Increasing competitiveness of CCGT plants in a dynamic market: An owner’s approach

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Content

- Background & Motivation

- Increasing operational flexibility
  - Decreasing minimum-load of a CCGT with GE GT26
  - Decreasing minimum-load of a CCGT with Siemens 4000F
  - Faster start-up of CCGTs with GE 9 FA
  - Increasing part-load efficiency in a CCGT with Siemens V64.3

- Summary
We are Uniper

Our operations:
- Power Generation
- Global commodities
- Energy Storage
- Energy Sales
- Energy Services

€1.71bn
100 years
31.6 GW

Main activities:
- Gas fired plants 11.7GW
- Coal fired plants 9GW
- Nuclear plants 2.5GW
- Energy storage
- Gas fields
- Gas pipelines & infrastructure
- Hydroelectric plants 4.25GW
- Trading
- Energy sales (small to large customers, electricity & gas)
- Services
- Regasification

Where we operate
40+ countries around the world

Employees: 13,000

Fast facts
4th largest generator in Europe
9bn m³ gas storage capacity
Background: Changed market conditions

- Maintenance regimes have moved from hours-based toward starts-based.
- This is largely due to commodity prices, demand and renewables growth.
- Start cost is key for driving value in markets with low power prices and spreads.

=> Measures to improve competitiveness:

Reducing PLANT start-up times

Increasing Low Part Load Range
## CCPP Grain – Main plant data

### Units EOH OH Starts
<table>
<thead>
<tr>
<th>Units</th>
<th>EOH</th>
<th>OH</th>
<th>Starts</th>
</tr>
</thead>
<tbody>
<tr>
<td>61, 71, 81</td>
<td>~ 50,000</td>
<td>~30,000</td>
<td>~ 1,250</td>
</tr>
</tbody>
</table>

### Basic Plant Data

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT Type &amp; Configuration</td>
<td>3 x GT26 single shaft</td>
</tr>
<tr>
<td>Combustion</td>
<td>sequential lean-premix</td>
</tr>
<tr>
<td>HRSG</td>
<td>Drum type, Triple Pressure Reheat</td>
</tr>
<tr>
<td>ST</td>
<td>Alstom STF15c</td>
</tr>
<tr>
<td>Generator</td>
<td>Alstom TOPGAS, hydrogen cooled</td>
</tr>
<tr>
<td>COD</td>
<td>June 2011</td>
</tr>
<tr>
<td>Capacity, CC</td>
<td>425 MWe (3x)</td>
</tr>
<tr>
<td>Pmin original</td>
<td>230 MWe</td>
</tr>
</tbody>
</table>
Modifications made and result

Switching off SEV burners individually

- Hardware modifications to the GT
  - Installation of 24 new shut-off valves in SEV fuel distribution system
- Software modifications of the logic were required covering the GT and BoP
- A review of Risk Assessments and a HAZID/HAZOP led by Uniper Technologies to assess the new risks to GT, HRSG and BoP was completed
- A Unit trial was completed on Grain Unit 6 to enable the assessment of:
  - Performance testing including confirmation of environmental performance at LPL
  - Operation of HRSG and BoP in various conditions
  - GB Grid Code testing

⇒ Emission compliant load could be reduced from 230 MW to 115 MW
Operating experience at Grain

- Early operating experience at Grain has been positive.
- Since installation in autumn 2015, Unit 6 has spent prolonged periods operating in LPL.
- The overnight shutdown has generally not been eliminated from Grain Unit 6 operating regime.

- Defects associated with the "Mercedes" strut which supports the hot end bearing.
- Modifications implemented to prevent overheating of the jacking oil system.
- The full impact of the uneven temperature profile on the LPT has still to be assessed and will continue to be monitored.

Images courtesy of GE
## CCPP Gönyű – Main plant data

### Unit EOH OH Starts

<table>
<thead>
<tr>
<th>Unit</th>
<th>EOH</th>
<th>OH</th>
<th>Starts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26,468</td>
<td>16,826</td>
<td>765</td>
</tr>
</tbody>
</table>

*as of 01st April 2016*

### Basic Plant Data

<table>
<thead>
<tr>
<th>GT Type &amp; Configuration</th>
<th>1 x SGT5-4000F(6), single shaft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion</td>
<td>Premix pilot, Dual Fuel</td>
</tr>
<tr>
<td>HRSG</td>
<td>STF, Triple Pressure (HP Benson) + Reheat</td>
</tr>
<tr>
<td>ST</td>
<td>Siemens SST5-5000, HP/IP + LP</td>
</tr>
<tr>
<td>Generator</td>
<td>Siemens SGen5-3000W</td>
</tr>
<tr>
<td>COD</td>
<td>May 2011</td>
</tr>
<tr>
<td>Capacity, CC</td>
<td>429 MWe</td>
</tr>
<tr>
<td>Pmin original</td>
<td>250 MWe</td>
</tr>
</tbody>
</table>
Part Load upgrade scope

• Implementation of CO Reduction (COR) package
  - Additional pressure measurements at compressor extractions
  - Activation of Air Pre-Heater (APH) during part load
  - OTC part load increase

• Installation of about 50 additional thermocouples at various HP evaporator harps. All TC’s are permanently connected to DCS
  → Early detection of instabilities
  → Ability to approach real HRSG load limit and to verify effectiveness of counter-measures
Expectations of COR Package

- Reduction of Minimum Environmental Load (site CO limit: 100mg/Nm³); Siemens expected value was **~196MW CC load**

- Increase of part load efficiency during a certain load range

- HRSG instabilities expected at low loads. Siemens advised to
  - increase HP system pressure to 95 bar (from 75bar)
  - increase blow-down rate in order to increase the mass flow
  - install additional orifices between HP Evap 1 and 2
Owner’s verification by dynamic modelling

- Uniper in-house engineering company Uniper Technologies (UTG) created steady-state and dynamic HRSG models to verify Siemens statements.

→ Siemens predictions verified but at even lower loads plus
→ Confidence given that no HRSG hardware modification is required

“Ledinegg” instabilities seen at different plant

min. load CCGT with 4000F
Results

- CO compliant minimum load could be reduced to 165MW (net)
- HRSG generally stable during tests, only at lowest test load some instabilities could be observed, mitigated by increasing HP system pressure

\[ \text{It was decided to set the minimum load to } 180\text{MW}_{\text{net}} \]

in order to utilise the wider load range while offering ancillary services.
**CCPP Connah‘s Quay – Main plant data**

<table>
<thead>
<tr>
<th>Unit</th>
<th>EOH</th>
<th>OH</th>
<th>Starts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>~125,000*</td>
<td>~107,000*</td>
<td>~1,500*</td>
</tr>
</tbody>
</table>

*varies by Unit, figures for Unit 3 June 2015

**Basic Plant Data**

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT Type &amp; Configuration</td>
<td>4 x GE 9 FA, DLN 2.6+,</td>
</tr>
<tr>
<td>Combustion</td>
<td>Natural Gas</td>
</tr>
<tr>
<td>HRSG</td>
<td>Stein, vertical Triple Pressure + Reheat</td>
</tr>
<tr>
<td>ST</td>
<td>Alstom</td>
</tr>
<tr>
<td>Generator</td>
<td>Alstom Type T255-420 three phase</td>
</tr>
<tr>
<td>COD</td>
<td>Mar 1996</td>
</tr>
<tr>
<td>Capacity, CC</td>
<td>4 x 355 MWe</td>
</tr>
</tbody>
</table>

Fast start up VLP on GE 9FA
Uniper/GE partnership overview

Multi-year agreement initiated December 2011 for joint development of more flexible CCGT operation

**GE scope:**
- Develop and conduct test program;
- Develop, validate, and implement new GT control software

**Uniper scope:**
- Conduct combined cycle plant modeling
- Analyses to evaluate operational impacts of new technology
- Develop risk mitigation measures;
- Make plants available for field testing;
- Implement necessary plant control software changes

⇒ Partnership approach results in better overall plant-level solution by engaging end-user throughout product development process
Conventional combined cycle plant starts too slow and costly to compete in real-time power markets ... cost, time to dispatch, and load profile

Need near-simple cycle load profile ... while controlling exhaust temperature to manage plant stress
What is OpFlex* VLP?

- Gas turbine control feature
- Allows independent control of load and exhaust temperature within the gas turbine boundaries ... true GT flexibility product
- Simple interfaces for integrating into existing plant operation
- Requires OpFlex AutoTune to manage combustor operability

* Trademark of General Electric Company.
Plant operating benefits with VLP

**Startup comparison – steam temperature matching (TM) & ramping**

<table>
<thead>
<tr>
<th>Conventional TM</th>
<th>VLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust flow/energy</td>
<td>Increased by ~130 MW</td>
</tr>
<tr>
<td>GT pressure ratio</td>
<td>Increased by ~40%</td>
</tr>
<tr>
<td>Combustion temperature</td>
<td>Reduced by ~60%</td>
</tr>
<tr>
<td>Temperature</td>
<td>Impact on load flexibility</td>
</tr>
<tr>
<td>Load flexibility</td>
<td>Reduced load imbalance</td>
</tr>
</tbody>
</table>

**Example: 450°C exhaust temperature**

- ~130 MW increase
- ~40% increase in exhaust flow
- ~60% reduction in heat rate
Comparison of conventional versus VLP combined cycle start-up curves (predicted)

With VLP:
- Near simple cycle load profile … higher load sooner
- Near simple cycle full load heat rate

With VLP:
- Exhaust temperature still controlled to limit equipment stress
- Reduce maximum exhaust temperature during start
### Results

#### Plant A Hot Start Comparison

<table>
<thead>
<tr>
<th></th>
<th>Pre-VLP</th>
<th>VLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up Fuel Cost Savings</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Start Time</td>
<td>c.130 mins</td>
<td>c.65 mins</td>
</tr>
</tbody>
</table>

#### Plant B Hot Start Comparison

<table>
<thead>
<tr>
<th></th>
<th>Original Unit</th>
<th>VLP Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare Op</td>
<td>143 Starts</td>
<td>233 Starts</td>
</tr>
<tr>
<td>Jun’14 – May’15</td>
<td>1,900 Hours</td>
<td>3,100 Hours</td>
</tr>
<tr>
<td>Time to 150MW</td>
<td>55 mins</td>
<td>10 mins</td>
</tr>
</tbody>
</table>

Combined cycle plant delivered near simple cycle start capability:
- More MW
- Less time
- Less fuel
Increase of part load efficiency

Situation
- CCGT Plant Kirchmöser with V64.3, COD 1994

Challenge
- Like most CCGT plants, the design is optimized for base load
- Plant rarely operates in base load as the power demand is determined by the rail network.

Solution
- Creation of HRSG and thermodynamic plant models, investigate possible operational and plant modifications to improve part load efficiency.
- Evaluate proposed modifications in terms of NPV and plant risk.

Value
- Improvement of about 1.0% point on part load efficiency.
- => NPV of about 1 Million €
Conclusion

• Uniper / OEM partnership delivered successful product enabling higher CCGT flexibility, e.g.
  - Low Part Load for GT 26 plant
  - Low Part Load for 4000F plant
  - Fast start up with VLP for 9FA

• Significant effort required to manage plant impacts and engineer implementations on site … partnership approach a best practice

• OEMs have valuable solutions for improving flexibility, but: They should be challenged

• Using our Owner’s technical capabilities has led to considerable improvement of our CCGT assets
Thank you!

Questions?