

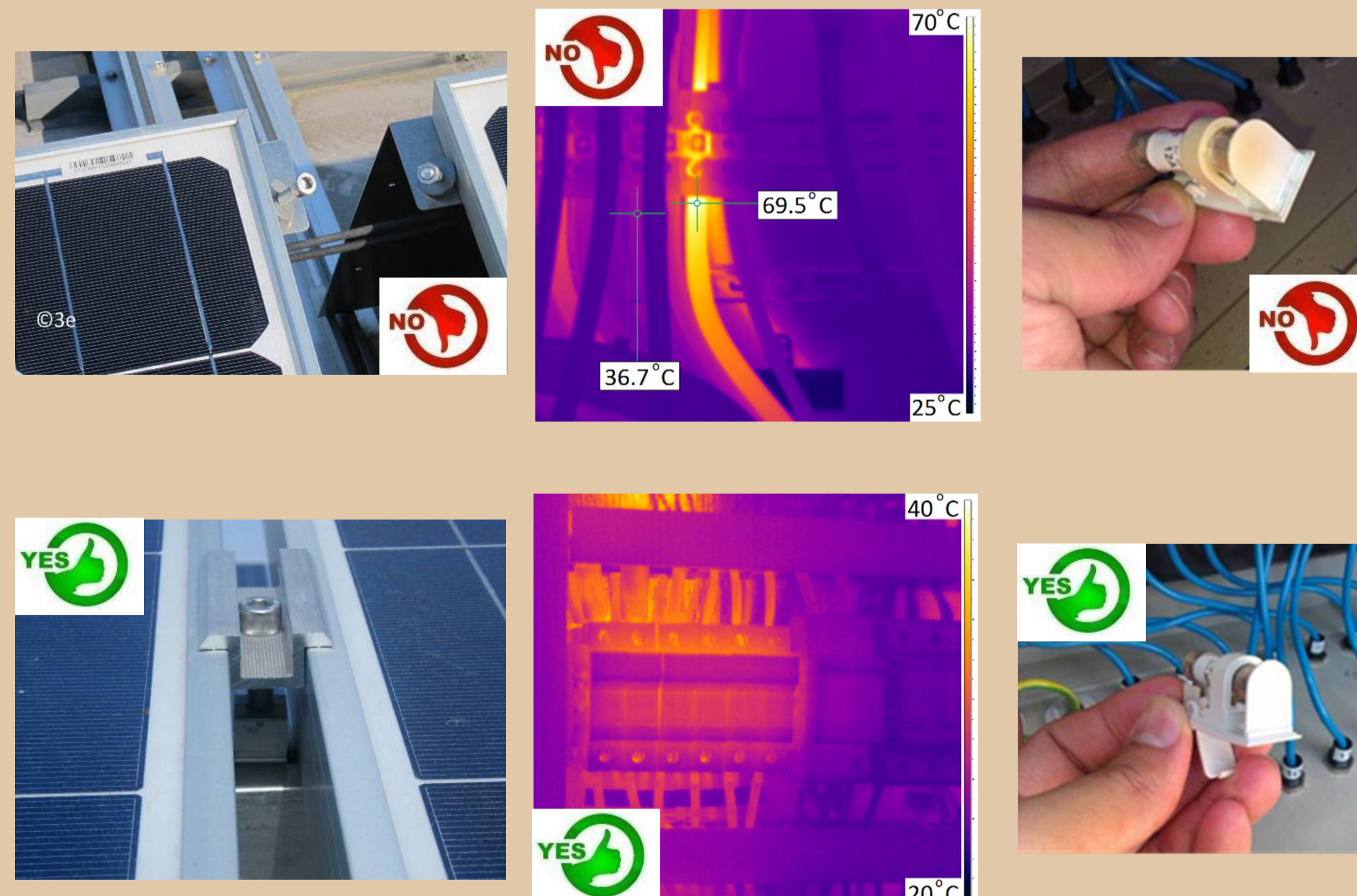
## 1. INTRODUCTION

- Grid-connected PV sector is maturing and spreading all around the world.
  - More than 100 GW of BIPV and large PV plants have been installed only in 10 years (80 GW last 3 years).
  - PV solar energy is the 3<sup>rd</sup> most significant renewable energy source (behind hydro and wind energy in terms of capacity).
  - PV solar energy can compete in cost terms with traditional energy sources even without additional subsidies (South Europe).
- PVCROPS project has compiled a manual with a collection of good and bad practices detected in PV plants
  - New PV installation will be more and more competitive: more reliable, efficient and cost-effective if errors and mistakes already done are avoided.

## 2. GOOD AND BAD PRACTICES: THE MANUAL

- Objective: to represent a useful reference for when a new installation is being designed and built.
- 129 pages and 229 pictures with an explanatory text.
  - Pictures related to good practices: show how the installation has to be done.
  - Pictures related to bad practices: show examples of what has to be avoided.
  - Pictures are classified in 7 categories:

- ◆ Civil works
- ◆ Supporting structures
- ◆ Connection boxes
- ◆ PV array
- ◆ Inverter
- ◆ Monitoring
- ◆ Others



## 3. MANUAL DOWNLOAD

- “Good and Bad Practices: Manual to improve the quality and reduce the cost of PV systems” is free available
  - Visit [www.pvcrops.eu](http://www.pvcrops.eu)
  - Different languages (soon): english, spanish, bulgarian, portuguese, french, dutch and arabian.

## 4. FUTURE OF THE MANUAL

- The manual will be periodically revised, improved and updated.
- All people is invited to collaborate (new situations and pictures are welcome).



## GOOD AND BAD PRACTICES IN PV PLANTS

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**ABSTRACT:** The PVCROPS project (PhotoVoltaic Cost rÉduction, Reliability, Operational performance, Prediction and Simulation), cofinanced by European Commission in the frame of Seventh Framework Programme, has compiled in the “Good and bad practices: Manual to improve the quality and reduce the cost of PV systems” a collection of good and bad practices in actual PV plants. All the situations it collects represent the state-of-the-art of existing PV installations all around Europe. They show how the different parts of an installation can be implemented properly or not. The aim of this manual is to represent a reference text which can help any PV actor (installers, electricians, maintenance operators, owners, etc.) not only to check and improve an already existing installation but will also, and mainly, avoid the previously known bad practices for the construction of a new PV installation. Thus, solving a priori the known errors, new PV installations will be more reliable, efficient and cost-effective and can recover the initial investment in a shorter time. The manual is going to be free available in the PVCROPS website in several languages.

**Keywords:** PV System, grid-connected, reliability, cost reduction, education and training

### 1 INTRODUCTION

Grid-connected photovoltaic (PV) solar energy is a technology which has come to play a significant role in the electricity generation and supply systems of many countries. Over a period of only 10 years, approximately 100 GW of PV capacity has been developed and constructed with close to 80 GW of that total having been built in the past 3 years. This represents an annual growth of close to 40%. For this reason, PV installations are the third most significant renewable energy source, behind hydro and wind energy in terms of capacity. This exponential growth has been evident in Europe, where close to 70% of the worldwide grid-connected PV power is situated. In fact, some European countries are meeting more than 5% of their annual electricity demand with PV energy (Germany and Italy) [1]. This rapid development has been accompanied by a gradual decrease of PV device costs, and this has propitiated that, in the south of Europe, PV solar energy now can compete in cost terms with traditional energy sources (gas, coal, oil, nuclear, etc.), even without additional subsidies.

The PV sector is maturing and spreading rapidly elsewhere in the World. Evidence of this is that last year (2012) was the first year in which PV power installed in the rest of the world was almost at the same level as that installed in Europe [1]. In order to continue with this growth, and to make PV solar energy more and more competitive, it is necessary to consider the best practices for PV installations. This involves avoiding the mistakes which occurred in the earlier installations. Thus, solving a priori the known errors, new PV installations will be more reliable, efficient and cost-effective and can recover the initial investment in a shorter time.

So, the PVCROPS project (PhotoVoltaic Cost rÉduction, Reliability, Operational performance, Prediction and Simulation) has compiled in the “Good and bad practices: Manual to improve the quality and reduce the cost of PV systems” [2] a collection of pictures that show the good and bad practices which have been detected in existing PV installations.

This manual is inspired in a previous text related to rural electrification that reports about good and bad practices in PV stand-alone installations [3].

### 2 GOOD AND BAD PRACTICES: MANUAL

#### 2.1 Objectives.

The main objective of the manual is to represent a useful reference for when a new installation is being designed and built. The good practices will be examples of how to implement these projects to get each individual device operating properly and avoid premature degradation. The bad practices will be example of mistakes which have previously been made and should be avoided.

The fact that this manual shows bad practices should not be interpreted as indicating that they are common in existing installations. On the contrary, PV installations are generally well constructed and are operating effectively, with good practices predominating. The manual tries to show those defects that have been detected and which can cause a reduction in the lifetime of the installation or in the resulting energy production. Therefore, such practices lead to a decrease in overall performance if they are not resolved.

The examples shown in the manual are related to

both PV plants and building integrated photovoltaic systems (BIPV). Most of the situations and examples it presents come from PV plants, but there are good and bad practices common in both installations.

It is necessary to point out that all the measures recommended in the manual are worthless if after a PV installation is built, it is not properly maintained. Following the recommendations presented in the manual will not guarantee a good performance from a PV installation. PV installations must meet the national electrical industry regulations and should include preventive and corrective maintenance to detect and quickly solve faults and failures that can appear during normal operation. It is advisable to install a monitoring system, operated by qualified personnel, that provides alerts in the event of faults in the PV installation during operation. A periodic review of the status and condition of the wiring, plugs, modules, inverters, etc. is essential. Only in this way the installation will operate properly, ensuring that it reaches its full design lifetime, a high availability level with high energy production and, consequently, lower costs for PV solar energy.

## 2.2 Organization

The manual is composed by 129 pages, including 229 pictures, and is divided in 4 chapters.

Chapter 1 is a brief introduction reporting the evolution of PV installation grid connected all around the world and the objectives of the manual.

Chapter 2 reports about the organization of the manual and explains how the manual is written.

Chapter 3 shows the good and bad practices which have been detected in existing PV installations. It is divided into 7 sections, each dealing with separate aspects of grid-connected photovoltaic installations, both PV plant and BIPV. These sections describe both typical good practice in terms of PV installations and some of the mistakes which can occur. The presentation is in the form of visual material, both photographs and diagrams, and a short text which describes the good and bad practice where relevant.

As noted above, each category is related to one of the main components or sub-systems of a PV system and is identified by a letter which indicates the aspect to which the figures refer:

- “C” for the civil works needed to implement the PV installation;
- “S” for the supporting structures holding the PV modules, the connection boxes and the cables;
- “W” for the connection boxes that save the live cables, fuses, switches and others devices from outdoors;
- “G” for the photovoltaic array or generator that transforms solar energy into electricity;
- “I” for the inverters that converts the DC power from the PV array to AC power to be injected into the grid;
- “M” for the monitoring devices and routines that supervise the operation of the installation and reports about it;
- “O” for those other aspects not dealt with the other categories, mainly those related with the integration of the installation in the environment.

All of the photographs are from real installations in various parts of Europe and represent the common procedures which are used for the construction of PV

installations. Avoiding bad practices and applying the examples of better practice will help to ensure that final PV installations will be free of premature degradation and frequent failure that will decrease the energy production of the system and, consequently, its profitability.

Fig. 1 shows the symbols used to report about a good practice (left) a bad practice (middle) and a situation that is neither a good or a bad practice but could be improved (right). These symbols highlight quickly and clearly the nature of the situation being presented.



**Figure 1:** Symbols used to report about good practices (left), bad practices (middle) or a situation that could be improved (right).

Finally, chapter 4 gives some links to web pages and forums in which information about PV installations can be found: news, research articles, general reports, analysis of PV technology, etc.

## 2.3 Example

Fig. 2 and Fig. 3 are examples taken from the manual. They show a bad and a good practice, respectively, and come from the section related to PV arrays, reporting about modules placement and shading.



**Figure 2:** Grid-connected PV installation with a supporting structure that cast a shadow over the panels behind it.



**Figure 3:** Grid-connected PV installation without shading between consecutive rows.

Fig. 2 shows a structure that cast a shadow over the panels behind it. Fig. 3 shows an installation without shading between consecutive rows. The explanatory text joined to the pictures in the manual helps to understand the situation that is shown in the pictures: the distance between PV modules must be large enough to avoid shading between rows even for winter time at noon (the critical time for shading in static installations as the sun is lower in the sky). Otherwise, the performance can be reduced.

#### 2.4 Download and languages

The manual is going to be free available in the PVCROPS website ([www.pvcrops.eu](http://www.pvcrops.eu)) and can be downloaded soon in several languages: English, Spanish, Portuguese, Bulgarian, French, Dutch, and Arabic. Fig. 4 shows the cover of the English version of the manual.



**Figure 4:** Cover of the “Good and bad practices: Manual to improve the quality and reduce the cost of PV systems”.

### 3 FUTURE OF THE MANUAL

This manual is conceived to be a reference text not only in its origin, but also in the future. It pretends to be a “live” reference. The text and pictures here presented are the first version of a manual that will be periodically revised, improved and updated. So, this manual has been submitted to PV forums of different countries [4], [5], [6], [7] and translated to different languages to get the widest diffusion. All the people is invited to participate in these forums, reporting about those situations not collected here and sending the pictures that reflect the good or bad practices.

### 4 SUMMARY

This paper reports about the “Good and bad practices: Manual to improve the quality and reduce the cost of PV systems”. This manual is composed by 129 pages, including 229 pictures that show the good and bad practices which have been detected in existing grid-connected PV installations. These practices are related with civil works, supporting structures, connection boxes, PV arrays, inverters, monitoring and others different aspects of an installation. The main objective of the manual is to represent a useful reference for when a new installation is being designed and built in order to avoid those defects previously done which can cause a reduction in the lifetime of the installation, in the resulting energy production or in the overall performance if they are not resolved.

### 5 ACKNOWLEDGMENTS

The “Good and bad practices: Manual to improve the quality and reduce the cost of PV systems” has been written in the context of the PVCROPS project (PhotoVoltaic Cost rEduction, Reliability, Operational performance, Prediction and Simulation), that is cofinanced by European Commission in the frame of Seventh Framework Programme.

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