Scenarios for a South African peaking CSP system in a short term

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Agenda

- Objective
- Rationale
- Methodology
- Load demand
- Scenario 1: peaking OCGT system
- Scenario 2: peaking CSP system and grid energy
- Scenario 3: peaking CSP system combined with OCGT
Background

Objective
- To investigate the feasibility of utilizing the CSP plants as peaking stations in South Africa

Rationale
- IRP 2010 – 2030 states that future peak load will be met by OCGT which operate using diesel and represents an allocation of 4,930 MW
- IRP does not identify the CSP as a potential peaking solution and allocates 1,200 MW
- CSP system with TES is a dispatchable source of electricity

Validity
- Competitive energy generation costs
- Guarantee of electricity to the grid
Methodology

Technology type

- Commercially available central receiver (Gemasolar CSP plant is used as the reference plant to obtain operating parameters)

\[(1 - \alpha) \dot{Q}_{in} = \sigma \varepsilon \sum_{i=1}^{n} A_i F_i (T_{r,i}^4 - T_a^4) + h A_r (T_r - T_a) + \dot{Q}_{out}\]

\[\eta_{TES} = 90\% \text{ roundtrip}\]

\[\eta_{th} = 1 - \frac{T_L}{T_H}\]

\[\eta_{optical} = 0.4254 \theta_Z^6 - 1.148 \theta_Z^5 + 0.3507 \theta_Z^4 + 0.755 \theta_Z^3 + 0.5918 \theta_Z^2 + 0.0816 \theta_Z + 0.832\]
CSP scenario: peaking power fuel saver

South Africa, Lesotho and Swaziland

Proposed sites: situated along the high capacity transmission line running towards Cape Town

Site average DNI: 2,636.43 kWh/m²/a
## Dispatch model

<table>
<thead>
<tr>
<th>Step</th>
<th>Plant 1</th>
<th>Plant 2</th>
<th>Plant 3</th>
<th>Plant 4</th>
<th>…</th>
<th>Plant n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin hour: Rank storage</td>
<td>E.g. 50% R=2</td>
<td>E.g. 40% R=3</td>
<td>E.g. 60% R=1</td>
<td>E.g. 5% R=n</td>
<td>…</td>
<td>E.g. 10% R=n-1</td>
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<td>For hour: Run full energy balance</td>
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<tr>
<td>Determine dispatch demand for hour</td>
<td>NA</td>
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<tr>
<td>Dispatch that hour</td>
<td>Dispatch if R1 full load &lt; demand</td>
<td>Dispatch if R1+R1 &lt; demand</td>
<td>Dispatch up to full load</td>
<td>Etc.</td>
<td>Etc.</td>
<td>Etc.</td>
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<tr>
<td>Deplete storage end of hour</td>
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<td>Based on dispatch</td>
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</tbody>
</table>
Load demand

- Take 90% of the maximum hourly demand in each day as the daily baseload limit
Scenario 1: OCGT energy supply

- The OCGT is used to meet the peak load
- The current capacity of OCGT is increased according to the IRP requirements

- Capacity OCGT = 5,000 MW
- OCGT_LCOE = 5.08 ZAR/kWh

- The OCGT is highly dependent on fossil fuel
- Prediction based on current SA conditions: fuel will likely increase
Scenario 2: CSP system and grid energy

CSP system is used to meet the peak load and the grid energy is used to meet the gap load that the CSP is unable to meet.

CSP Capacity = 3,300 MW
LCOE_CSP = 1.89 ZAR/kWh
Curtailment coefficient = 0.06
Fulfilment coefficient CSP = 0.82

- Grid energy is used to supply the gap demand
Scenario 2: CSP system and grid energy

- Grid energy is used to charge the HTF in the hot tank
- The energy purchase is based on the weather prediction model

Demand gap fullfilment = 0.58
Energy purchase scaling factor = 1
LCOE combined = 3.00 ZAR/kWh
Fulfilment coefficient total = 0.92
Scenario 3: CSP system and OCGT system

OCGT is used to supply the gap energy demand
LCOE_OCGT = 6.67 ZAR/kWh
(15% more than the scenario 1 LCOE)
Scenario 3: CSP system and OCGT system

- LCOE combined = 2.78 ZAR/kWh
- Fullfilment coefficient = 1
Conclusion

• Scenario 1: OCGT only = 5.08 ZAR/kWh + fluctuation vulnerability
• Scenario 2: CSP only = 1.89 ZAR/kWh + does not fullfil the demand
• Scenario 2: CSP and grid electricity = 3.00 ZAR/kWh + does not fullfil the energy demand
• Scenario 3: CSP system with the OCGT = lowest LCOE of 2.78 ZAR/kWh + guarantees electricity generation
• For implementation, a fleet of distributed CSP optimized to operate with the OCGT drop the net cost of electricity and show impressive resilience to fuel price fluctuations

Scenario 3 (CSP + OCGT as virtual hybrid peaking system) adds over 3,000 MW CSP without subsidy in the IRP horizon