Case study description only as reference example

Input:
• CTPP:
  • OCGT = 200MW
  Or (not mandatory both of them)
  • CCGT 300MW = TG 200MW + TV 100MW
• RES = PV 40MW
• Energy shifting services provision

Target:
• Maximization of cost savings
• Maximization of integrated performance

Reference production profile for CTPP and RES (PV)

CCGT:
• Flat production Monday-Saturday
• Turn off on Sunday

OCGT:
• Production only during peak hours, for example 2h/d, everyday at 9am and 6pm

PV:
• Average profile for each season (see xls file attached)

RES profile considered flat to simplify calculations
Preliminary but not exclusive examples of hybrid integration

Solver can propose different hybrid integration schemes not limited to:

Seeking process/plant synergies: Energy recovering, Equipment sharing, ....

OCGT: open cycle gas turbine; CCGT: combined cycle gas turbine; PV photovoltaic panels; MuVESS: MultiVector Energy Storage System
Open Cycle Gas Turbine scheme

Example and data available by literature

<table>
<thead>
<tr>
<th>Gas Turbine</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power base load / peak</td>
<td>128.3 / 138.4 MW</td>
</tr>
<tr>
<td>Speed</td>
<td>3000 rpm</td>
</tr>
<tr>
<td>Fuel flow rate</td>
<td>8.32 kg/s</td>
</tr>
<tr>
<td>N° of combustor</td>
<td>18</td>
</tr>
<tr>
<td>Efficiency @ base load</td>
<td>33.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compressor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression rate</td>
<td>14/1</td>
</tr>
<tr>
<td>Air outlet Temperature</td>
<td>379°C</td>
</tr>
<tr>
<td>Air flow rate</td>
<td>443 kg/s</td>
</tr>
<tr>
<td>Absorbed power</td>
<td>167 MW</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Expander</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet temperature base load / peak</td>
<td>1162 / 1208 °C</td>
</tr>
<tr>
<td>Gas flow rate @ outlet</td>
<td>453 kg/s</td>
</tr>
<tr>
<td>Gas temperature @ outlet</td>
<td>495°C</td>
</tr>
</tbody>
</table>
Open Cycle Gas Turbine scheme

Example and data available by literature

(1) Air inlet compressor
(2) Air outlet compressor
(3) Heat absorbed by the air in R1
(4) Outlet Air R1
(5) Heat to be provided with R2 system
(6) Gas turbine admission
(7) Heat released by the gas in R1
(8) Inlet gas R3
(9) Heat released by the gas in R3
(10) Gas to chimney
(11) Air flow rate @ compressor inlet
(12) Gas flow rate @ turbine inlet
(13) Cooling water

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Enthalpy</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C</td>
<td>15 kJ/kg</td>
<td>1 ata</td>
</tr>
<tr>
<td>377,7°C</td>
<td>388,21 kJ/kg</td>
<td>14,01 ata</td>
</tr>
<tr>
<td>377,7°C</td>
<td>388,2 kJ/kg</td>
<td>0 Mj/h</td>
</tr>
<tr>
<td>501,3 kJ/kg</td>
<td>1269,5 kJ/kg</td>
<td>13,47 ata</td>
</tr>
<tr>
<td>1160°C</td>
<td>0 kJ/kg</td>
<td>0 Mj/h</td>
</tr>
<tr>
<td>492,4°C</td>
<td>512,3 kJ/kg</td>
<td>1,03 ata</td>
</tr>
<tr>
<td>0 kJ/kg</td>
<td>0 Mj/h</td>
<td></td>
</tr>
<tr>
<td>492,4°C</td>
<td>388,2 kJ/kg</td>
<td></td>
</tr>
<tr>
<td>0 kJ/kg</td>
<td>0 Mj/h</td>
<td></td>
</tr>
<tr>
<td>492,4°C</td>
<td>512,3 kJ/kg</td>
<td></td>
</tr>
<tr>
<td>1620 t/h</td>
<td>0 t/h</td>
<td></td>
</tr>
</tbody>
</table>
Combined Cycle Gas Turbine scheme

Example and data available by literature

A Synchronous machine
TG Gas turbine
GVR recovery steam generator
TV steam turbine
CO condensator
PA feed water pump

Chimney

Turbogas and GVR
- @compressor inlet
  - Air temperature = 15°C
  - Air pressure = 1013mbar
- @compressor outlet
  - Air flow rate = 522,3kg/s
  - Air temperature = 382,3°C
  - Air pressure = 1396kPa
- @gas turbine inlet
  - Gas flow rate = 464,1kg/s
  - Gas temperature = 1405°C
- @gas turbine outlet – GVR inlet
  - Gas flow rate = 574,1kg/s
  - Gas temperature = 615,6°C
- @GVR outlet – chimney inlet
  - Gas temperature = 99°C

Steam Turbine
- SH steam
  - Flow rate = 252,8 t/h
  - Pressure = 12,87 Mpa
  - Temperature = 550°C
- RH steam
  - Flow rate = 292 t/h
  - Pressure = 2,73 Mpa
  - Temperature = 540°C
- IP steam
  - Flow rate = 48,3 t/h
  - Pressure = 2,86 Mpa
  - Temperature = 332°C
- LP steam
  - Flow rate = 24,9 t/h
  - Pressure = 0,63 Mpa
  - Temperature = 232°C
- steam discharged to the condenser
  - Pressure = 0,04 ata