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Assessing the real quality of PV modules

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ABSTRACT
With new industrial challenges faced by the PV industry – such as the striking development of Chinese manufacturers, and ever more demanding investors and financial institutions – the quality of PV modules has never been as important as it is today. Because normative requirements are not matching the buyers' expectations, the questions of what the real quality of a PV module is and how to assess it still remain. This paper analyzes the current situation in terms of quality and the causes of problems, and proposes some ways of addressing the issues in order for the industry to progress on the long path to excellence.

Introduction

Given the continuous FiT cuts in almost all the major markets, the demand for lower prices has led the PV industry to relocate to developing countries, in particular to China, which today accounts for more than 50% of the worldwide production of PV modules. With over 700 manufacturers in the country to choose from, ranging from family-owned businesses making a few hundred kilowatts of modules per year to huge stock-listed companies producing over a gigawatt in a year, it can be difficult to make a decision when it comes to selecting the right partner. In this context, distributors, EPC, installers and end-users are witnessing a flood of products of varying standards of quality. The reality of the situation is that there is apprehension with every purchase made from Chinese manufacturers, and the same question comes to mind each time: "What is the real quality of the products I am buying?"

This question has been around in the PV industry for many years, but there has so far not been any universally accepted answer. Quality remains subjective depending on the buyers' expectations. We can say that buyers generally expect a PV module to provide the right power output and to continue to do so for several decades. But on top of these basic specifications, there are some implicit requirements, such as safety for users and installers. Some new considerations have also been added with the evolution of the industry and the emergence of residential installations, in which respect end-users are more demanding in terms of the aesthetic aspect of products that are integrated into their homes. Of course, the monetary question is of utmost importance, as the industry is turning to investors who insist on a risk analysis of their investments.

The limitations of the IEC/ISO standards and accelerated aging tests

Nowadays, it is almost impossible for a manufacturer to sell their products without a certificate of compliance with IEC standards. However, all the experts, including certification bodies such as TUV, agree that IEC61215 for crystalline modules and IEC61646 for thin films do not cover all the aspects of quality for PV modules. In order to better understand why, it is important to understand the typical behaviour of a population of products – namely PV modules – and the related defect trend of this population over time.

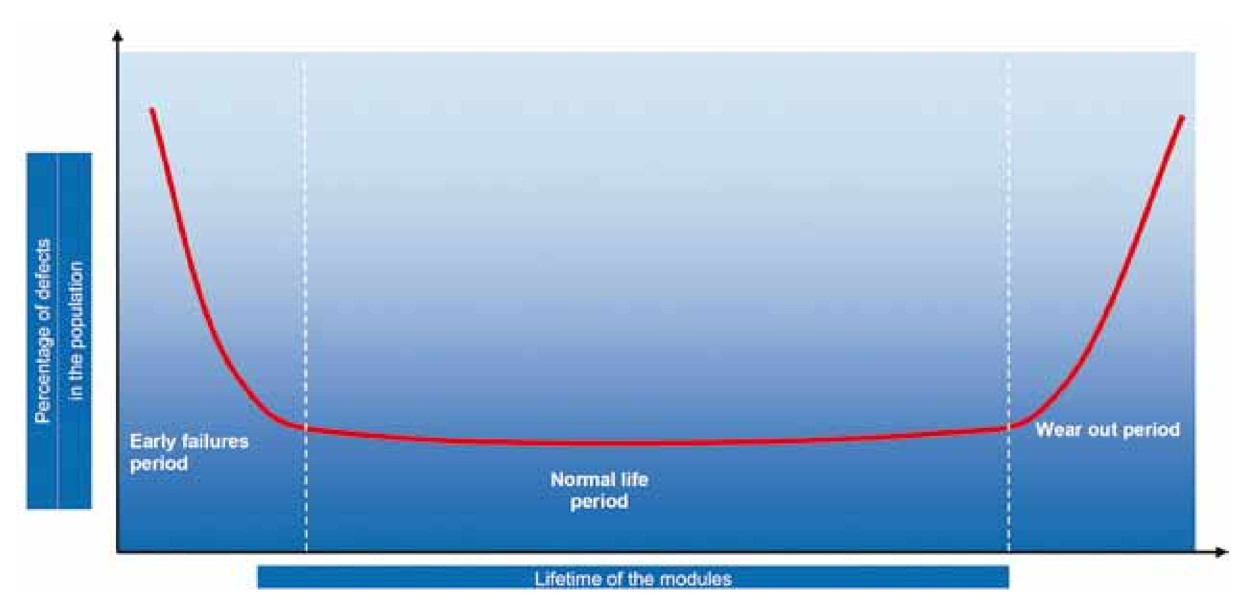

Figure 1. The bathtub curve.

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As in the case of populations of other products, PV module populations follow the ‘bathtub curve’ as shown in Fig. 1. A population of products (for instance a quantity of modules used to complete a 20MW project) will go through three different behaviours over three consecutive periods of time:

- An **early failure** period, during which the defect rate will be high and will decrease with time.
- A **normal life** period, during which the defect rate will be low and constant.
- A **wear out** period, during which the defect rate will increase with time and become high.

Typically, a lot of defects will occur during the early life of the modules due to poor design (causing epidemic failures), some modules not being manufactured according to the required design and correct process settings, or defective components being used. During the normal life of the modules, some defects will appear randomly at a very low rate. This is part of the normal behaviour of the population of any product. Finally, when the components start wearing out because they have reached the limit of their intrinsic endurance, the failures will increase until the whole population is worn out. To each of these periods correspond different types of defect and different causes, and consequently different ways of detecting and preventing failures.

The IEC standards do not address all the different periods of life of the products and their associated failures, and there are many reasons why:

- **Design qualification:** the standards have been developed for the qualification of the design of the PV modules. The tests performed are able to determine if modules produced in the same environment, with the same processes and with the same components, will have a ‘normal’ life. Due to time constraints and costs considerations, a single module will not be subject to the complete set of tests required by the standards. It is therefore difficult to assess the behaviour of the modules under real conditions.
- **Life expectancy:** it is specifically mentioned in the standards that the actual life expectancy of the modules will depend on the conditions under which they are operated. The tests are not truly representative of actual outdoor exposure for 25 years or more, because of the difference in climates, sun irradiance and various other conditions.
- **Sampling:** all the tests performed are based on samples of typically 8–10 modules. These samples are considered to be representative of the mass production, but in reality this is not necessarily the case. Modules sent to the laboratory for testing are carefully selected and prepared by the manufacturers, which biases their representativeness. In some cases, there is even malicious intent, which is highlighted by the example of a large manufacturer that, at the beginning of its operations, sent some modules from another company to take the tests.

To address the first two points above, a series of new tests have been developed in order to come as close as possible to the real operating conditions of the modules. However, due to the equipment and time necessary to perform these kinds of tests, and notwithstanding the fact that the modules come to the end of their life expectancy after testing, it is practically impossible to perform the tests on all the products. So there remains the problem of sampling and its representativeness of the whole population.

What are the real quality risks?

While most of the modules sent to the laboratory to obtain certificates of compliance pass these tests successfully nowadays, feedback from the field is indicating a high percentage of failures. Some investors were a bit disappointed in 2010 when they discovered that after one year in the field, over 90% of the modules from their 1MW project began to delaminate and ended up on the ground! In another case, a module set on fire, causing damage to part of the house on which it was installed. What is the common link between these products? – they were both certified compliant with IEC standards.

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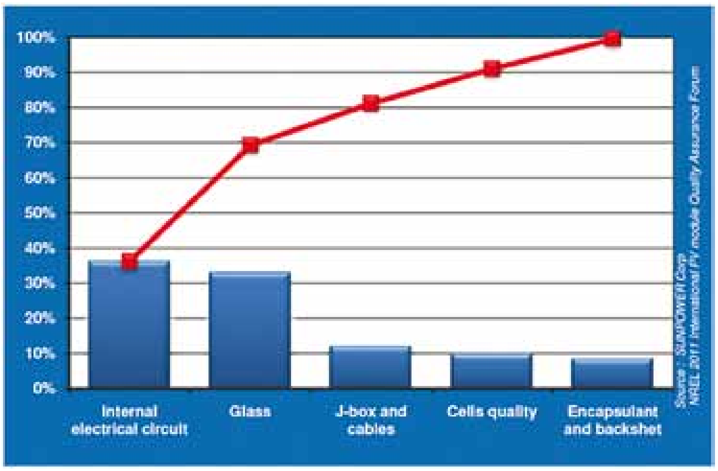
These examples, although of dramatic proportions, are still characteristic of the uncertainty regarding the performance and behaviour of products in the field. Indeed, whether or not these extreme situations make the news headlines, installers, users and investors are confronted everyday with issues related to the quality of their modules. As a result, confidence is undermined in the products and the whole industry suffers from those issues in terms of disparagement from rival industries. As of today, the industry still lacks reliable and statistically usable data to better understand what the problems are and to predict the future of the gigawatts of modules already installed. However, with industrial quantities of modules already installed for over a decade, some results and trends are now starting to take shape.

Fig. 2 shows the distribution of field failures according to data collected from 21 major manufacturers as presented during the NREL forum on quality assurance



Source : SUNPOWER Corp NREL 2011 International PV module Quality Assurance Forum

Figure 2. Distribution of field failures among 21 major manufacturers.

in San Francisco in July 2011 [1]. The feedback covers 8 years on average, but an extrapolation of the defect rate shows that at least 4% of the modules will fail after only 15 years. Different conclusions can be drawn from an analysis of the data. First of all, the data coverage of 8 years is less than a third of the life expectancy of the modules and did not take into account the DOA (dead on arrival) factor; the percentage of failed modules is therefore understated. Second, the data shows the distribution of failures at a particular age of the modules, but this distribution will evolve over time, as some defects such as those related to the quality of the cells are likely to appear later in the lifetime of the modules. All in all, it is unlikely that the expected reliability will be met.

In parallel to this field feedback, some manufacturers and third parties such as STS have started to report statistical analyses of the defects seen during inspections and quality control of large quantities of modules. The data that was used to predict the percentage of early failures of the modules and the period over which this will occur show the lack of maturity of the industry. The PV industry today is comparable to some extent to an industry such as consumer electronics as it was 25 years ago. Containers are filled with a percentage of defective modules that will not fulfil their function for even one day. Those defects, which could easily be avoided, range from damaged packaging and performance issues to cosmetic and workmanship issues, and account for up to 15% the modules inspected by STS.

What are the causes of failure?

The analyses conducted by the manufacturers and STS reveal that one important aspect of those failures, with consequences for both reliability and early failure rate, is that the vast majority of them are not linked to the module design itself but rather to the manufacturing processes and changes to the components.

While some efforts have been made recently in the industry towards the automation of processes, the main part of PV module production, including some critical steps of the process, remains highly reliant on manual operations. It is no surprise, then, that a lot of problems originate from human errors. On the other hand, automation has also led to some difficulties for manufacturers in setting up some increasingly complicated processes to satisfy the ever more demanding technology of modules.

Remarkably, since some manufacturers are still not equipped with reliable measuring equipment or not using it properly, measurements are misleading them into unknowingly producing defective products while convinced that the opposite is true. Finally, in tense economic situations, the temptation to reduce costs by using cheaper materials, despite the prohibition by certifying bodies, has played a significant role in the emergence of defects. A lot of new materials – such as encapsulation material, frames with different cross-sections or even solar cells of different grades – are being used in production without proper certification for mass production.

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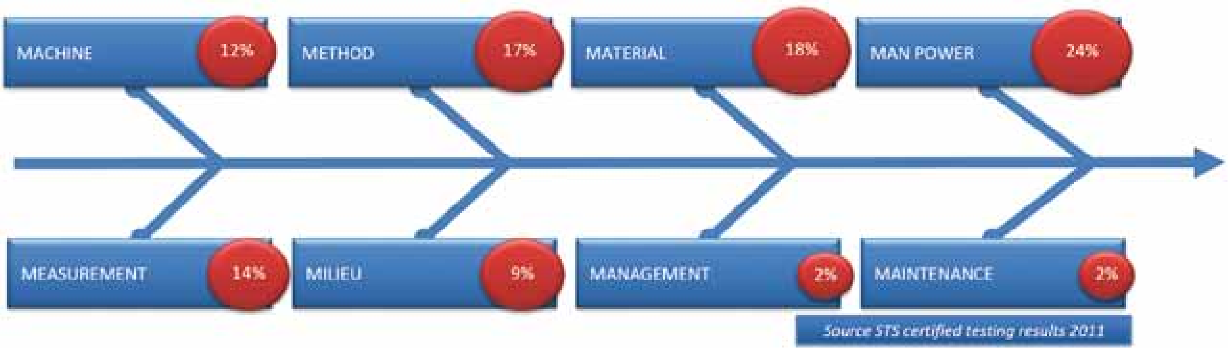
How to assess and prevent the risks?

The next logical question is, of course, how to prevent these risks. While manufacturers have put some effort into increasing the quality level of their products in the last couple of years, the greed for short-term profit and the imbalance between supply and demand often prevail against quality: hence the importance of independent assessments of quality by third parties. Even if compliance with



Source STS certified testing results 2011

Figure 3. A breakdown analysis of the causes of failures (also known as 8M analysis) showing, in the form of a fishbone diagram, the distribution of the causes attributed to the defects detected during STS inspections and testing activities.

IEC and UL standards has shown their limits in guaranteeing the quality level of the products, the standards should not of course be ignored, and purchasing PV modules that are not duly certified puts the buyers at risk. There is a continuing debate on whether to perform sampling inspections and what sampling levels to use, or whether to simply control everything and, if not, what to control.

In theory, if manufacturers perform most of the relevant tests to determine the quality level of a PV module, then why perform a 100% inspection of the modules? The question of maturity in the industry is raised again. Even though sampling provides a good confidence rate for a stable process, it is not really adapted to processes involving a lot of manual operations and unstable manufacturing processes as implemented today in the industry. In any case, sampling may address design issues and prevent epidemic failures, but the process and human errors, which are random by definition, cannot be entirely detected by this inspection method. Thus, a full quality control by an independent company seems to be, in theory, the best choice. However, because of economic and time constraints, some tests cannot be conducted on a large number of modules. The choice of tests to be performed must therefore be relevant to creating a correct balance of cost, lead time and quality.

Performance assessment

With current progress in technology, the assessment of performance (including performance under non-standard conditions) has become affordable in terms of investment. It is important to use as reliable a sun simulator as possible, meaning that conditions as close as possible to natural light are reproduced in a controlled manner. Even if the IEC 612215 standard requires only the use of class B sun simulators to assess the output power, it is highly recommended to use the class of sun simulator as defined in the IEC 60904-9 standard.

Cell quality

Since solar cells are the main components

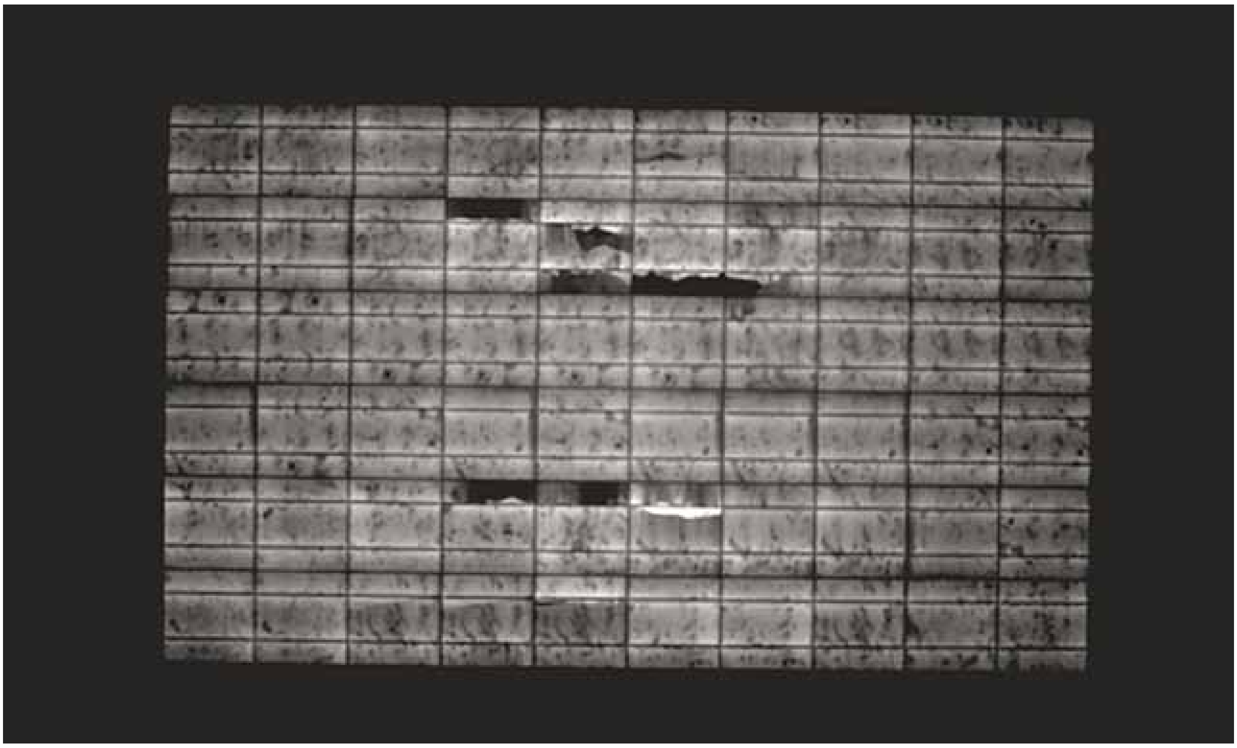


Figure 4. Electroluminescent imaging of a multicrystalline module.

of a PV module, it is mandatory to inspect them carefully. An easy-to-use and non-destructive way of assessing the quality of the cells is to check them under electroluminescent light (Fig. 4). This method uses a property common to all semiconductors that is the opposite of the normal use of solar cells. While a solar cell produces electricity when irradiated by light photons, the opposite reaction is also true. An electrical load is applied to the cell, which will then emit some radiation that can be captured by a camera, and the more efficient the cell, the higher the radiation. Areas such as cracks, which are not emitting radiation, indicate a lower efficiency than elsewhere and therefore a problem in this area of the cell. The different defects observed provide an indication of the future behaviour of a cell and consequently of its reliability.

Workmanship

A careful visual inspection of the products can also reveal some serious defects. These could be dimension or connection issues that can cause problems during installation; sealing defects that may not ensure adequate protection of the cells in harsh environment conditions; or sharp edges that can lead to injuries to installers. The list of problems is a long one.

Production monitoring

An expertly carried out monitoring of the production process completes the testing aspects, in order to guarantee a total quality approach focusing on continuous quality improvement.

The financial aspect

Quality has of course some direct consequences for the return on investments made for any PV project. Since all manufacturers provide warranties on products for at least five years, and on performance for over 20 years, there should be no concern about costs incurred due to quality issues. The fact is that warranties normally do not cover shipping and installation costs or loss of profit related to defective modules. In the end, the cost of a claim is often much higher than originally anticipated, and claims should be avoided as much as possible. Product defects can have a significant impact on profits, hence the need for improved quality assurance. In a recent study of a 12.5MW project [2], it was demonstrated that an increase of 1% in yield can increase the project profitability by 10%.

Another aspect of the financial issue is from the point of view of the manufacturer. On the one hand, the cost of a claim is at least as high for manufacturers as for buyers. On the other hand, there are also some indirect consequences for manufacturers, such as the loss of business opportunities, which can be very costly in a small industry such as PV. In this regard, some third parties have already recognized that the assessment of quality should be cost effective and have made some efforts to support the buyers and the manufacturers with services that do not exceed 1% of the cost of the products.

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Conclusions

Even if most stakeholders have clearly understood the importance of providing quality modules, the question of what is a good quality product still remains unanswered. There are obviously some gaps in the current definition of IEC standards; compliance may be necessary for manufacturers to sell their products, but it is not sufficient to ensure the quality level of the product up to the buyers’ expectations. On the one hand, tests are being developed to estimate the true reliability of products; on the other hand, screening of large quantities with simple and relevant tests remains necessary to separate the grain from the chaff. Third parties have to play an important role in helping both manufacturers and buyers to collaborate in the common goal of developing the industry for a brighter future.

References

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About the Author

Thibaut Lemoine received a master’s degree in mechanical engineering from the French National Engineering School of Belfort (ENIBe) and a master’s degree in international industrial business management from the University of Technology Belfort Montbeliard (UTBM). He has more than 12 years’ experience in both the manufacturing field and quality control, having worked for major French groups in industries ranging from automotive and stationery to consumer electronics and PV. Thibaut has been in China for 10 years, working in partnership with major manufacturers, and is a co-founder of Senergy Testing Solutions Ltd, where he is currently the General Manager.

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