QUALITY CONTROL DURING THE SUPPLY OF PV MODULES: FUNDAMENTAL KEY TO GUARANTEE THE PROFITABILITY OF PV INSTALLATIONS

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ABSTRACT: The aim of this paper is stating the reasons why it is necessary to carry out a quality control during the PV modules supply in the development of a PV installation to obtain its maximum energy production. Moreover, this work marks the guidelines to follow and the basic quality control to carry out and make sure that the installed PV modules have the quality level to guarantee the profitability of the installation during its operative life. Finally, commonly detected defects during tests carried out in the Enertis Laboratory for PV characterization are showed.
Keywords: PV Modules, Quality Control, Testing and Characterisation.

1 INTRODUCTION

The world photovoltaic market has experienced a high increase in the last years due to, among others, political commitment adopted by several goverments and reflected in the long term promotional tariffs in many countries, in special Germany, Spain and USA.

At the end of 2006, data indicated that the total installed capacity of photovoltaic energy worldwide exceeded 6500 MWp in comparison with 1400 MWp at the end of 2001 [1], so the annual increase rate of PV installations is higher than 35% since 1998. At the end of 2007, the total PV power installed exceeded 9100 MWp as Fig. 1 shows [2].

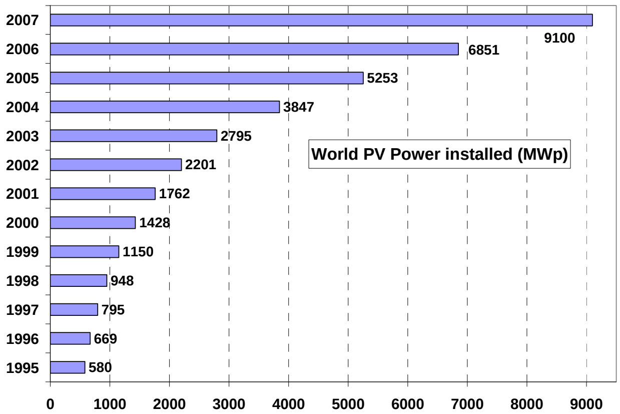

Figure 1: PV Power installed evolution in the past 13 years.

A clear example of this situation is the photovoltaic market in Spain, where the installed power reached 643 MWp at end of 2007, so 450% higher than 2006, and 1000 MWp are forecasted for 2008. Besides, the industrial investment in photovoltaic sector during 2007 exceed 536 million euro, 500% higher than 2006. So then, the spanish productive capacity has reached 350 MW in 2007, 18% out of net world capacity [3].

Due to this situation of world PV market, the bussiness of PV components is experiencing a continuous process of growth. A great many different manufacturers and products are appearing in the market and causing confusion due to unclear specifications, different prices and doubtful qualities. This circunstance is reflected in a reduction of the market share of the main 10 companies of PV industry in the last years, with a decrease from 85% in 2004 to 75% in 2007. This effect is highly remarkable in the PV modules market and it is necessary to carry out appropriate quality controls that include an inspection of the manufacturing processes and inspections at the modules reception according to IEC-61215:2005.

In the same way, the shortage of silicon and the “boom” of PV market have produced a decrease of the silicon quality due to the appearance of many new manufacturers of silicon ingots and wafers. Many of these companies, coming from other industrial sectors, do not keep up with the necessary quality levels of the polysilicon and their manufacturing processes [4].

2 QUALITY CONTROL IMPORTANCE IN PHOTOVOLTAIC MODULES

The module is the most important component of the PV system due to two main reasons. The first reason is technologic because it is the component which converts the incident irradiance into electric power; and the second one is economic because the cost of modules is commonly upon 50% of the total cost of PV installations. These two reasons, among others, make necessary to conduct a suitable quality control of modules during the supply.

2.1 Necessity of quality control

The photovoltaic modules have a very long life so it is essential to check that they will work correctly for at least the period guaranteed by the manufacturer. Focusing only on the origin of module’s manufacturer and its certificates as quality control is not enough. This behavior is not correct because certifications are obtained for a concrete model of module with certain components and a specific design. It would occur, for instance, that the production of monocrystalline modules from a manufacturer obtained the IEC-61215:2005 certification but the production of polycrystalline did not, so this certification should not qualify the polycrystalline ones. Also, the market conditions of components may produce the manufacturer’s punctual change of design or the inclusion of different components from the original ones that passed the certification.

The origin of module’s manufacturer is not an important aspect because, some European companies have not enough capacity and they need to buy OEM brand modules or laminated modules in China.

Another important aspect is the fact that there are different production lines into a factory, each one differently technologically equipped which need optimized parameters. A wrong setup in a certain part of the line can obtain output modules without enough quality. Therefore, a company can produce modules with different qualities in a certain period of time.

2.2 Avoiding the use of manufacturer guarantees

The module manufacturer guarantee covers its electrical production for at least 25 years, in most of the cases. If a batch of modules does not fulfil this requirement, the production of the PV plant will experience a dramatic drop, depending on the moment of the failure. Moreover, the guarantee only covers the module but it does not usually cover the dismounting of defective modules, the shipping cost of new modules from the manufacturer and the replacing of these new modules in the PV plant. In addition to theses costs, the profit reductions due to the drop of electrical generation will increase the economic losses. To avoid these future problems, the quality control of a PV installation can not be just limited to a punctual check of its production or during a short period of time, but it is necessary to implement an integral quality control of the modules during manufacturing process. This way the acquisition of modules with probable future degradation failures will be minimized.

2.3 Inclusion of quality controls in the supply contract

If a low electric performance or a specification breach are detected in the modules, it's very useful if you have included in the supply contract this quality control and the acceptance and rejection plan. This way you will avoid the manufacturers guarantee, just refusing the modules, and minimizing the economic risks assumed by the different entities involved in the installation of the PV plant.

2.4 Cost of quality control

An important aspect is the cost of this quality control of PV modules, specially for the builder. Enertis Solar has made quality controls of modules and many PV installations and its experience says that, depending on its depth, the quality control must be between 0.5-1% of the total investment in photovoltaic modules. This cost is quite smalll if it is compared with the profit losses, between 5-10%, caused by low performances of the PV modules [5].

Obviously the cost of the quality control depends on the number of samples for testing. Enertis Solar advice to do always the sampling for tests according to ISO 2859.1:1999 with the aim to select the number of samples appropiated to a predefined cost.

3 MODULE DEGRADATION EFFECTS ON PV SYSTEMS PERFORMANCE

Degradation is considered as the termination of the ability of a module to perform its primary function which is to provide safe, useful electric power. Usually, degradation of modules is not caused by one isolated factor, but it depends on multiple factors that interact causing degradation. That interaction of factors is quite difficult to simulate in the laboratory.

According to manufacturers guarantee the module degradation average is below 1% per year in the first 10 years and below 0,8% per year in the module's complete life. The omission of quality control could produce installations with defective modules in strings. For instance, studies carried out by the National Renewable Energy Laboratory (NREL) show module performance losses about 1-2% per year in systems tested over ten-year period [6] and the LEEE-ISAAC laboratory has measured losses ranging from 0.7 and 8.2% respect nominal power after first 15 month of exposure [7].

It is very important to remark that a few modules with power degradation in a PV installation can reduce its performance drastically. Sandia National Laboratories have detected degradation in performance of entire arrays of 50% from the initial rating after 12 year of exposure [8]. This dramatic reduction of performance was motivated by specific problems such as complete failure of individual modules in strings.

4 EFFECTIVE QUALITY CONTROL OF PV MODULES

The certification IEC 61215:2005 of PV modules includes 17 tests which determine the thermal and electrical characteristics of the module. Also, the tests show that the modules are able to be exposed during large periods of time in outdoor conditions without failures.

Regarding the quality control of a PV module supply, we must say that it is not possible to do all the tests in each module because of two reasons: several of them are destructive tests, and the realization of all non-destructive tests is too expensive. Also, it would be necessary a long time for the quality control.

Enertis Solar has developed a Quality Assurance Program for PV installations which includes a PV module quality control with three tests of the IEC 61215:2005 certification and an additional non-destructive test. This quality control is showed in Fig. 2.

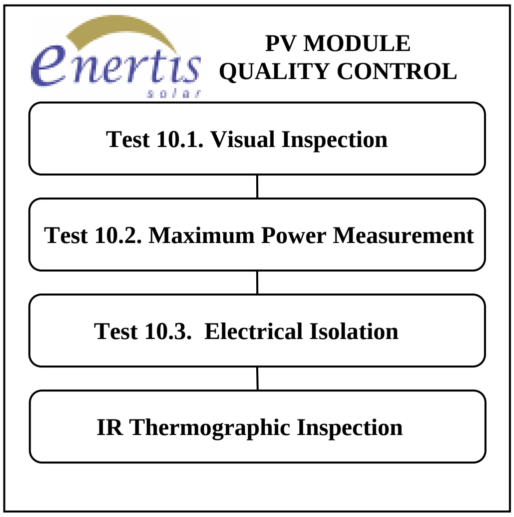

Figure 2: Tests included in the quality control proposed.

For the manufacturer acceptance and agreement of the quality control and its inclusion in the supply contract, the tests have been executed in laboratories with suitable equipment and carried out by technical staff according to IEC 61215:2005.

5 DEFECTS DETECTED DURING QUALITY CONTROLS OF PV MODULES

In this section, the tests are briefly commented and defects commonly detected in PV modules are showed. The tests have been executed in the Enertis Solar Laboratory for PV module characterization.

5.1 Test 10.1. Visual Inspection

This test is carried out with a minimum illumination of 1000 lux and contains 30 inspection points grouped in 4 essential parts of the module: front, back, frame and junction box.

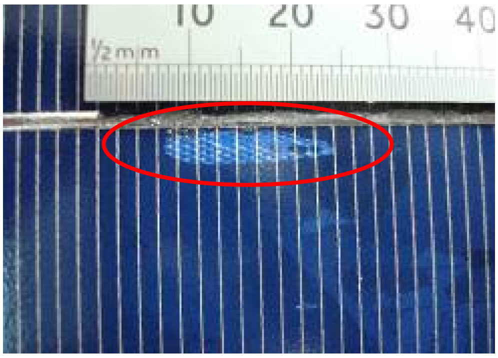

Figure 3: Bubble on a cell.

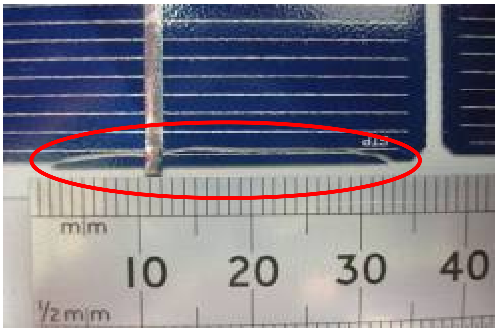

Figure 4: Cracked cell.

Figure 5: Partially shaded cell.

Typical defects detected are: bubbles (Fig.3), metallic inclusions, chips or cracks in cells (Fig.4), misaligned cell connection string, partially shaded cells (Fig.5), short-circuited junction box (Fig.6), non uniform sealant in frame (Fig.7), etc.

5.2 Test 10.2. Maximum Power Measurement

This test is carried out with a solar simulator Class AAA according to IEC-60904-9 which determines the electrical parameters in STC conditions (Irradiance 1000 W/m^2, 25 ºC and spectrum AM1.5G).

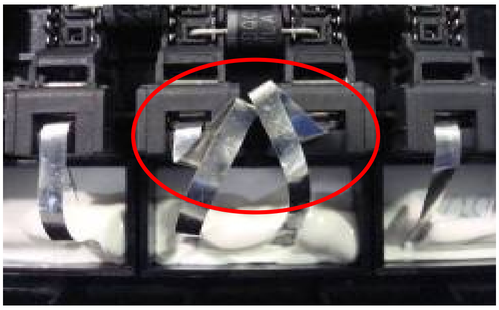

Figure 6: Short-circuited junction box.

Figure 7: Non uniform sealant in the back sheet. It can produce inclusion of moisture and dielectric problems.

It is recommendable to measure the maximum power before exposure because in case of detecting values lower than specifications, it is possible to make use of the manufacturer guarantee and reject the supply. In this case, the low power is only due to defective performance and it is not related to the initial power degradation that occurs normally in the first hours of exposure. However, if the modules have been exposed, the performance of modules is regulated by the power guarantee (commonly 90% in the first 10 years and 80% in 25 years).

Figure 8 shows an example of measurements of maximum power corresponding to a sample of modules from a PV installation. The values are represented respect of power range from specifications. Maximum power is normally lower than specification and manufacturer Flash-Report, but inside of range Pn ±3% before exposure.

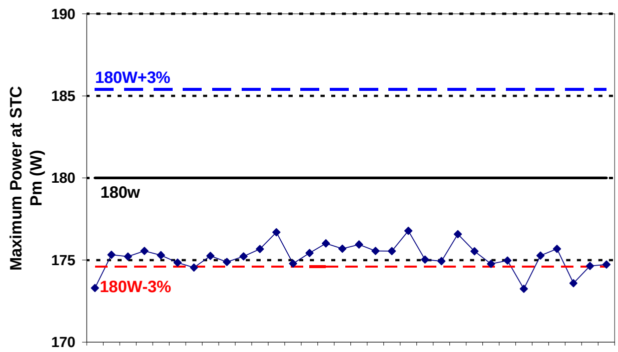

Figure 8: Example of maximum power measurements of 32 monocrystalline 180 ±3% Wp modules.

The experience of Enertis Solar indicate that most of manufacturers are really closer to low limit of tolerance range than upper limit, Pn-3% or Pn-5% depending of photovoltaic module specifications.

5.3 Test 10.3. Electrical Isolation

The aim of this test is to analyze if the PV module has a correct electrical isolation between its current conductor parts and the frame. In this test the absence of dielectric breakdown is checked and the isolation resistance is determined.

The failed tests during the quality controls are mainly related with defective laminated processes and faulty frame assemblies.

5.4 IR Thermographic Inspection

This inspection allows to detect defects which are not visible with a naked eye: cracked or broken cells (Fig.9), hot-spot in cells (Fig.10) or their connections and welding (Fig.9,11), non active cells or region which does not contribute to photogeneration and failures in bypass diodes wiring.

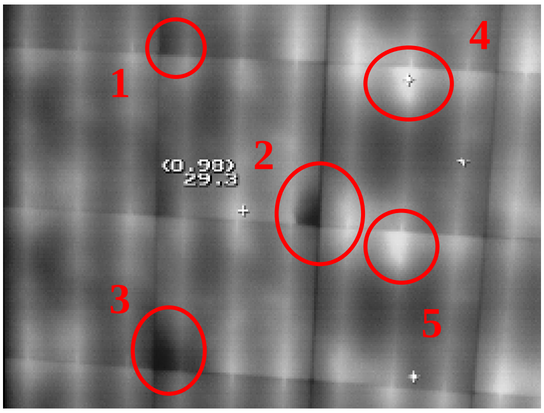

Figure 9: PV module with three broken cells (1, 2, 3) and two hot spots in cell interconnections (4, 5).

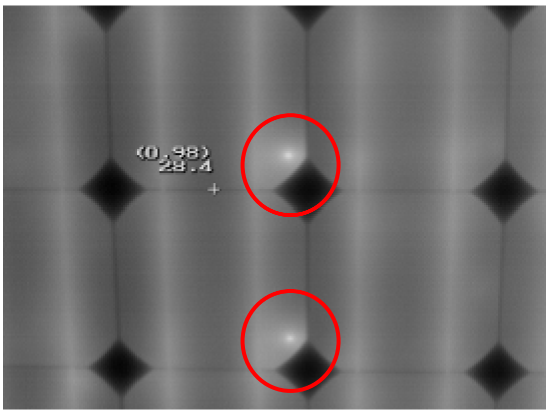

Figure 10: Hot spots in cells due to fabrication process.

6 CONCLUSIONS

The cost of a PV installation is high so it is indispensable to carry out a quality control, specially concerning photovoltaic modules because they are the most important components of the system and their cost is upon 50% of total cost of installation. It is important to remark that inexpensive tasks like these can avoid millonaire losses.

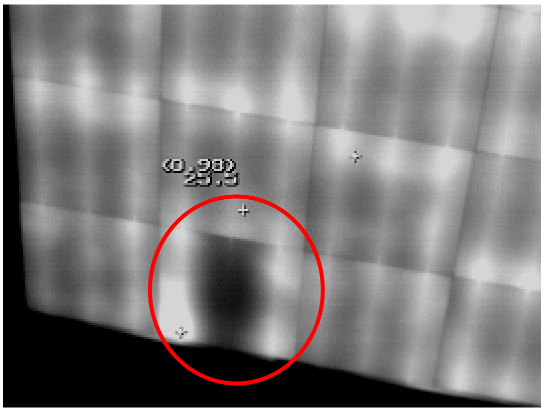

Figure 11: Hot spot caused because internal busbar is not correctly welded and the current is forced to be extracted only through other two busbar increasing resistance.

Besides, the current photovoltaic market has generated a high number of module manufacturers with uncertain quality. This paper explains the main reasons why an effective quality control is required, focusing in avoiding manufacturing guarantee to reduce costs. Advices for the inclusion of quality control on the supply contract and its appropiated cost are also given.

Moreover, this article proposes a basic quality control, which includes four tests, and marks the guidelines to carry them out. Finally, defects commonly detected in the application of this model of quality control in many PV installations are shown.

7 ACKNOWLEDGEMENTS

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