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REVIEW OF LOW PERFORMANCE PV PLANTS IN THEIR EARLY PHASE OF LIFE IN SOUTH OF SWITZERLAND

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Introduction

The aim of this project was to identify the most relevant critical issues during the early stage of operating life (systems up to 5-7 years old) through a series of inspections on plants with reduced energy yield and located in Ticino, Switzerland.

Durability and reliability of photovoltaic (PV) modules represent an important concern for module manufacturers, PV system installers and particularly for investors interested in a cost-competitive PV system with a reliable and predictable energy production during the modules' lifetime.

The lifespan of a rooftop PV plant can be estimated around 25-30 years, while the oldest plant in Europe, the TISO 10kW installed in Campus Trevano, has exceeded 35 years of life . As in any system, defects and problems typically occur in the early years (childhood problems) and at the end of life of the system itself.

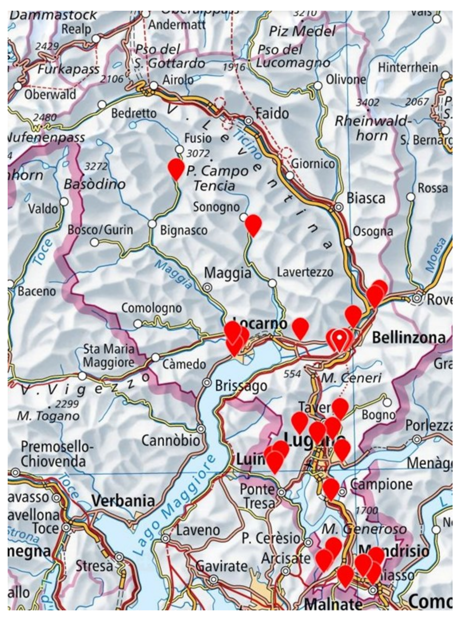
A PV rooftop system includes multiple elements whose lifespan depends not only on the reliability of the individual elements but also on design of the whole system, on quality of the installation and on maintenance over time. The study of childhood problems includes all aspects that contribute to the operation of a photovoltaic system.

Approach

During 2019, **30 rooftop PV systems**, built in the last 5-7 years, out of a total of approx. 4200 plants (1.4% of the installed power in Ticino) were tested in accordance with international standard and inspected. The 30 PV plants were chosen from those with reduced production or already with indications of defects, built in the last 5-7 years in Canton Ticino, Switzerland.

A total of 560 strings were checked (I-V curve measurement, insulation measurement, visual inspection, etc.). 360 pictures with infrared thermography (IRT) were taken on half of the PV plants (14 out of 30 plants). The visual inspections were carried out directly or with the help of a drone. The traceability of defects was limited by the difficulty in accessing the roofs, in particular the pitched ones, for carrying out a detailed visual inspection of the modules and for carrying out infrared thermography.

The collected and measured data and the knowledge acquired were subsequently summarized and shared through workshops with stakeholders (designers, installers and owners of systems). Actions to reduce risks are proposed, both for existing plants and for new installations.



Results

The types of defects, errors or faults encountered during the analyses can be grouped into four different areas:

1. Errors in the design of the system

2. Plant or component construction errors (wiring, cables and connectors, modules, inverter ...)

3. Maintenance problems (soiling, fault traceability, ...)

4. Aging defects (faults, hot-spots, burns or oxidations in cells or connectors, ...)

The design "errors" found are mainly related to partial shading problems. Rarely due to component sizing problems. Construction errors can be divided into PV module construction errors and wiring or connection errors. The installer can avoid the wiring errors with a correct execution, but cannot always verify the quality of the components.

The degradation of the energy yield caused mainly by inadequate maintenance of the PV systems can be easily recovered with proper management (i.e. cleaning). However, careful design can limit the need for maintenance and correct user documentation facilitates the verification of malfunctions.

Maintenance: soiling is the main issue

At almost all locations, soiling of the solar modules can be seen at the edges of the modules or covering completely the modules. Only a few projects show heavily soiled solar modules where hotspots are formed (Figure 2). Long-term soiling effects seem to be a driver of observed performance loss rates in particular in less tilted modules.

Dirt on the modules is present in most of the systems analyzed. The causes can be manifold:

- PV modules with little inclination (10 ° - 15 °)
- Edge of the module near the surface of the flat roof.
- Trees nearby
- Factories or nearby traffic

Dirt can be fairly uniform with loss of transparency in all cells of the module. It can also be heterogeneous, with accumulations at the edges of the module or there can be dirt from bird droppings or from stains of various kinds or leaves or even stones.

Figure 2: Heterogeneous soiling on the edges of the modules with corresponding hot-spots.

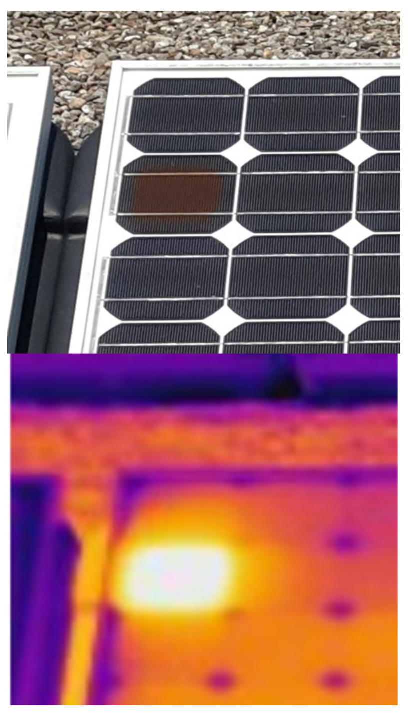


Figure 3: cell degradation and hot-spot

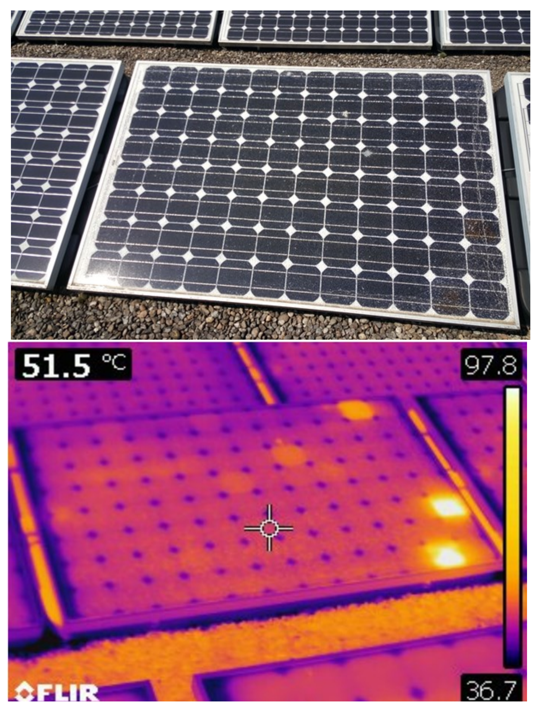


Figure 4: Module glass broken with corresponding hot-spot

Electrical degradation:

The measurements of the current-voltage characteristic carried out on each string of the 30 PV fields, allows to compare the maximum real power Pm, measured in real conditions but extrapolated to STC, with the nominal power Pm at STC declared in the module datasheets PV is multiplied by the number of modules per string.

The sum of the rated powers at STC does not consider the losses in the cables nor that in the connectors.

The differences found therefore correspond to the sum of all the loss parameters of the DC wiring part (cables and connectors), the measurement precision (precision of the equipment and sensors, alignment of the sensors, etc.) and the actual defects that you want to determine.

The graph in Figure 1 shows the differences between the rated power of all the strings and the measured power extrapolated to STC.

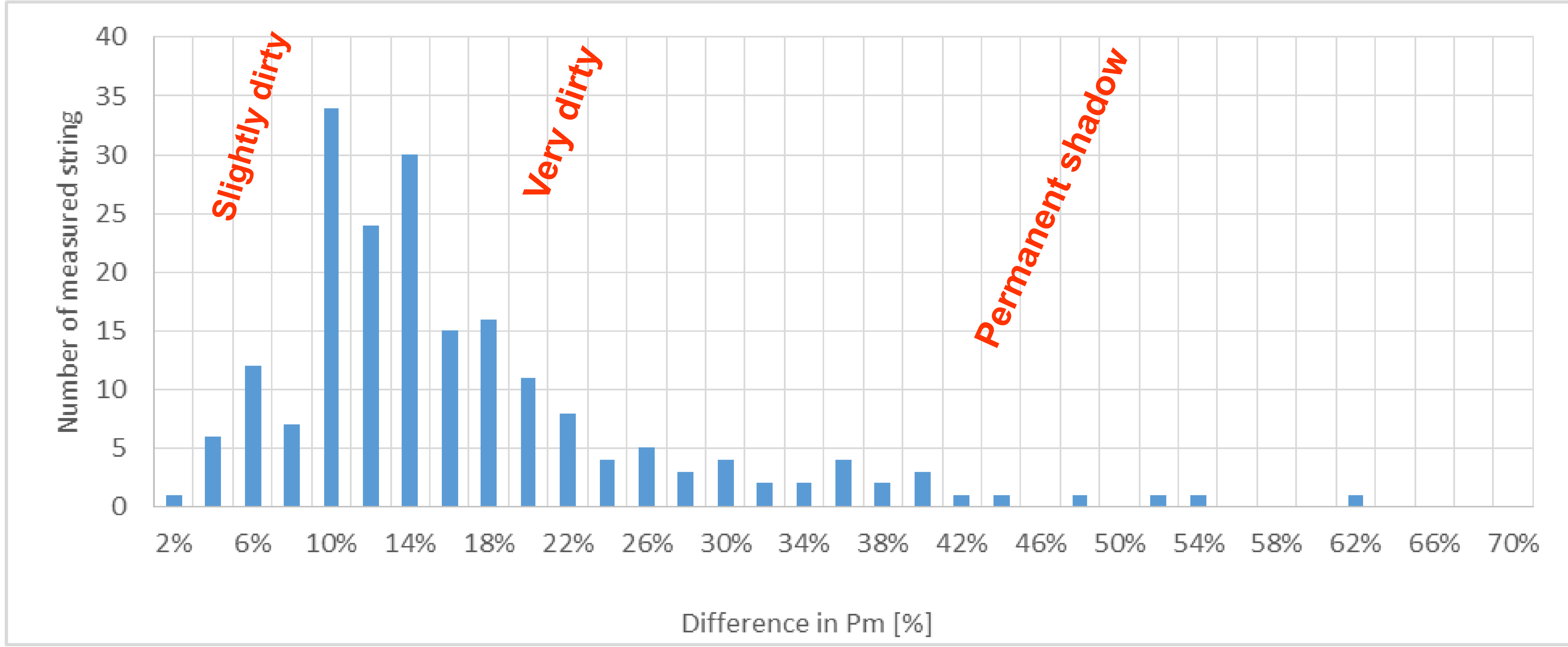


Figure 1: Degradation of the string power Pm_measured (extrapolated to STC) with respect to Pm_nominal (STC).

Occurrence of defects / errors / faults (Table 1):

In almost all the strings, the measured power extrapolated to STC was, as expected, lower than the rated power.

In addition to the decrease in power, the most frequent problem encountered is the presence of dirt on the modules (88.9%).

Partial shadows were present in 53.3% of the PV plants, of which 30% were permanent shadows (16.7% of the total), in our opinion attributable to a design error.

The dirt on the inverters is generally not an important issue, but it may affect the operation of the inverter and do not allow to operate at full power. 1.4% of the strings were disconnected (3 out of 203).

	Defect/Error/Faults	Qty.
1	Power degradation (STC)	96.5 %
2	Soiling on the module	88.9 %
3	Shadowing	53.3 %
4	Permanent Shadowing	16.7 %
5	Defect/soiling on inverter	10.0 %
6	Front Glass broken	3 (tot)
7	Disconnected string	1.4 %

Table I: Occurence of defects / errors / faults in the 30 selected PV plants

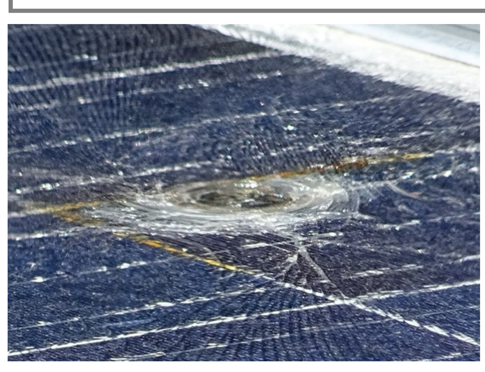


Figure 5: Module glass broken

Figure 6: connector design defect

Conclusion

Errors in the **"design"** phase and in the **"maintenance"** phase are the two main causes of malfunctions in the systems in the early stage of life.

A more careful design according to the rules of photovoltaic technology, sometimes even at the expense of the number of photovoltaic modules installed, could further improve the quality of the rooftop systems and increase the amount of renewable energy generated.

In five plants out of 30 there were permanent shadows and in half of the plants there were partial shadows (trees, chimneys, antennas or other roofs).

Soiling of the modules is the predominant element in maintenance problems. In the management of the plants, it is essential that there is the possibility of tracing malfunctions or a drop in production. Therefore, it is necessary to note the energy produced at the inverter's input point or to have a monitoring of the total production of the photovoltaic system without self-consumption. The meter at the entrance of the building is not sufficient to determine if the system is properly functioning because it is not possible to discriminate the self-consumed component of the energy produced. Furthermore, it is necessary to have the data of the monthly and annual production simulation as a comparison with the real production.

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