Visit to the Moura Photovoltaic Power Station in Portugal

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This photovoltaic (PV) power facility was brought to our attention by a SKADS group, who held a meeting in Lisbon and visited the station in Oct, 2008. The site (Long 38.19696; Lat 7.21290) is located beside Amareleja in Portugal, a small town about 25 km away from Moura, the largest town in the district.

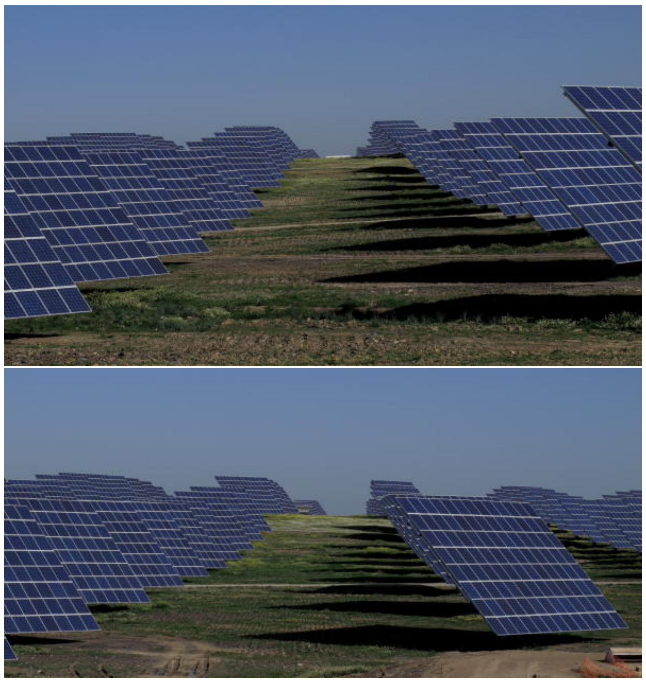

Figure 1: Two general views of the array of PV panel assemblies.

The facility consists of 2520 large assemblies (Figure 1) of solar panels (trackers), mounted on towers. The panel assemblies are mounted on a flat frame at a fixed Zenith angle of 45 degrees and track the sun in Azimuth over a range of 240 degrees. Each panel assembly is 142 m^2 (13 x 10.9 m) and contains 104 polycrystalline silicon modules, each capable of about 180 W peak. The panels, supplied by Yingli Solar, are guaranteed to operate at greater than 80% efficiency for 25 years.

The site occupies 250 hectares of land. The company owns 320 hectares total.

The power delivered to the grid by the total of 262080 panels is ~46 MW peak and ~10 MW average (93 million KW-h per year). The plant has been in full operation since Dec. 2008.

The builder and owner of the plant is ACCIONA Solar, a subsidiary of a large Spanish-based conglomerate with offices around the world (30 countries). (We understand that a share of this plant has recently been sold to Mitsubishi).

We were interested in this project for two reasons:

1. The array and number of elements in the array resembles the core of the SKA. Thus the project planning, execution time and other aspects of construction could provide an example of what is possible for the SKA in terms of installation time, cost of infrastructure, etc.
2. The generation of solar power on the two candidate sites is a real possibility. Thus this new installation could provide relevant data on the feasibility and cost of photovoltaic solar power and its cost.

We met the following key project people at the site:

- Miguel Arraras, Manager Acciona Solar. Located in Spain.
- Francisco Aleixo, Civil engineer with Acciona. In charge of planning and executing the construction of the system.

- Jose M. Liqete Garcia, Director Comercial for STI norland, the company which supplied the structural and mechanical components of the solar panel systems.

We arrived with an extensive agenda, which after re-organization is reflected in the following items. Our hosts were very open and accommodating.

1. Project Management Aspects: pre-construction design time, execution time (planned schedule vs actual schedule).

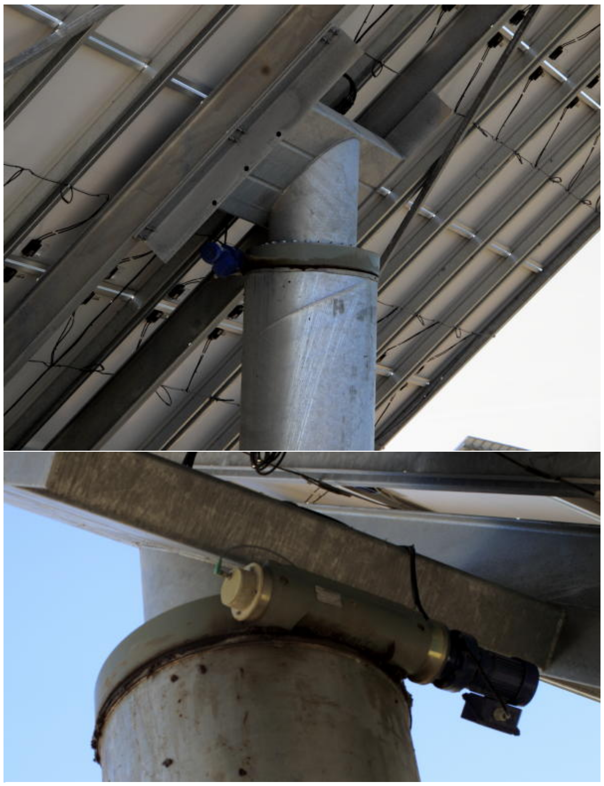

Figure 2: Drive mechanics for a panel assembly. The drive consists of a fixed ring gear mounted on the support post and a motor driven worm gear.

- The project started in Jan 2007, when Acciona Solar purchased the assets of a consortium that included the local municipality. The most important asset was the right to connect to the power grid. Thus this point marks the starting time for the project.
- Land and permits were acquired from Jan to Nov 2007.
- Engineering design and procurement was started in Feb 2007, in parallel with permitting, and continued until Nov 2007, when actual construction began.
- STI norland began production of the mechanical and structural components in Dec 07 and completed the supply of the 2520 assemblies by June 2008 (7 months). The drives and structure were built in an assembly plant by a crew working one 8-hour shift per day. Using a total of 140 working days (20 per month), the output rate is estimated to be 18 units per day.
- Total construction time was ~13 months and there seemed to have been few problems with the schedule.
- Cost of civil works was about 5% of the total cost of 261 MEuro.
- Labour was sourced mainly from the local population, and workers were trained on the job by the company as needed. An average of 150 workers (250 peak) were needed on the site.

2. Procurement and contracting

- The solar panels were purchased from Yingli Solar of China (Figure 4).
- As noted above the mechanical and structural components were procured from STI norland (Figures 2 and 3).
- A small company was also created in the region to carry out some of the panel assembly. This company continues to assemble PV components for external sale.

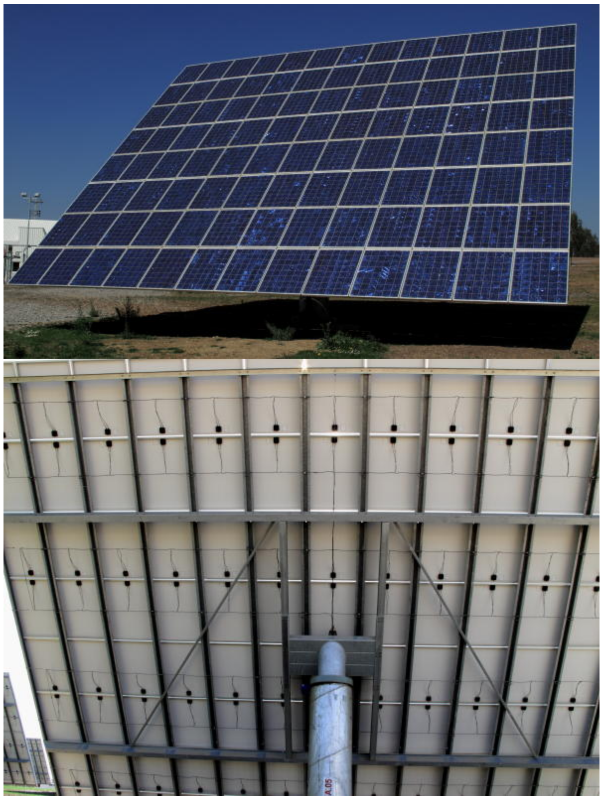

Figure 3: Front and rear view of panel assembly. The outputs of the panels are connected in a series-parallel fashion and wired directly to the inverter pods located throughout the array.

- We were not informed of what sort of tendering process was used for these components. No delays were indicated in either of these procurements.
- Coordination of the external contracts with in-house work was done directly by Acciona Solar.

3. Cost of Energy

- The all-inclusive cost of generation from this facility is estimated by Acciona to be 0.30 Euro per kWh. In particular this includes the cost of financing and depreciation. Although we do not have a breakdown, the financing costs can be estimated. Using an interest rate of 5%, the cost of an interest-only loan of 261 MEuros is 13 MEuro per year. This is 0.14 Euro per kWh, based on delivered power of 93 M kWh per year. Depreciation, based on a 25 year lifetime, would be an additional 0.11 Euro per kWh. This leaves about 0.05 Euro for actual operations. Clearly these are a simple-minded calculations meant merely to provide a bit of context to costs.

4. Comparison of Solar Technologies

- Why choose photovoltaic (PV) technology as compared with solar thermal? Acciona has experience with both types of systems. They argue that PV has its place and emphasize the following points: If there is access to the grid, PV has the advantages of system simplicity and linear expandability. The Moura system is clearly simple to build and install. Solar thermal requires the use of multiple technologies, including steam generators and potentially handling molten salt for storage. Although generation with steam is very mature technology, it is complex and requires considerable maintenance. Solar thermal systems also need access to a water supply.
- The Moura station is limited to 46 MW, purely as a political constraint. The station could be easily enlarged, should the need arise.
- PV does not provide on-site energy storage. Acciona emphasize that there have been developments with battery systems that may enable more cost effective battery storage in the near future. Production of hydrogen for energy storage is also a rapidly developing technology.

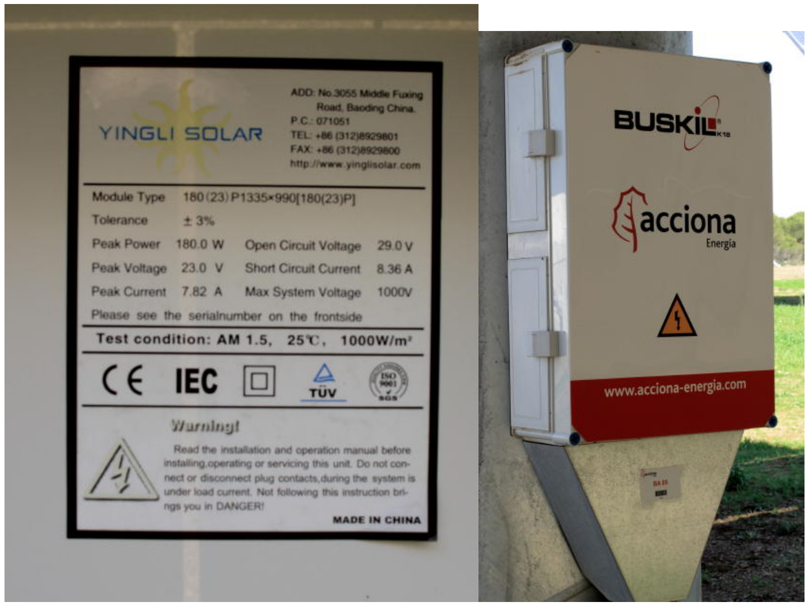

Figure 4: Tracker detail. Left: Name plate showing the PV panel manufacture and specifications. Right: Local control and monitoring unit for each tracker assembly. Each tracker operates autonomously.

5. Maintenance

- The plant is too new to obtain mean time between failure (MTBF) information.
- As noted above, the PV cells have a 25 year guarantee.
- Cleaning is not cost efficient. Rain is sufficient to keep the panels clean.
- Trackers are designed for 150 km/hr survival wind speed.
- The general simplicity of the system indicates that very little maintenance will be required.
- The system contains a fully computerized monitoring system, which provides the site operators with a complete picture of system health. Figure 4 shows the control box for one of the trackers.

6. SKA Discussion

- Acciona is interested in the SKA and are willing to provide advice on power and infrastructure issues, and wish to remain in communication with the project. They see the SKA as a high profile project and understand the benefit of company involvement from that perspective.
- There was an extended discussion of EMI issues and power equipment. The PV system contains many DC-to-AC converters that involve large-current solid state switches (Figure 5). Almost all power systems contain such equipment. Slew rate control of switch waveforms is not under user control. Designing bespoke systems to improve control of RFI would be very expensive – thus we must control EMI by other means. Francisco Aleixa suggests that all such equipment should be housed underground to

Figure 5: The two white boxes in the centre of the picture are inverter units that receive DC power from the panel assemblies and output AC power to the plant substation.

provide natural shielding. In the extreme temperature environments of the candidate sites, this also has the benefit of keeping the equipment cooler and closer to constant temperature, provided sufficient air flow is provided.

- Acciona is quite interested in the design of small power systems (~100 kW) for the remote SKA stations. If they were designing a system today it would consist of PV arrays, a small wind generator and sufficient battery storage for 24 hour operation.