Accurately modeling and effectively maximising returns on large scale PV plants

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Session Topics

• Key risks identified for regional solar PV projects
  – Design and Construction Phase
  – Operations Phase, including plant performance
• Lessons learned to develop more accurate models for payback times in future projects
  – Irradiance data selection, given regional climate & data
  – Performance ratio estimation, based on lessons learned from regional operating data
Mott MacDonald Introduction

14k staff

140 countries

£1bn turnover

Employee owned
1,600+ power specialists work for 4 client groups

- Constructors/contractors/OEMs
- Asset owners/developers
- Funders and Lenders
- Governments and Regulators

Four (4) main roles:

- Lender’s engineer / Owner’s Engineer / Independent Engineer / Contractors’ Engineer

We work internationally from six main locations in power:

- UK/Europe
- USA/Canada
- Middle East
- Asia Pacific (and SEA)
- Southern Africa
- Indian sub-continent
A top global firm in power sector consultancy with pioneering role in the solar and wind sector for 15 years

Strong global track record: > 6GW for solar; > 25GW for wind

Strong presence in South East Asia from our offices in most countries in SEA

Supported **1.4 GW of Solar projects in SEA (Thailand, Malaysia and Philippines)**

Supported **2.3 GW of Solar projects in Asia Pacific**

We have worked on 75% of the operational Solar / Wind capacity in SE Asia

Compiled **Regional Technical Guidelines for PV plant financing** in SE Asia – disseminating to investors with GIZ in Philippines, Malaysia and Indonesia
Regional Project Status
## SEA Solar Project Status – Public Information

<table>
<thead>
<tr>
<th>Country</th>
<th>Solar Project Status (MWp)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Installed</td>
<td>Under</td>
<td>Pipeline</td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>≥ 42</td>
<td>-</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>150.5</td>
<td>69.7</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Philippines</td>
<td>≥ 23</td>
<td>≥ 30</td>
<td>1,354</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>~ 1,400</td>
<td>≥ 130</td>
<td>~ 1,500?</td>
<td></td>
</tr>
</tbody>
</table>

Sources: MM Project Database; MEMR, Indonesia, March 2014; SEDA, Malaysia, Sept 2014; DOE, Philippines, Sept 2014; EPPPO, Thailand, June 2014; press releases
SEA Solar Projects – PV Modules Used

Estimated breakdown by capacity; sourced from Mott MacDonald project database
Key risks identified for regional solar PV projects
Key technical issues from project design

• Common design shortcomings
  – Flood mitigation and drainage design
  – Mounting structure foundations
  – Cable selection (capacity, insulation), ducting
  – Materials selection with respect to corrosion

• Equipment suitability to environment
  – Inverter response to high humidity / temperature
  – DC breakers (high temperature in string box)
Key technical issues in project operation (1)

- Poor O&M is a key risk; range of qualified 3rd party O&M contractors in Thailand; still emerging in other markets
- Irradiance has typically been higher than projected based on historical ground measurements
- Plant performance ratios are typically in the range 75-80%; shortfalls typically from plant downtime
  - Downtime due to modules, inverters, BOP and grid
- Grid overvoltage a key risk, especially in rural areas or weakly interconnected islands
  - Related plant outages uncompensated under the PPAs
Key technical issues in project operation (2)

• Unusually high inverter outage hours at some plants
  – Protection settings and nuisance tripping (wrt overvoltage)
  – Lack of local maintenance base for some inverter suppliers
• Poor repairs; affecting electrical terminations
• Intelligent monitoring of plant performance not yet standard practice
  – Accurate irradiance measurement in plane of array
  – Synchronised plant AC output measurement
  – Software to meaningfully interpret operational data
Lessons learned to develop more accurate models for payback times in future projects
# Solar Irradiance Data Sources

## Gathering Data
- Terrestrial versus satellite data sources – fundamentals
- Available data sources in region (e.g. MeteoNorm, SolarGIS, 3Tier, National Meteorological Agency, etc)
- Availability of ground measurement stations in region
- Site meteorological station for accurate long term prediction (pyrometers, reference cell)

## Data Analysis
- Correlation/verification of two independent sources of Irradiance data e.g.
  - National Meteorological Agency, SolarGIS, etc
- Independent Energy Yield Analysis, using:
  - In-house modelling
  - off-the-shelf software (PVSYST)
Regional Solar Irradiance Profile
Solar Irradiance Selection Considerations

• Available irradiance data accuracy varies significantly across the region
  – Countries with more complex topography subject to higher variations in irradiance conditions
  – Long-term, quality-controlled pyranometer measurements close to the site (e.g. within 20 km) the best possible irradiance data source

• Satellite-derived irradiance data an essential tool, but only subject to suitable validation
  – Validation must be for ground measured data in a similar climate to the Project site, and ideally located close by
<table>
<thead>
<tr>
<th>Capture Losses</th>
<th>System Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Losses</td>
<td>Typical Annual Average Losses in % (in SEA)</td>
</tr>
<tr>
<td>Spectral</td>
<td>0.5% loss to 0.5% gain</td>
</tr>
<tr>
<td>Shading</td>
<td>1 - 5% loss</td>
</tr>
<tr>
<td>Soiling</td>
<td>1 - 2% loss</td>
</tr>
<tr>
<td>Angular</td>
<td>1 - 3.5% loss</td>
</tr>
<tr>
<td>Low irradiance performance</td>
<td>3.5% loss to 2% gain</td>
</tr>
<tr>
<td>Temperature losses</td>
<td>4 – 12 % loss</td>
</tr>
<tr>
<td>Power tolerance</td>
<td>3% loss to 2% gain</td>
</tr>
<tr>
<td>Light-induced degradation (LID)</td>
<td>0 – 2 % loss</td>
</tr>
<tr>
<td>MPP tracking losses</td>
<td>0 - 1% loss</td>
</tr>
<tr>
<td>Mismatch</td>
<td>0.5 – 1% loss</td>
</tr>
<tr>
<td>DC and AC cabling losses</td>
<td>1 - 4% loss</td>
</tr>
<tr>
<td>Inverter curtailment</td>
<td>0 - 4% loss</td>
</tr>
<tr>
<td>AC/DC Inverter conversion</td>
<td>1 - 4% loss</td>
</tr>
<tr>
<td>Transformer</td>
<td>1 - 2% loss</td>
</tr>
<tr>
<td>Auxiliary</td>
<td>0 – 2% loss</td>
</tr>
<tr>
<td>Unavailability</td>
<td>0 - 2% loss</td>
</tr>
</tbody>
</table>
Mott MacDonald Validation Analysis

- In-field Operating Data
- Plant Design
- PV module Laboratory Test Result

Validation Analysis → PV Plant Performance Modelling

- Modelling Error

Actual Power Output + Calculated Power Output

- Less than 1 % difference compared to actual energy output
- High correlation coefficient on a one minute basis (more than 99%)

Good agreement between Mott MacDonald’s in-house modelling and actual plant performance under the observed environmental conditions for both plants

Mott MacDonald
References


• “Gaining confidence in PV module performance through laboratory testing, factory audit and analysis of in-field data”, POWER-GEN Asia, Bangkok, October 2012. Napier-Moore, PA; Verojporn, S.

Thank you for your attention