. An exact definition would be: 'The yield factor is the ratio of net energy production during plant life and the cumulative energy used for construction, operation and operating supply items'. This concept is only meaningful in the context of using regenerative energy sources, as photovoltaic plants, insular ore grid connected.

Three of the IEC standard 61724 performance parameters [2] may be used to define the overall system performance with respect to the energy production, solar resource and overall effect of system losses. These parameters are the performance ratio, final PV system yield and reference yield.

The final PV system yield Y_f is the net energy output E_{PV} divided by the nameplate d.c power $P_{maxG,STC}$ (STC – Standard Test Condition 1000 W/m^2, 25^0C) of the installed PV array. It represents the number of hours that the PV array would need to operate at its rated power to provide the same energy. The units are hours or kWh/kW:

$$PR = \frac{AC - GridinjectedEnergy}{PVSystemEnergyInSTC} \tag{1}$$

The Y_f normalizes the energy produced with respect to the system size, being a convenient *way to compare the energy produced by PV systems of differing size.*

The specific plant losses are described through L_C - capture losses, losses that are caused by obfuscation, temperature grown, mismatching, limitation through dust, losses generated by energy conduction in the photovoltaic modules and L_S – system losses, caused by inverter, conduction and loses of passive circuit elements.

The reference yield Y_r is the total in-plane irradiance H divided by the PV's reference irradiance G. It represents the under ideal conditions obtainable energy. If G equals 1 kW/m², then Y_r is the number of peak sun hours or the solar radiation in units of kWh/m². The Y_r defines the solar radiation resource for the PV system. It is a function of the location, orientation of the PV array, and month-to month and year-to-year whether variability:

$$Y_A = \frac{E_{PV}}{P_{\max G,STC}} \quad (2)$$

To compare on different locations mounted grid connected PV systems, the performance ratio is a decisive value [2]. The performance ratio is the Yf divided by the Yr. By normalizing with respect to irradiance, it quantifies the overall effect of losses on the rated output due to: inverter inefficiency, wiring, mismatch and other losses when converting from d.c. to a.c power, PV module temperature, incomplete use of irradiance by reflection from the module front surface, soiling or snow, system down-time and component failures.

$$Y_f = \frac{E_{PV,AC}}{P_{\max G,STC}} \quad (3)$$

Performance ratio PR values are typically reported on a monthly or yearly basis. Values calculated for smaller intervals, such as weekly or daily, may be useful for identifying occurrences of component failures. Because of losses due the PV module temperature, PR values are greater in the winter than in the summer and normally fall within the range 0.6 to 0.8. If the PV module soiling is seasonal, it may also impact differences in PR from summer to winter. Decreasing yearly values may indicate a permanent loss in performance. Considering the increasing degree of effectiveness, the performance ratio PR factor can reach ideal annual values between 0.8 and 0.84.

The PR being a dimensionless quantity that indicates the overall effect of losses [5] on the rated output, does not represent the amount of produced energy, because a system with low PR in a high solar resource location might produce more energy than a system with a high PR in a low solar resource location. However, for any given system, location and time if a change in component or design increase the performance ratio PR, the final yield Yf increase accordingly. PR values are useful for determinations if the system is operating as expected. Large decrease in PR indicates events that significantly impact performance, such as inverters not operating or circuit-breaker trips. If the PR decrease moderate or small, it indicates that a less sever problem exists. The performance ratio PR can identify the existence of a problem, but not the cause. To identify the cause of the existing problem, a research at the site is needed.

GRID CONNECTED PHOTOVOLTAIC PLANT AT THE UNIVERSITY 'EFTIMIE MURGU' RESITA

The grid connected photovoltaic system [3] mounted at the 'summer theater' of the University `Eftimie Murgu` Resita, since middle of may 2008, is putted together from four high performance standard solar modules of type Multisol 150, manufactured by Scheuten Solar – Germany [6], with a total capacity of 600W/h. The system is completed with a Sunny Boy 1100 inverter and a completely online monitoring system of the PV, made from a Sunny Webbox and the Sunny Sensorbox. This monitoring system [4], build up like in figure 1, allows a detailed supervision of the PV plant, produced energy, measuring and saving values of solar radiation, ambient and module temperature, wind speed and direction.

The measured values and the current energy yield are visualized and archieved in the Internet, through the sunny web portal [7], figure 2.

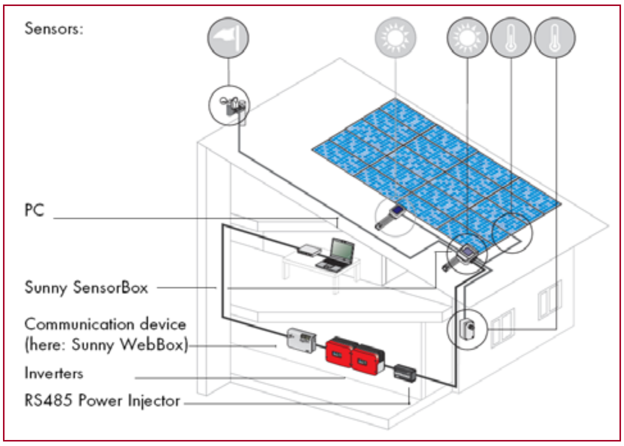

Figure 1 Complete scheme, photovoltaic and monitoring system

SPECIFIC YIELD FOR THE SOLAR PHOTOVOLTAIC GRID CONNECTED SYSTEM AT THE EFTIMIE MURGU UNIVERSITY

This paragraph allows us an overview of the specific yield factor Y_A for the grid connected photovoltaic system, for a time period of almost one year, from middle of May 2008 until the end of March 2009.

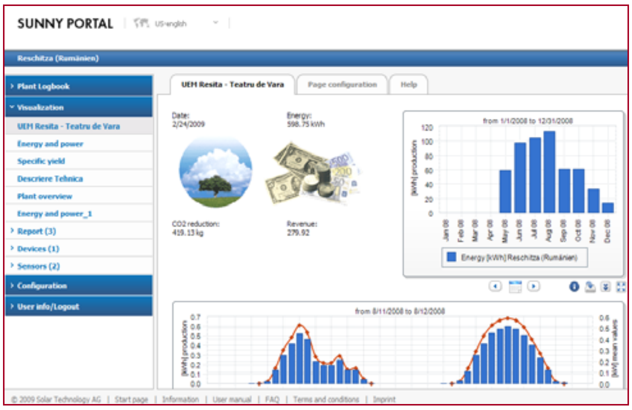

Figure 2 Sunny web portal on-line monitoring

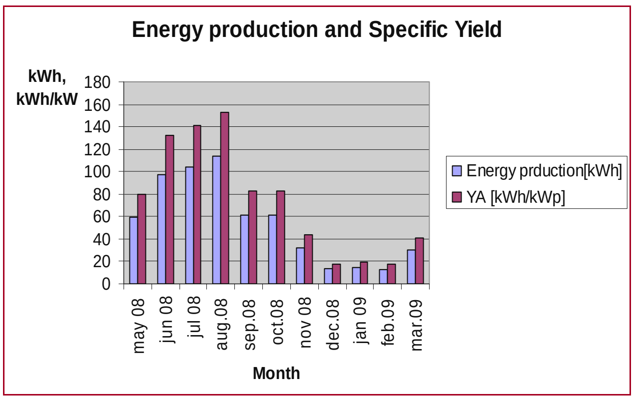

Figure 3. Energy production and array yield

Figure 3 represents the energy production and the specific yield factor for this period. A more detailed, daily, overview of the yield factor in the analyzed period is given in table 1.

Table 1 Daily Specific Yield Factor

	Specific Yield Factor - YA [kWh/kWp]										
	may 2008	jun. 2008	jul . 2008	aug. 2008	sept . 2008	oct . 2008	nov. 2008	dec. 2008	jan . 2009	febr. 2009	mart. 2009
1	0,00	4,72	5,78	6,49	5,65	4,64	1,57	2,30	0,12	2,32	0,00
2	0,00	5,15	5,99	5,80	4,54	1,59	1,61	1,84	0,00	1,69	0,03
3	0,00	6,11	5,76	5,69	5,39	3,80	2,68	0,27	0,22	0,85	1,31
4	0,00	5,22	4,96	5,61	5,18	2,43	2,28	0,51	0,24	1,15	3,62
5	0,00	3,65	3,92	5,81	5,24	0,12	1,12	1,68	0,24	0,97	1,05
6	0,00	2,12	6,08	6,28	5,68	2,51	1,70	0,16	0,77	3,26	4,73
7	0,00	1,78	5,80	5,78	4,82	2,89	2,35	0,12	2,16	2,66	0,30
8	0,00	2,16	4,51	5,76	2,97	2,54	1,24	0,38	0,01	1,89	0,39
9	0,00	2,45	4,95	2,46	5,73	2,09	1,66	0,49	0,64	0,09	3,11
10	0,00	1,96	3,22	4,81	5,28	2,88	2,95	1,74	1,11	1,93	1,61
11	0,00	5,34	5,99	4,73	3,82	3,89	2,69	0,85	0,38	0,32	2,53
12	0,00	4,46	5,81	6,08	3,86	4,27	2,53	0,19	1,07	0,00	0,97
13	0,00	3,88	5,65	5,86	0,82	3,59	2,36	0,54	0,76	0,00	0,72
14	0,00	2,96	4,61	5,28	1,07	2,09	1,28	1,73	0,65	0,00	3,95
15	1,58	2,32	1,15	5,85	0,15	3,50	2,30	1,24	0,22	0,00	6,35
16	5,59	5,27	3,53	4,95	0,69	3,59	2,36	0,88	0,08	0,00	0,50
17	4,68	5,70	5,11	5,28	0,57	0,12	0,20	0,89	1,70	0,00	0,80
18	5,39	3,41	4,97	6,14	0,35	4,23	1,27	0,05	2,57	0,00	0,24
19	4,70	3,41	5,93	6,23	1,07	3,64	0,39	0,12	2,03	0,00	3,11
20	5,24	5,36	6,12	5,97	0,55	3,89	2,24	0,08	2,32	0,00	4,77
21	3,72	5,89	5,08	5,57	0,69	3,62	0,09	0,11	0,45	0,00	1,85
22	0,76	6,00	0,51	4,45	1,64	3,61	0,38	0,49	0,80	0,00	5,15
23	4,85	1,89	1,23	4,26	3,14	3,43	0,14	0,15	0,46	0,00	0,00
24	6,62	5,58	2,19	1,89	2,51	0,18	0,95	1,70	0,22	0,00	0,00
25	4,74	5,84	1,11	4,53	0,64	0,30	0,16	0,01	0,31	0,00	0,00
26	5,05	5,70	2,70	6,18	0,80	0,64	0,04	0,08	0,20	0,00	0,00
27	5,85	5,20	6,09	3,89	0,58	3,39	0,77	0,04	0,95	0,00	0,00
28	5,73	1,76	5,11	3,59	1,73	3,20	1,88	0,05	0,08	0,00	0,00
29	6,08	5,95	5,70	1,26	2,66	1,76	1,18	0,00	0,09	0,00	0,00
30	5,59	6,03	6,14	3,97	4,89	1,15	2,57	0,01	0,18	0,00	0,00
31	5,32	0,00	6,14	5,23	0,00	3,15	0,00	0,01	0,55	0,00	0,00

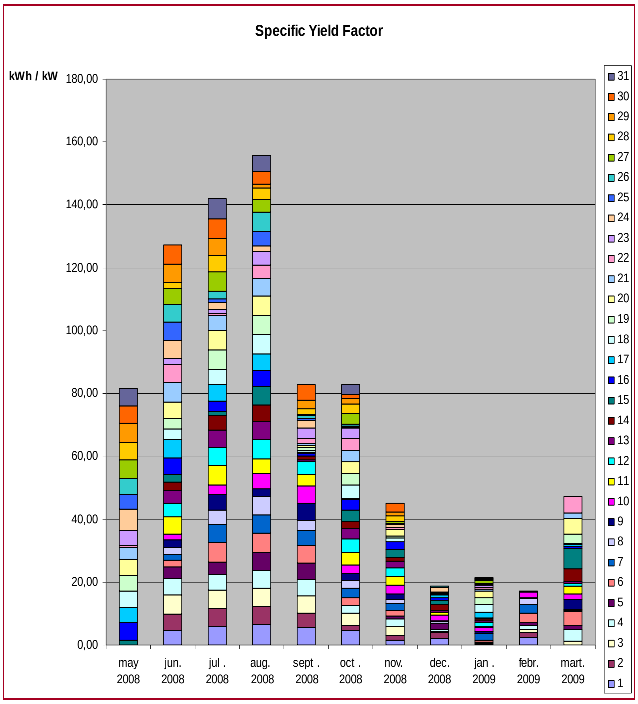

Figure 4 Daily yield factor, May 2008 – March 2009

CONCLUSIONS

Analyzing the specific yield factor, the photovoltaic plant owner can have a permanent look of the time, in hours expressed, that the system works in STC and obtains indicate or a higher energy *production. As shown, during summer the yield factor has a much higher density in June, July and August and the lowest in December, January and February.*

REFERENCES

[1] IEC, `Photovoltaic System Performance Monitoring – Guidlines for measurement, Data Exchange and Analysis, IEC Standard 61724`, Geneva, Switzerland, 1998

[2] Energy yield factors for the generation of electrical energy, www.sealnet.org

[3] CRISTIAN P. CHIONCEL, PETRU CHIONCEL, BERINDE FLORIN, GILBERT-RAINER GILLICH Monitoring system for photovoltaic power plant, Analele Universităţii "Eftimie Murgu" Reşiţa, Fascicola de Inginerie, ISSN 1453-7394, 2006

[4] CRISTIAN P. CHIONCEL, DIETER KOHAKE, PETRU CHIONCEL, NICOLETA GILLICH Solar photovoltaic monitoring system implemented on the location Resita, Analele Universităţii "Eftimie Murgu" Reşiţa, Fascicola de Inginerie, ISSN 1453 – 7394, 2008

[5] www.iea-pvps-task2.org Performance of Photovoltaic-Anlagen: Resultate einer internationalen Zusammenarbeit im IEA-PVPS Task 2

[6] www.scheutensolar.com

[7] www.sunnyportal.com

AUTHORS & AFFILIATION

[1.] CRISTIAN P. CHIONCEL,
[2.] DIETER KOHAKE,
[3.] LADISLAU AUGUSTINOV,
[4.] PETRU CHIONCEL,
[5.] GELU OVIDIU TIRIAN

[1,3,4] "EFTIMIE MURGU" UNIVERSITY, RESITA, ROMANIA
[2] FH GELSENKIRCHEN, GERMANY,
[5] "POLITECHNICA" UNIVERSITY OF TIMISOARA, FACULTY OF ENGINEERING HUNEDOARA, ROMANIA