Startup time reduction for Combined Cycle Power Plants

8th International Gas Turbine Conference
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October 12, 2016

Imagination at work
We are better together: Our History

- 1928: Alstom creates world’s first gas turbine for generating electricity (Brown Boveri Company)
- 1939: Alstom introduces advanced class GT24/GT26 gas turbines
  (ASEA Brown Boveri)
- 1972: Alstom installs world’s largest steam turbine generating set
  (Brown Boveri Company)
- 1995: Alstom’s Thermal Services passes 1,000 steam turbine retrofits worldwide
- 2000s: GE’s Power Generation Services launches software solutions business
- 2012: GE develops first jet engine, later used in aeroderivative and gas turbine technology
- 2015: Alstom - Thermal Services
- 2014: GE Power Generation Services
- 1997: GE’s Power Generation Services introduces FA technology for gas turbines
- 1995: GE opens the world’s first licensed power plant
- 1957: GE’s Power Generation Services launches its monitoring and diagnostics capabilities
- 1942: 20% of the world’s electricity is produced with Alstom Power equipment
- 1892: Founded

Power Services
Operational flexibility

Increasing share of renewables leads to increased grid volatility

Fast back up can be achieved by Combined Cycle Power Plants:

- Non-spinning reserve: requires fast and/or more frequent start-ups
- Spinning reserve: operation on low part load to increase available load range
STARTUP TIME REDUCTION

Typical cold start sequence

Phase 1:
- GT start and synchronisation
- Condenser evacuation
- Start of steam by-pass

Phase 2:
- Water / steam chemistry
- ST run-up and synchronisation
- ST warm-up

Phase 3:
- Load increase based on allowable GT and ST gradients

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Phase 1
GT start

Phase 2
Combined cycle start

Phase 3
GT and ST loading

GT only loading release
CC loading release

Parameter (%)

Start GT idle ST release ST idle Plant full load

n_{GT} n_{ST} P_{GT} P_{ST} P_{CCPP}
Warm and hot start duration

<table>
<thead>
<tr>
<th>Sample of approximate time (in minutes)</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>20-25</td>
<td>80</td>
<td>45</td>
</tr>
<tr>
<td>Warm</td>
<td>20-25</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>Hot</td>
<td>15-20</td>
<td>10</td>
<td>20-25</td>
</tr>
</tbody>
</table>

Warm starts:
• Phase 2 time is reduced because it is possible to warm-up the ST more quickly

Hot starts:
• Phase 2 almost completely eliminated because ST is still hot
• ST loading can be done with higher gradient
On which phase should be the main focus?

Depends on “type of start” that is most important for the expected operation profile:
- Cold start: phase 2
- Warm start: phase 2 and 3
- Hot start: phase 1 and 3

“Keeping warm” of HRSG and ST allows to move from one category in the next
Phase 1: GT startup
Improvement potential during GT startup phase (phase 1)

Reduce time to GT start release:
• Maintain HRSG level (and pressure):
  – Keep HRSG warm
  – N2 capping
• Pre-sequencer

Purge credit

Improve condenser evacuation:
• Auxiliary steam to keep HRSG warm and to draw vacuum
• Vacuum ring pump
Keep HRSG warm

**Short term:**
- Stack damper
- Improve cold end insulation
- Reduce water losses

**Longer term:**
- Sparging steam in evaporator

**Benefits:**
- Reduces time to make steam available
- Reduces life consumption of pressure parts
- Less deposit loading
Purge credit (NFPA85)

Purge before light-off of GT:
- At least five volume changes
- Not less than 5 minutes

Purge during GT run-down (accepted since 2011):
- Normal engine run down
- Credit if unit can be kept in purged condition between restarts
- Solution for gaseous fuels: Triple block and bleed with pressurized pipe section

Monitoring: Instrumentation

Section between block valves V2 and V3 is pressurized with air / inert gas at standstill

Time saving: 5 – 10 minutes
Preservation of energy and reduction of HRSG stress
Phase 2: Combined cycle startup
Improvement potential during CCPP start-up phase (phase 2)

Pre-warming the steam turbine
Plant startup sequencer optimisation

Don’t wait for steam turbine warm up:
• Uncoupling water/steam cycle from gas cycle

Reduce waiting time for steam quality:
• Preservation to corrosion product loading:
  – Maintain pressure in HRSG:
    • Keep warm or nitrogen capping
  – Chemistry
• Improved sampling:
  – Degassed conductivity
  – Upgrade of sampling system
Uncoupling steam turbine from gas cycle

Loading of the GT to a high load without waiting time for the steam cycle

Steam temperature control:

• GT inlet guide vane schedule
• Uprated or additional desuperheater
  – Economizer bypass
• Ambient air injection
  – Reduces life consumption of pressure parts and gas path components of HRSG

Power optimized startup to support the capacity market
Keep steam turbine warm

- Improve the startup in cold condition by actively keeping ST in warm condition
- Reduce lifetime consumption
- Preserve ST during standstill
- Maximum benefit for cold starts
 Improved chemical sampling

Degassed conductivity measurement

Sampling arrangement for cycling:

• Remote on/off: switch off during stand still to maintain heat and water level
• Remote sample line flushing
• Automatic pressure and flow regulation for different steam conditions

HP boiler steam cation conductivity at cold start

CC Start-up Time / 12 October 2016
Phase 3: Combined cycle loading
Improvement potential during CCPP loading phase (phase 3)

Increase GT loading gradient:
- HRSG life study, trade off between life and economic opportunity

Pre-warming:
- ST
  For increased gradient
- HRSG
  For reduced life consumption
Different levels of detail:

- **Level 1: basic life assessment**
  - Calculation of creep & fatigue in accordance with boiler design code
  - Corrosion risk assessment

- **Level 2: on-site assessment**
  - Inspection and condition assessment

- **Level 3: finite element analysis**
  - More detailed review for critical components

Typical output of level 1 assessment:
Case studies
Case study: KA26-1 in Europe

**Requirement:**
- Dispatch from any condition (cold/warm/hot) to 180 MW within 30 minutes

**Elements of GE solution:**
- Start and load GT with ST on by-pass
- ST is started later:
  - GT Exhaust temperature optimization
  - New HP/IP desuperheaters setpoints
  - Steam turbine warm-up logic

180 MW in 30 minutes (1x GT only, cold start, ST to follow)
Case study: KA26-2 in Europe

Requirement:

- Short notice dispatch from any condition (cold/warm/hot) to full GT load within 45 minutes (tertiary reserve)

Elements of GE solution:

- Purge credit
- Fast condenser evacuation
- New GT and ST start operation concept
- Increased GT and ST loading gradients

580 MW in 43 minutes (2x GT only, cold start, ST to follow)
Case study: Installation of HPRH line on OEM units in Italy

Requirement:

• The market in Italy requires all CCPP to be flexible and reduce the start-up time below 1 hr

Elements of GE solution:

• Modelling and design of new warm-up line
• Noise study
• INAIL certificate (local authorization body)
• Structural verification
• Installation and commissioning

After the installation, the HRH line heating time was reduced from 2.5 hours to 0.5 hours
## Summary

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
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</thead>
<tbody>
<tr>
<td>Keep HRSG warm</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Keep HRSG and ST warm</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>Purge credit</td>
<td>X</td>
<td></td>
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<tr>
<td>Uncouple Gas and Steam cycle:</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>- VIGV</td>
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<tr>
<td>- Desuperheater</td>
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<tr>
<td>- Ambient air injection</td>
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<tr>
<td>Improved sampling</td>
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<td>X</td>
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<tr>
<td>HRSG life assessment and GT and/or ST gradient increase</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispatch and startup optimization on-line tools</td>
<td>X</td>
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