Putting CPV to the test

Engineers at ISFOC have racked up more than ten years of experience in operating, optimising and analysing CPV plants. To find out what they have learnt over that time Richard Stevenson quizzes CPV technology manager Maria Martinez and maintenance manager Eduardo Gil.

Q Broadly speaking, how is ISFOC assessing the performance of CPV?

A **Maria Martinez (MM).** ISFOC is a public R&D company, and our focus is to foster and promote CPV industrialization. With this purpose, when we were founded in 2006, our goal was to carry out electric power-plant installations with the CPV technologies available in those days. Up to 3 MW was the first idea.

Technologies were selected in a public call for tenders. In the first phase, three different suppliers were installed [at our headquarters] in Puertollano (Ciudad Real) and in a second location 300km away, Almoguera (Guadalajara). We have 800 kW in Puertollano and 300 kW in Almoguera in operation and connected to the grid since September 2008. Puertollano is our main installation where most of the performance studies are carried out.

For the power plant of Puertollano, one supplier was Concentrix Solar, who became Soitec Solar in 2009, and since October 2016 is owned by Stace Electric. The second is SolFocus and the third Isofotón – for those two, the suppliers are not available, but we don't know if in the future someone will begin working again with their products.

We have 200 kW of Concentrix – 36 concentrators of 5.5 kW. Each concentrator has its own inverter.

We have 200 kW of SolFocus. Here we have different types of concentrators, different versions, in order to test them. We have two concentrators of 7 kW; another 28 of 6 kW; and additionally, two more of 9 kW of a next-generation product, which were installed in May 2012. Each concentrator has its own inverter.

And then we have Isofotón. Here we have CPV plants and one flat-PV plant mounted on two-axis trackers, with the goal of making some comparison between CPV and flat PV performance. For the CPV plants we have 27 concentrators of 11.1 kW, with three centralized 100 kW inverters.

The first objective of all these installations was to help the suppliers. They had feedback about the qualification of the modules, the characterisation of the CPV plant, and the long-term performance. We were always collaborating with them and giving them our support to improve their products. All made new versions of their products that can be found here, in Puertollano.

We have a lab for the qualification of modules (standard IEC-62108) and trackers (standard IEC-62687). New developers have been always working with us. We can carry out tests to improve the product during the design phase.

We also have in our installations the prototypes of new developers, for instance Isofoton and Semprius. Isofotón installed in 2012 two concentrators of their last generation. Also, we have a prototype, but not connected to the grid, from Semprius. The CPV module of Semprius set a world record efficiency of 33.9 percent in 2012 and at ISFOC the real performance of the module in real operation in the field was assessed.

Q Is your local climate typical for a CPV installation?

A **MM.** No. We have a good, sunny summer, but during winter we have lots of cloudy days.

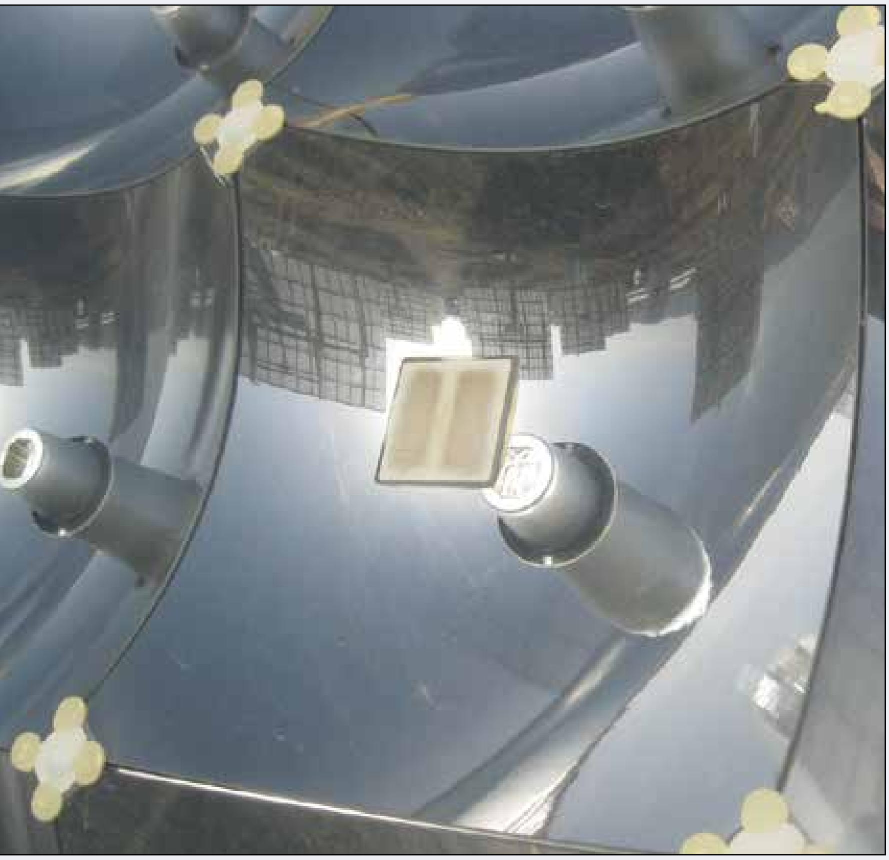
CPV optics focusing the sunlight onto a CPV cell

During the summer, when we have plenty of hours with high values of direct irradiance, we often observe peak values higher than 1000 watts per square metre. So, for assessing CPV, I think we are a good location, because we have high temperatures and high irradiance values. We also have some sunny and cold days that are very helpful to model CPV technology in best operating conditions – high irradiance and low temperatures.

The DNI in Puertollano is around 2,200 kilowatt-hours per square metre. It's one of the highest values in Europe, but it is far away from values in South Africa or Australia, where they see 3500 kilowatt-hours per square metre.

Q **The role of the compound semiconductor industry is to provide multi-junction cells that operate at high levels of concentration. So far, is it fair to say that your data suggests that the cells are up to this task?**

A **MM.** Yes, although we are not experts in evaluating solar cells in depth, we can indicate that not too many issues, related to solar cells, have been detected so far.


A CPV receiver illuminated through a multi-phase reflective optic

We are members of the IEC committee, and what we see is that there is a lot of effort being carried out to improve the efficiency and performance of CPV cells, keeping always in mind the reliability of the devices.

Q **One of your installations contains an early-generation module that has degraded significantly over the years. Tell me about the issues with the optics of that module?**

A **MM.** The first thing that I want to remark is that this module was used for making the installation here in 2007. At the beginning of the project, all the technologies were required to pass some IEC-62108 tests to ensure the reliability of their design, and this technology was failing some of the tests.

In Spain, in those days, a feed-in tariff existed for PV installations, and to obtain those benefits it was mandatory to connect our plants before September 2008, since an important income for ISFOC comes from selling this electricity. Therefore, we decided to go ahead with the installation of this version of the product, although we knew it was failing in some lab testing.

On the one hand, from an R&D point of view, this was a great opportunity to verify if the failures detected in the lab were going to be reproduced in the field. On the other hand, we had a contract with the manufacturer, to maintain our income. If the failures were reproduced, affecting the performance, they would replace some of the concentrators. Finally, failures were repeated in the field. In 2012, they replaced the 18 kW with a new-generation product that was IEC-62108 certified.

The first issue occurred in the first years. It was the gasification of some of the materials inside the module, that were deposited over the optics surface. The effect is like some scattering of the light, reducing the energy that reaches the cells.

There was also some damage to the secondary optics caused by the concentrated sunlight, some kind of failure in the reflective coating.

The most important result that we obtained from this experience is that the IEC-62108 standard is working. It was possible to detect in the lab, with tests, some of the failures occurring in the field.

But some other failures were not possible to detect, so further work is needed in the standardization committee to modify the tests if possible. Failures related to long-term exposure to direct or concentrated sunlight are not so easy to reproduce.

Q **Do you think that when designed with skill and care, modules can be robust, showing minimal degradation?**

A **MM.** Yes. We have some technologies that have been operating for more than ten years. Up to now, everything is working at the same level as it was in the beginning.

It's also important to say that our installations are prototypes. The next products were even better than the ones we have here.

Q **Based on your data, what have we learnt about the reliability of tracker designs?**

A **Eduardo Gil (EG).** I would like to remark that our trackers are based on preliminary designs. At the time, the CPV community focused its efforts on developing CPV modules to be as efficient and reliable as possible. When we started operating and maintaining our CPV power plants, we started to be aware of the importance of other components.

We learnt that the identification of all key components responsible for the vast majority of unavailability is essential to reduce unplanned intervention, increasing the reliability of the trackers. However, if reliability and maintainability weren't taken into account during the early stages of the design, when the cost of making any change is cheaper, the cost of increasing the reliability during the operation time would be unaffordable.

Q **Do you see any concerns relating to reliability when moving to higher concentrations, such as focusing light by 2000 suns rather than 500 suns?**

A **MM.** We are not experts in cells. Going to a higher concentration means that more heat dissipation in the module and the cell is needed. Most modules have passive cooling. And perhaps higher concentration will require active cooling, which it is not desirable because it would be more complex and expensive during installation and O&M tasks.

We have systems here with small cells that are working up to 1000 suns. But going to higher concentration, in my view, may require a move to dense CPV receivers with solar dishes or parabolic mirrors, including active cooling for heat dissipation – like Solar Systems, Raygen, in Australia.

> We have systems here with small cells that are working up to 1000 suns.But going to higher concentration, in my view, may require a move to dense CPV receivers with solar dishes or parabolic mirrors, including active cooling for heat dissipation .

I know that one way to reduce the cost of a concentrator is to increase concentration without increasing the cost of the rest of the elements. But I think that perhaps 2,000 suns is too high at present.

Q **To me, it is the parts of the system that I have given little thought to that are to blame for the most failures. These are control systems and firmware. Why have they been so problematic? And can these weaknesses be addressed?**

A **EG.** Not all software and firmware is problematic. That only occurred with one of our partners who decided to design their own inverter, due to the fact that there wasn't in the market any specific inverter for CPV technology.

We also suffered from hardware issues. That inverter included the control system in the same box. It had caused several problems, because of the heat generated inside.

Thanks to our data analysis and support, they improved the software and were aware of the heat dissipation problems.

One of the CPV plants located at ISFOC headquarters

Some years later, some inverter manufacturers adapted their design for CPV technology. This partner decided to use commercial inverters in their system, avoiding the problems of the combination of inverter and the controller of the tracking system.

Q A significant proportion of CPV downtime is also due to issues associated with encoders and limit switches. What's the role of these components, and can they be improved?

A **EG.** A tracker usually has two encoders: one for the elevation axis, and one for the horizontal axis. Basically, the encoder is a counter. It sends the position of the tracker to the control board.

Regarding the limit switch, it is used to prevent the tracker from reaching a forbidden position during operation. It's a normally closed contact, but when it is pressed, the contact opens and stops the current.

We now have more than ten years of experience in the operation and maintenance of tracking systems. We have detected many of these components located in an improper place. Most of the time, the encoder is in a place where, for example, water can get inside; if it were better located, it would work properly. It's not really a problem with the component; it's a problem with the design of the tracker.

Q Now that the most likely causes of failure for a CPV system have been identified, what figures should be possible for uptime and annual degradation?

A **EG.** Up to now, we don't have enough records to answer this question. In our opinion, the degradation of mechanical parts is always a controversial topic and depends on not only the maintenance strategy deployed but also on the operational environment where the CPV is installed. High winds, extreme temperatures, heavy rains, etc., will play an important role.

MM. And if we talk about degradation of the CPV technology itself, the CPV modules, we can say that this is one of our fundamental analyses. We are continuously analysing the performance of the CPV plants but filtering out all the data related to maintenance and operation incidences, which means analysing the performance of the CPV technology only. We compare the energy of production with the DNI accumulated for the different years of operation. What we have up until now – and what we hope will continue in the future – is that the level of degradation is less than one percent per year. It's in the same level as flat PV.

Q **Is there a role for preventive maintenance in the operation of a CPV plant?**

A **EG.** Of course there is a role for preventive maintenance in the operation of CPV plants. Preventive maintenance is essential for boosting the market confidence of this technology. Many people believe that maintenance is an extra cost, however, from our point of view, it's an investment. During the first years of operation of our CPV power plants, we evaluated and adapted all the operation and maintenance protocols for CPV technology, which allowed us not only to increase reliability of our CPV power plants, but also to reduce drastically the maintenance costs, increasing the uptime of the systems installed at our facilities.

The main idea is that we pay for maintenance to gain reliability and availability of our CPV plant. Optimised maintenance strategies increase production revenue, and that means more income for the investor.

Q **You have found that operation incidences would be lower if more support were given by suppliers. But some suppliers are no longer in business. That must be a concern for efforts to rejuvenate this industry, as investors in CPV will want to be supported by system makers that will be in this industry for many years to come?**

A **MM.** Economic issues have really strangled the photovoltaic sector.

Manufacturers of CPV were trying to develop a different product, like some special PV technology, so for them it was even more difficult to obtain funds from banks or investors. Without investment, you cannot make any improvement to the technology. A lot of companies were pushed to close their business, because of this crisis.

I think, and hope, that new CPV developers will not suffer from this issue. The story of Concentrix, Soitec and Stace Electric shows that if you have a good a product, someone will have confidence in it.

I hope that in the near future we will have again big partners in this industry.

Q **Compared to the figures quoted about a decade ago, is the levelised-cost-of-energy coming down, due to a greater understanding of reliability issues?**

A **EG.** The levelised-cost-of-energy is coming down due to two main reasons. On the one hand, the CPV installation cost has dropped significantly from 2009 to 2018 – this fact strongly affects the levelised-cost-of-energy.

On the other hand, our maintenance strategy has allowed us to increase reliability. In other words, it has allowed us to reduce the maintenance cost, so the levelised-cost-of-energy also comes down because of this cost reduction.

Moreover, it is important to remark that year-after-year, the three-junction cells are beating the efficiency record. This also helps to reduce the levelised-cost-of-energy.

Q **Do you see any signs for a possible re-birth of the CPV industry?**

A **MM.** Yes, I think so. Inside the community, what we see is that again there are new developers, university researchers and small companies fighting to demonstrate that their product has a place in the electricity generation market.

A sample of active companies nowadays: BSQ Solar, Spain; Raygen, solar dishes and central tower receivers, Australia; Morgan Solar, Canada; MagPower, Portugal; and don't forget about Stace Electric, Canada, who currently owns the technology of Concentrix Solar.

Moreover, we must name some projects that are funded by public entities, such as CPV4all and CPV Match, demonstrating that there are some interesting developments in CPV.

Finally, it must be said that there are new CPV concepts under development that could enlarge the market of the technology – like hybrid CPV-thermal systems, which use an active cooling of the solar cells to warm up fluids – or BICPV – building integration CPV – that are being explored by the CPV community.