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431 - "Solar XXI" building PV systems: performance during the first two years of operation

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Abstract

The purpose of this paper is to present the results obtained in the first two years of operation of the grid-connected photovoltaic (PV) systems installed in the named "Solar XXI" building. One PV system, made with multicrystalline silicon modules, has a peak power of 12 kW and was installed on the façade; another system made with amorphous silicon modules has a peak power of 6 kW and was installed in the surrounding park area near the building.

From 1st February 2006 until 31 July 2008, the measured daily average, of the building electrical energy consumption, was about 75 kWh and the two PV systems produced in average about 72 % of this energy. The averaged measured Performance Ratio of the systems was about 0.84 for the PV Façade and about 0.76 for the PV in the Park.

Keywords: BIPV, Grid Connected PV systems, PV micro-generation

1. Introduction

The Portuguese commitment for electricity production from renewables, in the framework of the EU Directive 2001/77/EC, was that 39 % of all the electricity consumed in Portugal in 2010 should come from renewable energy sources. However in 2007 the Portuguese government decided a new objective of 45 % of renewable electricity in 2010.

Until the end of 2007, Portugal had an estimated installed PV capacity of about 17.4 MW, resulting from the start up of the new power plant at Serpa, with 11 MW, and of other plants of the order of 1 or 2 MW, witch gave rise to a jump in the installed PV capacity in the last year.

It is expected that in the next few years new jumps will appear due to power plants already announced mainly the one related to the big power plant of Moura with a final installed capacity of 46.41 MWp, which already started, and also the ones to be installed at several places in the South of Portugal and a 6 MWp power plant at the distribution market MARL near by Lisbon.

Recent legislation in Portugal related to energy production from renewable energy sources, namely Decree Laws 225/2007 and 363/2007, have provided the framework for the development of Building Integrated Photovoltaics (BIPV) in the electricity domestic market with a feed in tariff dependent of the integration of solar thermal solutions.

The PV market in Portugal is still dominated by the objective, which was stated for 2010, of 150 MW for PV conventional centrals plus 50 MW for BIPV (DL 225/2007). This market is almost completely filled and no new licences are being attributed for centrals or BIPV, putting a cap to the market growth.

The new law for micro-production (DL 363/2007) which started to be implemented this April, is supposed to contribute with about 10 MW of new PV capacity installed each year and until now it is well accepted by the consumers of electricity, stimulating the domestic production of electricity.

In this context the new "Solar XXI" building pretend to be, an example of low energy consumption for new buildings and simultaneously it is, an experimental facility of INETI´s Renewable Energy Department.

Fig. 1. The Solar XXI Building and the PV systems installed, in the façade and in the car park area.

The building and the surrounding car park, integrate two Photovoltaic grid connected systems: a 12 kWp system installed on the south vertical façade of the building with a heat recovering system in the back of the photovoltaic modules used to heat the offices of the south side of the building, and a 6 kWp system installed in the car park area as a shading device. The PV systems are part of a demonstration project, supported by the Portuguese PRIME Program. The building is an energy efficient building optimizing geographic orientation and natural lighting with integration of both passive and active solar thermal solutions, see also Gonçalves et al [2].

The purpose of this paper is to present the results obtained in the first two years of operation of the installed PV systems in terms of performance yields and contribution, of the energy produced, to the electrical energy needs of the building. We will present the results obtained for the two PV technologies used, amorphous silicon in the park and multicrystalline silicon on the façade, and the observed seasonal variations in performance, due mainly to temperature effects.

2. The Solar XXI PV systems

2.1 PV Façade

The PV façade has 76 multicrystalline silicon modules BP3160, with a total peak power of 12,16 kW and an area of 95,6 m^2.

The direct current (d.c.) produced by the PV generator will be converted to alternate current (a.c.) with three inverters Fronius IG 40. Each inverter have a nominal power of 3,5 kW, a maximum efficiency of 94,5 % and an European efficiency of 93,5 %.

Table 1. Façade - PV Modules configuration

Inverter	Modules / string	Nr. of strings	Peak power (W)
1- Fronius IG 40	7	4	4 480
2- Fronius IG 40	8	3	3 840
3- Fronius IG 40	8	3	3 840
Total			**12 160**

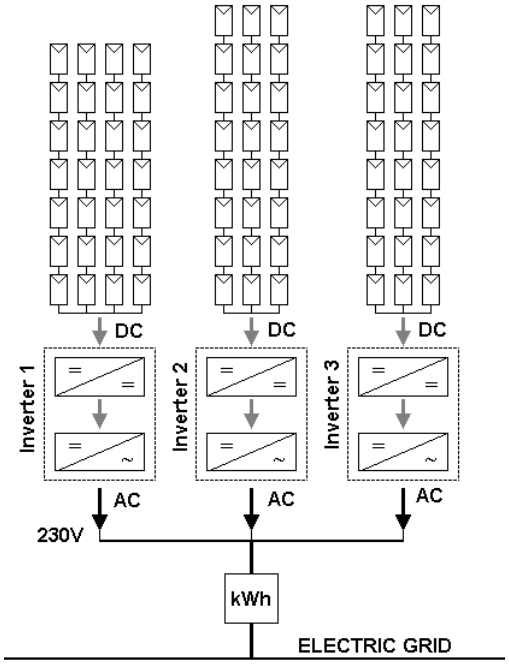

Fig. 2. PV Façade system configuration.

2.2 PV in the Park

The PV installed in the car park area, as shadow device, has 100 amorphous silicon modules Kaneka GEA60, installed with a 15º tilt, a total peak power of 6.0 kW and an area of 95,0 m^2.

The d.c. produced by the PV generator will be converted to a.c. with two inverters SolarStocc PS4000HV, with a nominal power of 3,3 kW. These inverters have a maximum efficiency of 94,4 % and an European efficiency of 93,1 %.

Table 2. Park - PV Modules configuration

Inverter	Modules / string	Nr. of strings	Peak power (W)
1- SolarStocc PS4000HV	5	10	3 000
2- SolarStocc PS4000HV	5	10	3 000
Total			**6 000**

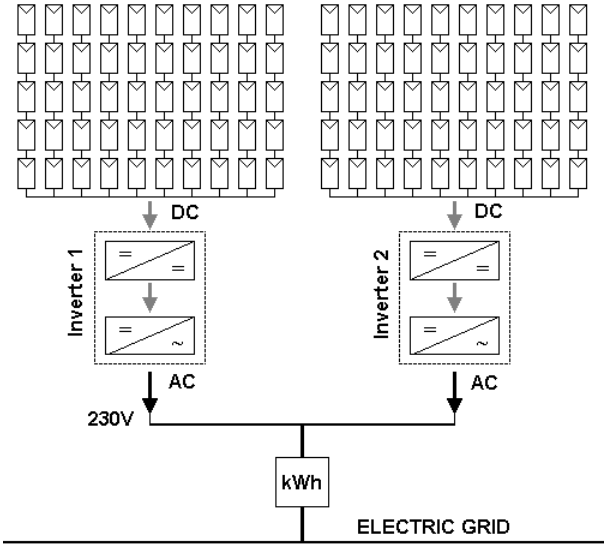

Fig. 3. PV Park system configuration.

3. Monitoring results

3.1 PV façade system results

The systems have been monitored since their installation at June 2005, for the façade, and December 2005, for the park.

Fig. 4 presents the values of the monthly averages of the daily energy produced in the façade, per installed peak power. In general, this system produces more energy in winter periods with a maximum average daily production of 47.3 kWh at November 2007. The production minimum occurred at June 2005 with a daily average production of 20.2 kWh.

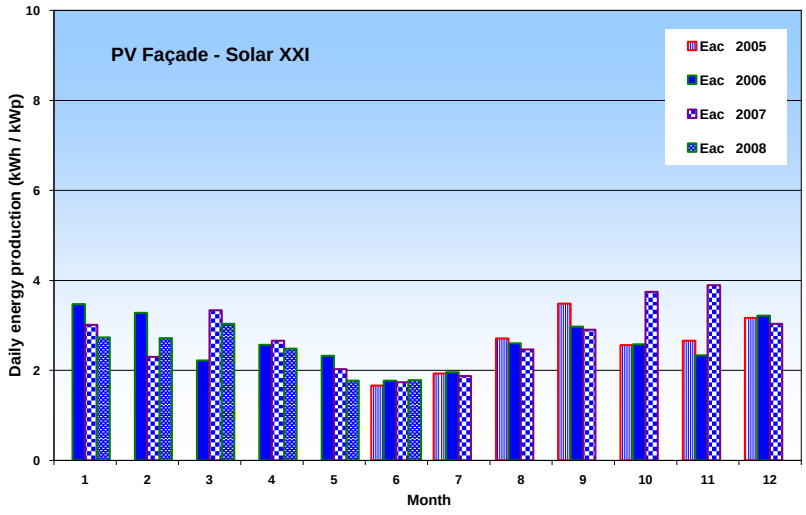

Fig. 4. PV façade - Monthly average of the daily energy produced, per installed peak power.

At Table 3 we present the yearly irradiation and yearly energy produced by PV Façade system. The average yearly irradiation measured in the vertical façade, is about 1 155 kW/m^2 and the energy production is about 977 kWh per kW of peak power installed.

Table 3. Yearly energy produced by PV Façade system, per installed peak power.

Year	Power (kW)	Irradiation (kWh/m^2)	Production (kWh/kW)
2006	12.16	1 118	950
2007	12.16	1 193	1 004

3.2 PV Park system results

Fig. 5 presents the values of the monthly averages of the daily energy produced in the park, per installed peak power. This system produces more energy in summer periods with a maximum average daily production of 34.8 kWh at July 2006 and July 2007. The production minimum occurred at December 2007 with a daily average production of 11.1 kWh.

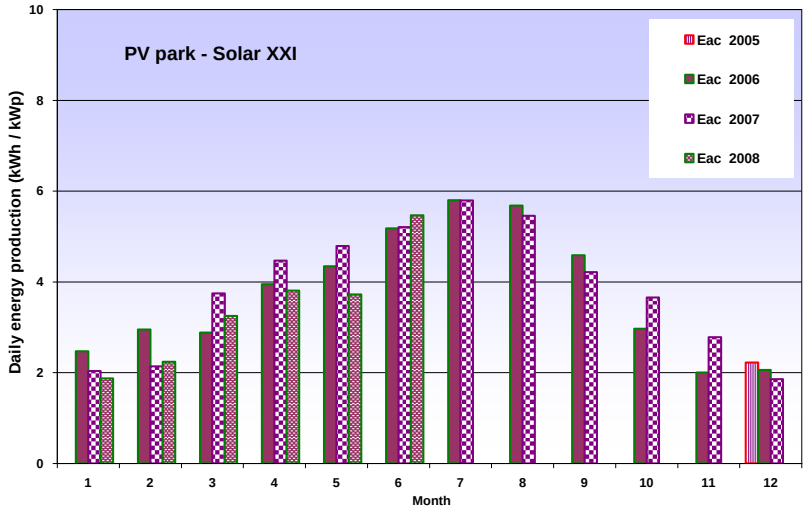

Fig. 5. PV park system - Monthly average of the daily energy produced, per installed peak power.

At Table 4 we present the yearly irradiation and energy produced by PV Park system. The yearly irradiation measured, in the 15º tilted surface, is about 1 790 kW/m^2 each year and the energy production is about 1 400 kWh per kW of peak power installed. The low production in 2006 year, despite the bigger irradiation, is due to an inverter failure during two weeks in the month of May.

Table 4. Yearly energy produced by PV park system, per installed peak power

Year	Power (kW)	Irradiation (kWh/m^2)	Production (kWh/kW)
2006	6.00	1 799	1 366
2007	6.00	1 781	1 407

This results show that the energy production by installed peak power of the façade system is about 28.6 % lower than for the park system, this is due mainly to the lower incident irradiation on the façade surface.

3.3 Global PV systems results

The energy production of both systems in 2006 is presented in Fig. 6, and for 2007 is presented in Fig. 7. For the year of 2006, the maximum daily average energy produced took place in August, 64.5 kWh, and the minimum occurred in November, 39.33 kWh. In 2007, the maximum was 65.7 kWh in October and the minimum was in 39.7 kWh in February.

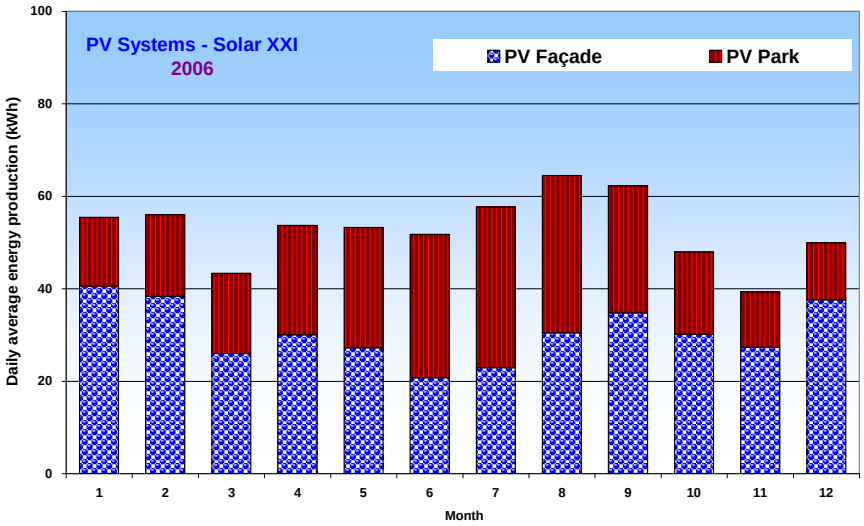

Fig. 6. Solar XXI – 2006 - Monthly average of the daily PV energy produced.

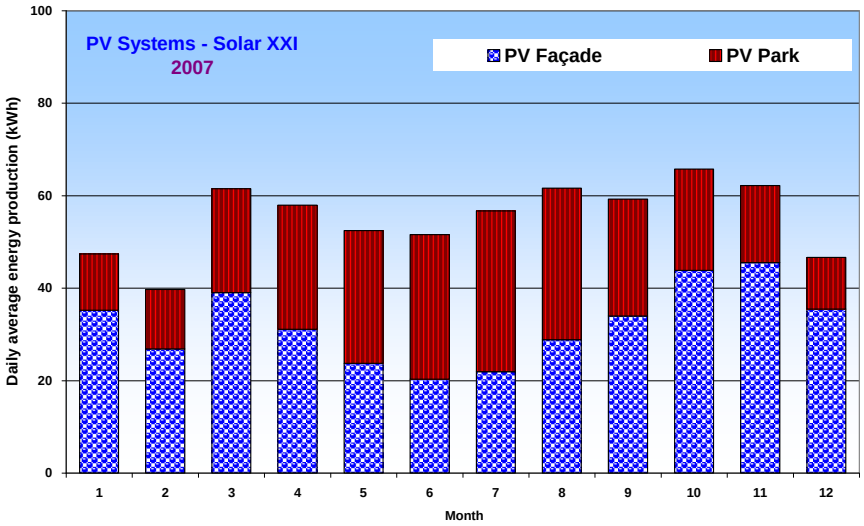

Fig. 7. Solar XXI – 2007 - Monthly average of the daily PV energy produced.

The yearly total energy produced by the PV systems, is depicted in Table 5 and Table 6, varying from 19.4 MWh in 2006 to 20.2 MWh in 2007.

Table 5. Yearly energy produced by Solar XXI PV systems, 2006

2006 Central PV	Potência (kW)	Área (m^2)	$E_{CA\ PRec}$ (kWh)
Fachada	12.16	95.6	11 118
Parque	6.00	95.0	8 197
Total PV	18.16	190.6	19 315

Table 6. Yearly energy produced on Solar XXI PV systems, 2007

2007 Central PV	Potência (kW)	Área (m^2)	$E_{CA\ PRec}$ (kWh)
Fachada	12.16	95.6	11 745
Parque	6.00	95.0	8 442
Total PV	18.16	190.6	20 187

3.4 Performance Ratio results

The performance results show that amorphous silicon modules installed in the park have an average performance ratio of 0.76 and the multicrystalline modules installed in the façade have a value of 0.84, due mainly to lower average irradiance values leading also to lower average working temperatures.

Table 7. Yearly performance ratio averages in the PV Façade and PV Park systems.

Year	PR PV Façade	PR PV Park
2006	0.844	0.745
2007	0.832	0.771

4. Energy produced by the PV systems versus energy consumed

From 1st February 2006 until 31 July 2008, the daily average electrical energy delivered to the grid by the PV systems was 53.7 kWh, corresponding to 23.6 kWh produced in the park and to 30.0 kWh produced in the façade, Table 8.

The average daily consumption of the Solar XXI building was of 74.6 kWh and the contribution of both PV systems to satisfy this consumption was about 72 %.

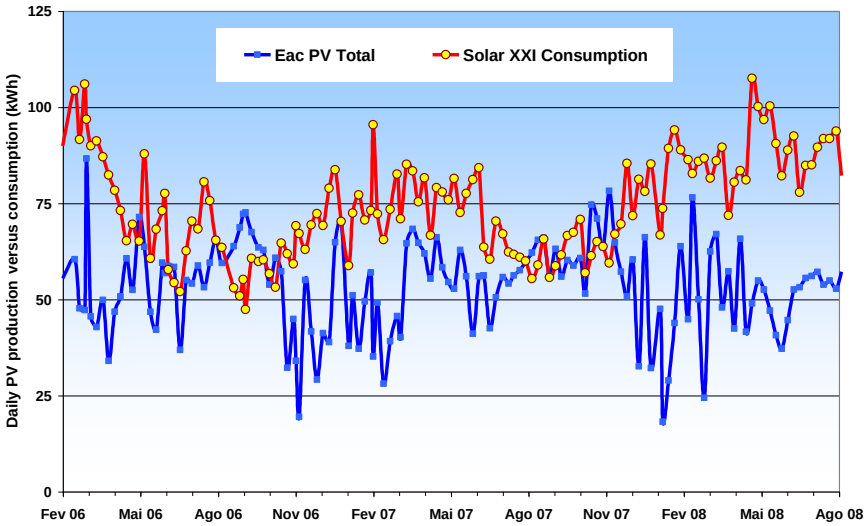

Fig. 8. Measured electrical energy produced by the PV systems and consumed in the Solar XXI building.

Table 8. Daily averages values of the energy produced by PV systems and consumed in the building.

Eac PV Park	Eac PV Façade	Eac PV Total	Solar XXI Consumption	PV / Consumption
kWh	kWh	kWh	kWh	%
23.6	30.0	53.7	74.6	72.0

5. Conclusion

The monitoring data of the two PV systems installed at Solar XXI building, shows very good performances. The daily average electrical energy delivered to the grid by the PV systems was 53.7 kWh, corresponding to 23.6 kWh produced by the amorphous silicon modules installed in the park and to 30.0 kWh produced by the multicrystalline modules in the façade.

The measured average daily consumption of the Solar XXI building was of 74.6 kWh and the contribution of both PV systems to satisfy this consumption was about 72 %.

References

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