COMPARISON OF C-SI, A-SI AND CDTE TECHNOLOGIES WORKING AT THE SAME CONDITIONS, AFTER THE FIRST YEAR OF ELECTRICITY PRODUCTION

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ABSTRACT: Grid connected solar plants are a good opportunity for their use for research as a secondary objective. In countries were feed-in tariffs are still active, it is possible to include in the design of the solar plant elements for its use for research. In the case of the solar plant presented here both objectives are covered. The solar plant of this work is formed by PV modules of three different technologies: Multicrystalline, amorphous and CdTe. In one part of the solar plant, the three technologies are working at the same conditions, not only ambient conditions but also similar voltage and current input to the inverters. Both the commercial and the experimental parts of the solar plant have their own independent inverters with their meters but are finally connected to the same meter to inject. In this work we analyse the results for the first year of operation of the experimental solar plant. Productions of three different technologies in exactly the same conditions are compared and presented. According to the results, all the three technologies have conversion efficiencies dropping when the temperature increases. Amorphous module experiences the lesser reduction, whereas the multicrystalline module suffers the most.
Keywords: Photovoltaic modules; grid-connected; module efficiency; temperature coefficient

1 INTRODUCTION

The decline in the price of the PV modules and the increase in the price of the electricity will provide a new scenario where the feed-in tariff will not be necessary for the recovery of the initial investment. The most suitable technology to be used will depend on the ambient conditions, the surface area availability and the possibilities of orientation.

A small grid connected solar plant has been into operation in one of the roofs of the EUIT Agrícola of the UPM since December of 2012 with the following coordinates: 40.4426 °N, 3.7295 °W. It serves not only to produce electrical energy, but also aids to research and educational objectives [1].

In this present paper, the whole year performance in 2013 of three different, commercially available PV modules in the same outdoor conditions, not only ambient conditions but also similar voltage and current injected into the inverters, has been studied and compared.

2 MATERIALS AND METHODS

2.1 Three technologies set-up

The whole plant is divided into a commercial and an experimental field. The commercial one consists of 45 mc-Si modules from manufacturer A with 280Wp and 18 mc-Si modules from manufacturer B with 235Wp. In total, it can supply 16830Wp and it is connected to an inverter with 4MPPT, model Sunny Tripower 15000TL-10.The experimental field contains 3 different types. The STP230-20/Wd module from manufacturer A is based on multicrystalline silicon technology, whereas the 0101282 module from manufacturer C and the FS-382 module from manufacturer D are based on amorphous silicon and CdS/CdTe thin-film technology, respectively. Table 1 presents the most important data of the modules as given in the data sheets from the manufacturers [2]. In addition, those datasheets are obtained at standard test condition (STC) ($1000W/m^2$, 25^oC and 1.5Am) established by the IEC 60904-1[3].

Figure 1: Roof of the building where the solar plant is located.

2.2 Data acquisition

The data measurements were realized by a monitoring system integrated in the inverters and connected to a server provided by the SMA manufacturer. Apart from the four inverters, a sensor unit is connected to internet throughout a server that sends data to a wed portal. The electrical parameters of every MPPT [4-5] and the ambient parameters are recorded and can be easily accessed using remote tools. Table II summarizes the features of the instruments.

Table I: PV module performance data as given by the manufacturers, and measured.

	mc-Si	a-Si	CdTe
Pmax	230Wp	105Wp	82.5Wp
Vmp	29.8V	30.5V	48.3V
Imp	7.72A	3.44A	1.71A
Voc	36.8V	41.1V	60.8V
Isc	8.25A	4.05A	1.94A
FF	75.8%	63.0%	70.0%
Efficiency	13.9%	6.9%	11.5%
Array configuration	7sx1p	8sx2p	5sx4p
Area	9.9m2	23.2m2	14.4m2
Power	1610Wp	1680W	1650Wp

Table II: Features of the systems used for data logging

	A	B
Pdc max	15260W	1320W
Vdc max	1000V	400V
Idc max	36A	12.6A
Pac max	15000W	1200W
η_{max}	95.8%	92.1%

*A stands for the inverter Sunny Tripower 15000TL

*B stands for the three inverters Sunny boy 1200

3 RESULTS AND DISCUSION

This assessment is based on measurements recorded in the period from 1-January-2013 to 31-December-2013, shortly after the system was set in operation. For the year 2013, data were collected for everyday of the year, at 15min intervals. After selected, therewere a total of more than 40,000 recordings of three different technologies in the period.

Figure 2 shows the power output per square meter of the three different PV modules versus the measured global irradiance. Irradiance lower than 100W/m^2 is not taken into account due to the sensitivity of the irradiance sensor.

The multicrystalline silicon module has the highest power output per square meter over the whole irradiance range, and the amorphous module yields the lowest power output of the three modules. Each of the quantities power output per square meter of the three PV modules were estimated as linear function of the global irradiance when the irradiance is lower than 900W/m^2. When the irradiance is higher than 900W/m^2, there will be a cutoff in the power output of all the three PV modules because of the saturation of the single-phase inverters and the temperature. This phenomenon is more significant in amorphous module due to its higher total power output that makes it easy to reach the saturation of the inverters.

In figure 3, it can be observed that the efficiency of the multicrystalline module is highest, but there is a clear decline when the global irradiance is above 850W/m^2; the efficiency of the CdTe module is moderate and the decline is not as remarkable as multicrystalline module; amorphous module yields the lowest efficiency and has much the same decline as multicrystalline module, but it also has some advantages in price. In addition, during the clear summer days, the amorphous module achieves better results than c-Si module, due to a combination of spectral effect and thermal annealing and low temperature coefficient.

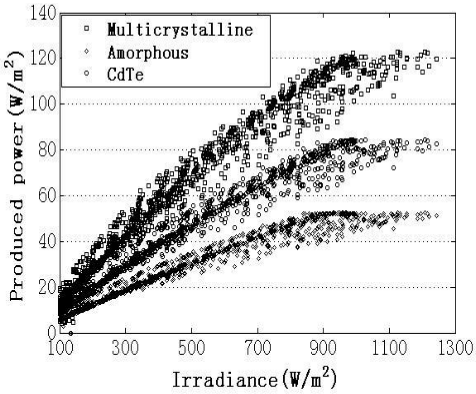

Figure 2: Produced power per square meter versus global irradiance for the multicrystalline, amorphous and Cdte PV modules, 2013.

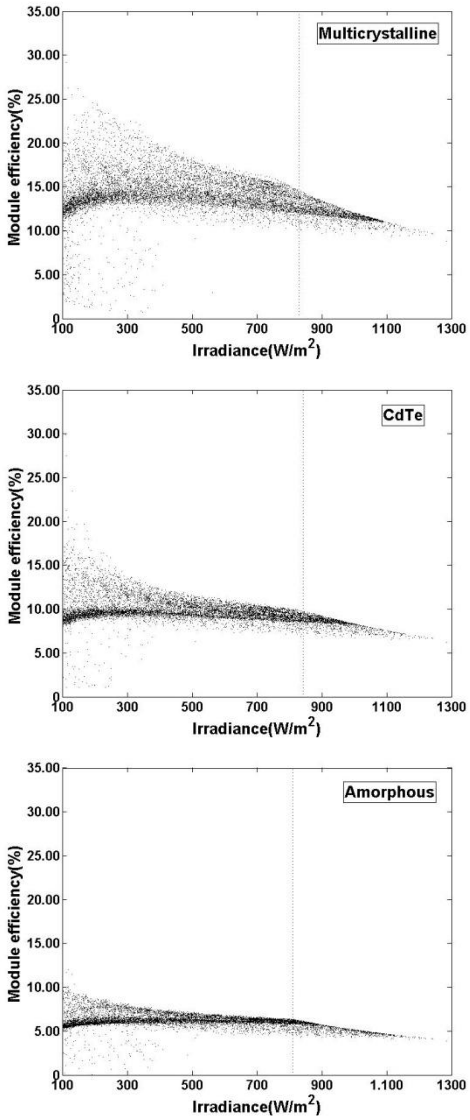

Figure 3: Module efficiency versus measured global irradiance, 2013.

Figure 4 Shows module efficiency versus ambient temperature for all modules with the first-order fitting, the recordings corresponding to global irradiance between 850W/m^2 and 900W/m^2 were chosen.

The gradients of the three fits represent the linear temperature coefficients. The temperature coefficients of multicrystalline module and CdTe module are both negative, the former's is less than the latter's. It means that with rising temperature, the efficiency of the multi-crystalline module suffers a faster decline than the CdTe module.

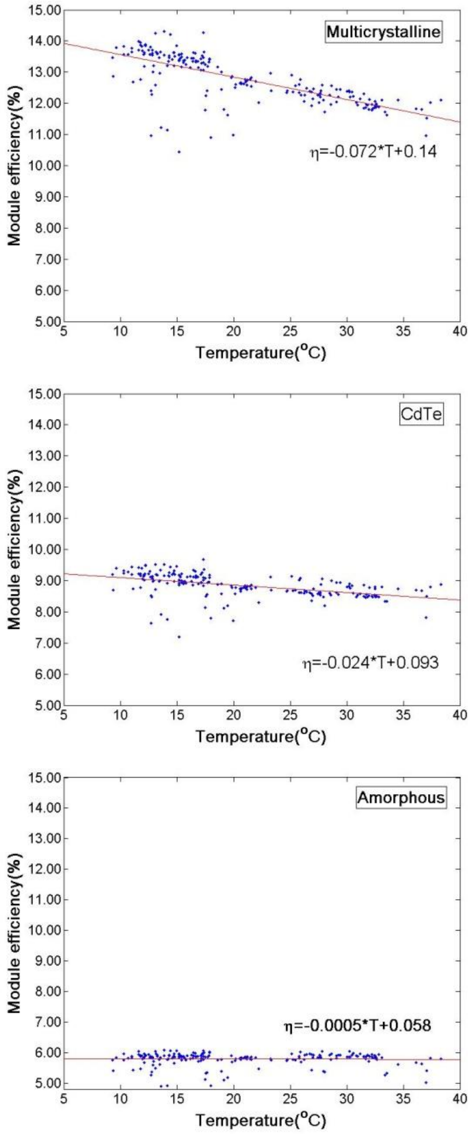

Figure 3: Module efficiency versus ambient temperature for all modules with the first-order fitting, 2013. Only measurements corresponding to global irradiance between 850W/m^2 and 900W/m^2.

The temperature coefficient of amorphous module is almost equal to 0. It does not mean this module does not suffer a decline in efficiency when the irradiance is increasing, but this decline is not as high as in multicrystalline module. One reason for this phenomenon is the small difference in global irradiance affecting the efficiency. Because the temperature coefficients of all PV modules must be negative; among those three PV modules, multicrystalline module is the most one and amorphous module is the last one [6]. In addition, the micromorphous silicon module (a-Si/μc-Si), when subject to high temperatures, is able to recover some of efficiency initially lost due to Light Induced Degradation, achieving during the warmer months a performance higher than the other technologies tested [7].

4 CONCLUSION

A solar PV plant has been installed on the roof of one building of UPM since the end of 2012. In the present work we have compared the conversion efficiencies of three PV different technologies in 2013. According to the results, the two main factors restricting the conversion efficiency are the temperature and the saturation of the inverters.

A-Si technology shows the lesser conversion efficiency, but the least significant decrease with temperature, followed by CdTe. Conversely, c-Si technology offers the highest conversion efficiency but suffers a higher decrease with temperature.

Additionally, the saturation of the inverters limits the total outputs of the three types of modules. Such limit is mandatory in the Spanish regulation frame.

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