UTILITY SCALE PV: LEVERAGING SPANISH EXPERIENCE IN THE US MARKET

Matt Anderson
June 29, 2010
ARIES WORLDWIDE

- Global renewable energy engineering and project development company since 1987
- References in 20+ countries
- 160+ employees

- 15 MW PV In operation
- 150 MW CSP in construction
- Offices in Madrid, San Francisco, and Shanghai
### PROJECT INFORMATION

<table>
<thead>
<tr>
<th></th>
<th>ARSOL-1</th>
<th>ARSOL-Toledo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project name</strong></td>
<td>ARSOL-1</td>
<td>ARSOL-Toledo</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Damiel, Spain</td>
<td>Toledo, Spain</td>
</tr>
<tr>
<td><strong>Site</strong></td>
<td>40 ha / 99 acres</td>
<td>80 ha / 198 acres</td>
</tr>
<tr>
<td><strong>Electrical connection</strong></td>
<td>To 15 kV line</td>
<td>To 66 kV line</td>
</tr>
<tr>
<td><strong>Operation date</strong></td>
<td>February, 2008</td>
<td>July, 2008</td>
</tr>
</tbody>
</table>

### SOLAR FIELD

<table>
<thead>
<tr>
<th></th>
<th>2-axis tracking 25 kWp/tracker</th>
<th>2-axis tracking 12.5 kWp/tracker</th>
</tr>
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<tbody>
<tr>
<td><strong>Type of structure</strong></td>
<td>2-axis tracking 25 kWp/tracker</td>
<td>2-axis tracking 12.5 kWp/tracker</td>
</tr>
<tr>
<td><strong>Solar panels</strong></td>
<td>Suntech STP 175S-24/AC</td>
<td>Suntech STP 270S-24/VB</td>
</tr>
<tr>
<td><strong>Number of solar panels</strong></td>
<td>33,150</td>
<td>43,200</td>
</tr>
<tr>
<td><strong>Inverters</strong></td>
<td>Siemens 100 kW</td>
<td>Siemens 100 kW</td>
</tr>
</tbody>
</table>

### CAPACITY & PERFORMANCE

<table>
<thead>
<tr>
<th></th>
<th>5 MW</th>
<th>10 MW</th>
</tr>
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<tbody>
<tr>
<td><strong>Nominal capacity</strong></td>
<td>5 MW</td>
<td>10 MW</td>
</tr>
<tr>
<td><strong>PV power installed</strong></td>
<td>5.80 MWp</td>
<td>11.66 MWp</td>
</tr>
<tr>
<td><strong>Plant performance</strong></td>
<td>Contractual PR 72%; current PR during operation 80%</td>
<td>Contractual PR 73%; current PR during operation 80%</td>
</tr>
<tr>
<td><strong>Gross annual energy</strong></td>
<td>11.70 GWh/year</td>
<td>22.95 GWh/year</td>
</tr>
</tbody>
</table>
1. DESIGN & CONSTRUCTION

2. OPERATION AND MAINTENANCE
1. DESIGN & CONSTRUCTION

1.1. Site selection
1.2. Equipment selection
1.3. Engineering design
1.4. Site preparation
1.5. Commissioning
1. CONSTRUCTION PHASE

1.1 SITE SELECTION

Solar resource

... SW US has solar resource about 20% > Spain
1. CONSTRUCTION PHASE

1.1 SITE SELECTION

Wind conditions
1. CONSTRUCTION PHASE

1.1 SITE SELECTION

Soil Conditions
1. CONSTRUCTION PHASE

1.2. EQUIPMENT SELECTION

Fixed vs tracking structure

<table>
<thead>
<tr>
<th></th>
<th>Area needed</th>
<th>Production</th>
<th>Plant Availability</th>
<th>Energy Consumption per 1MW</th>
<th>1 MW Construction time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Structure</td>
<td>6.3 acre/MW</td>
<td>Base production</td>
<td>99.5 %</td>
<td>0.5 MWh/year</td>
<td>2 weeks</td>
</tr>
<tr>
<td>1 axis tracking</td>
<td>10 acre/MW</td>
<td>19 % increase</td>
<td>97 %</td>
<td>5.1 MWh/year</td>
<td>4 weeks</td>
</tr>
<tr>
<td>2 axis tracking</td>
<td>19 acre/MW</td>
<td>34 % increase</td>
<td>96 %</td>
<td>38.9 MWh/year</td>
<td>6 weeks</td>
</tr>
</tbody>
</table>
1. CONSTRUCTION PHASE

1.2. EQUIPMENT SELECTION

Fixed vs tracking structure

Array Technologies
Duratrac 1-axis tracker
1. CONSTRUCTION PHASE

1.2. EQUIPMENT SELECTION
1. CONSTRUCTION PHASE

1.2. EQUIPMENT SELECTION

Redesign during operation
1. CONSTRUCTION PHASE

1.2. EQUIPMENT SELECTION

Redesign during operation
1. CONSTRUCTION PHASE

1.2. EQUIPMENT SELECTION
1. CONSTRUCTION PHASE

1.3. ENGINEERING DESIGN

Shading issues

Partial shadings on one cell

PV module BP270-2170 of BP Solar

Effect of shadows on PV modules
1.3. ENGINEERING DESIGN

Shading issues

Two axis tracker plant with 16% shading losses
1. CONSTRUCTION PHASE

1.3. ENGINEERING DESIGN

Shading issues

Two axis tracker plant without shading
1. CONSTRUCTION PHASE

1.3. ENGINEERING DESIGN

Shading issues
1.3. ENGINEERING DESIGN

Shading issues
1. CONSTRUCTION PHASE

1.3. ENGINEERING DESIGN

Foundation: Screw vs. Vibration Embedment vs. Ballasts

SunPower T20 Tracker at Nellis Airforce Base
1. CONSTRUCTION PHASE

1.3. ENGINEERING DESIGN

Inverters

The information provided in the graph contains merely general descriptions or characteristics of performance which, in case of actual use, do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in the terms of contract.
1. CONSTRUCTION PHASE

1.3. ENGINEERING DESIGN

Transformers

Power output/temperature relation for a Siemens 100 kVA Transformer
1. CONSTRUCTION PHASE

1.3. ENGINEERING DESIGN

Cooling systems
1. CONSTRUCTION PHASE

1.4. SITE PREPARATION

Expensive earth movement and civil works ...
1. CONSTRUCTION PHASE

1.4. SITE PREPARATION

... or just trenches and foundations
1.5. COMMISSIONING

• Key elements to check before the acceptance tests:

  • Cable trace
  • Inverter measurements
  • Tracking systems (mechanical and I&C)
  • Electrical protections
  • Control system
  • Grounding
1.5. COMMISSIONING

Commissioning without connection to the Grid requires a source of power for the inverters and a load for the energy produced.
2. OPERATION AND MAINTENANCE

2.1. Panel Cleaning
2.2. Operation
2.3. Performance of the Plant
2.4. Thermal inspections
2.5. PV Control and Monitoring System
2.6. O&M Costs
2. OPERATION AND MAINTENANCE

2.1. PANEL CLEANING

- Panels that are not periodically cleaned can have 5-8% power loss
- Use of groundwater may cause mineral deposits on the panels
- Use of deionized water may damage panel frame
- Effect of cleaning on power production is not as important as often stated
- Panel cleaning schedule is very site and technology specific
2. OPERATION

Real production data of different technologies of PV Plants in Spain
2. OPERATION AND MAINTENANCE

2.3. PERFORMANCE OF THE PLANT

Production increase after 1 year of operation (2 axis trackers 10MW PV Plant)

+ 31.2 %
2. OPERATION AND MAINTENANCE

2.4. THERMAL INSPECTION
2. OPERATION AND MAINTENANCE

2.5. PV CONTROL AND MONITORING SYSTEM
2. OPERATION AND MAINTENANCE

2.6. O&M COSTS

Case Study: Tucson Electric Power (TEP) 3.51 MWp Springerville, AZ PV Plant

- Installed between 2001-2004
- 26 x 135 kWp systems, fixed structure, Schott modules and Xantrex inverters
- EPC cost $5.40/Wp ($3.33/Wp panels!)

<table>
<thead>
<tr>
<th>Year</th>
<th>Scheduled</th>
<th>Unsched.</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>2002</td>
<td>$0.004</td>
<td>$0.001</td>
<td>$0.005</td>
</tr>
<tr>
<td>2003</td>
<td>$0.004</td>
<td>$0.012</td>
<td>$0.016</td>
</tr>
<tr>
<td>2004</td>
<td>$0.003</td>
<td>$0.002</td>
<td>$0.005</td>
</tr>
<tr>
<td>2005</td>
<td>$0.003</td>
<td>$0.001</td>
<td>$0.004</td>
</tr>
<tr>
<td>2006</td>
<td>$0.002</td>
<td>$0.002</td>
<td>$0.004</td>
</tr>
</tbody>
</table>


UNSCHEDULED MAINTENANCE COSTS BY CATEGORY

- DAS
- Inverter
- Junction Box
- PV
- System
- AC Disconnect

14% 59% 3% 6% 12% 14%
## LEARN FROM SPANISH MARKET EXPERIENCE?

<table>
<thead>
<tr>
<th></th>
<th>SPAIN</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market driver</td>
<td>Real Decreto 661/2007</td>
<td>State RPS</td>
</tr>
<tr>
<td>Incentives</td>
<td>FiT</td>
<td>ITC, MACRS, State incentives</td>
</tr>
<tr>
<td>Utility scale electricity price</td>
<td>0.44€/kWh for 25 years; new projects 0.31€/kWh</td>
<td>PPAs in range of $0.12 - $0.22/kWh</td>
</tr>
<tr>
<td>Guarantees</td>
<td>2 year EPC Performance Guarantee + equipment warranties</td>
<td>Performance Guarantee? EPC Workmanship + equipment warranties</td>
</tr>
<tr>
<td>Grid-tied PV capacity addition in 2008</td>
<td>2500 MW+</td>
<td>292 MW</td>
</tr>
<tr>
<td>Grid-tied PV capacity addition in 2009</td>
<td>Approx. 40 MW</td>
<td>441 MW</td>
</tr>
<tr>
<td>Future</td>
<td>Retroactive FiT cuts or 400 MW/year market?</td>
<td>Nationwide RPS? FiT?</td>
</tr>
</tbody>
</table>
THANKS FOR YOUR ATTENTION

![arsol_1_5mw.png](https://www.aries.com.es/wp-content/uploads/2016/12/arsol_1_5mw.png)

Arsol 1 (5MW) ARIES PV Plant
For additional information, please contact:

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