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40 years of the TISO PV plant: update on the oldest PV system connected in Europe

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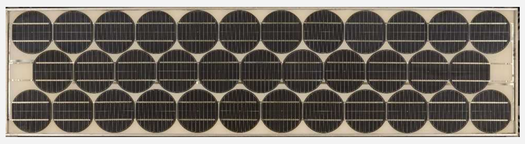
ABSTRACT

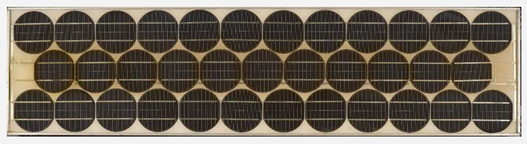
The 13th May 1982, the energy produced by the TISO 10 photovoltaic plant was fed into the electric grid in Lugano for the first time. A part of the 288 modules is still delivering energy today, 40 years after the installation, far beyond the most optimistic expectations. The project, started to study the possible technical and safety problems posed by the connection of a PV plant to the electrical grid, has become a living example of the long-term reliability of photovoltaics. The regular quality checks, performed indoor on 18 reference modules and outdoor with visual and infrared inspections, among the other things, are the key to understand the correlation between power degradation and defects. In this poster, we will present the last measurements on 12 modules from the 48 still installed and we will analyse the evolution of power performances and failures. The 12 modules removed and analysed in laboratory represent one complete substring over four, the one mounting the less performing modules of the new set.

Results after 35 years

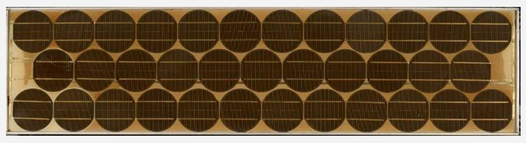
- The degradation rate of the electrical performances of the modules, precisely measured with indoor measurements throughout the whole life of the system are far to be uniform: 2 different groups could be identified; one with a negligible degradation rate of -0.2%/year, the other with a degradation rate of -0.69%/year, much higher but still compatible with a 25 years' warranty at 80% of the original power.
- The two distinct behaviours were most probably related to the use of different suppliers for PVB encapsulants.
- The different evolution of the yellowing of the encapsulant (browned PVB, yellowing of the central cells' row, transparent PVB) led to the classification of modules in 3 classes (Class "A" white module, class "B" mild yellow module, class "C" browned module), which matches the information of three different PVB suppliers.
- Class 'A' modules were all included in the best perfomers' distribution.
- After 35 years there were multiple mechanisms, working together towards a faster, not linear degradation.



Class "A" module: no yellowing



Class "B" module: mild yellowing in the middle

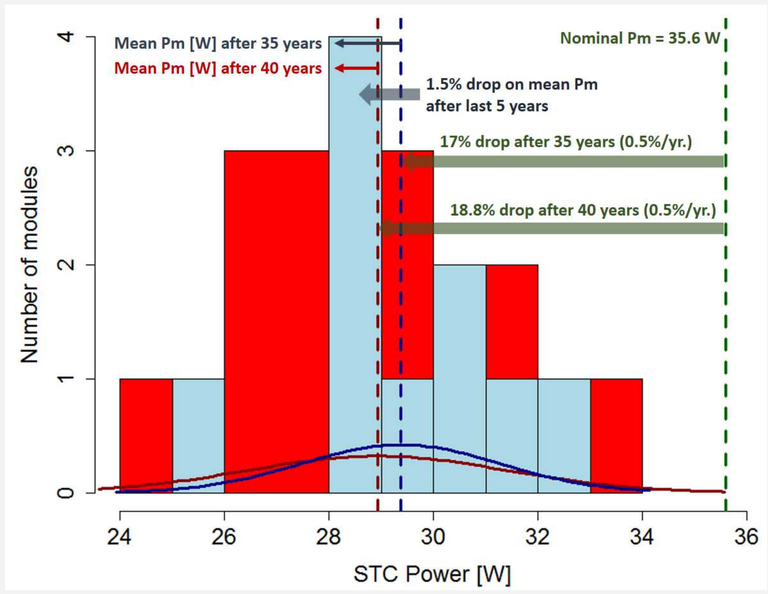


Class "C" module: browning

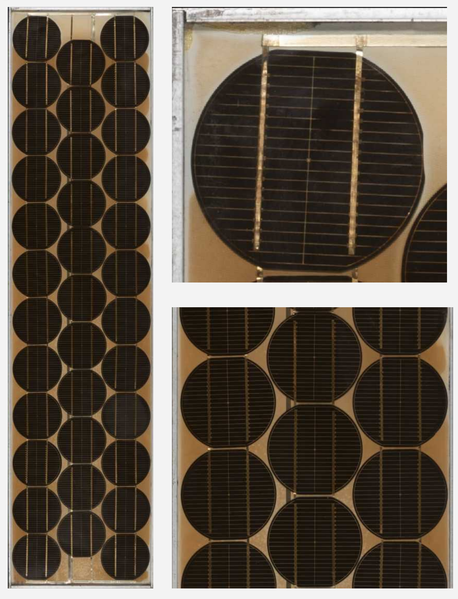
Verification after 40 years

- 48 modules of the 288 original plant were re-installed, all with successful insulation test results, without critical hot spots and with the highest performances of the lot, measured indoor in the SUPSI PVLab.
- The modules of the new TISO PV plant have been organised in 4 substrings of 12, connected to one SMA 1200 inverter and monitored at single string level.
- The system is back operative since October 2019. Data acquisition, for problems related to the LAN connection, absent after the moving of the SUPSI DACD campus in Mendrisio, has started again in May 2020.
- In March 2022, 3 modules were changed because of problems on 2 out of the 4 strings. Two modules were changed in the first string, the one mounting lower performances modules.
- The 10 modules installed originally in String 1 have been analysed in laboratory, comparing the original results with the ones obtained five years before. Further to electrical performance test and electroluminescence test, high resolution pictures of all the modules were shot, to quantitatively detect changes in the visual inspection.

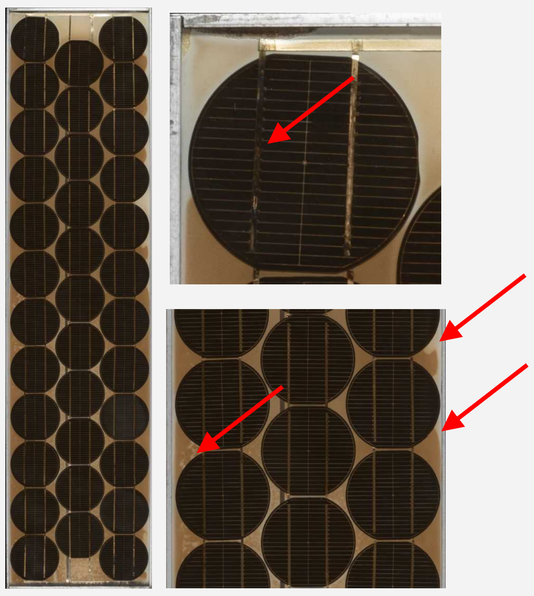
String 1 modules (Visual and IR)



Distribution of power classes of String 1 after 35 (blue)and 40 years(red)



Visual inspection after 35 years



Visual inspection after 40 years

Results after 40 years

- The mean power of 10 modules out of 48 of the new TISO PV plant has lost 1.5% after 5 years. The loss over 40 years is –0.47%/year, still in line with the standard 80% warranty of modern panels. Considering that in 1982 the warranty of ARCO solar was 5 years [M.Green, PIP 2005], the result is excellent.
- The visual inspection on the worst module, (6.9% power loss in five years) performed through high resolution digital images, highlights an important degradation of cell contacts, with increase in series resistance, increase in yellowing , confirmed by 2.1% Isc loss and oxygen bleaching due to increasing losses of the encapsulant: despite the increasing degradation patterns the module is still retaining 77% of the average nominal power for the TISO modules, as measured in laboratory (35.6W).
- On two out of three of the replaced modules the problem is at wiring level, with one connector blown for an electric arc.
- The monitoring of the strings 2,3 and 4 exhibits still values of 70% in terms of DC performance ratio, in line with the indoor results.
- TISO is the living demonstration that a lifetime of more than 40 years for a PV plant is possible.