Development of the GT36 Sequential Combustor

Gerhard Früchtel, Douglas Pennell

Verbrennungsforschung in der Schweiz 2017; ETH Zürich
Agenda

- GT36 introduction
- GT36 CPSC combustor
- GT36 validation
- Conclusions & questions
More than 160 Years Background

- Acquisition of Alstom advanced HDGT technology and Assets
- Acquisition of Power System Manufacturing
- Incorporation of Joint Ventures with Shanghai Electric Company
- 100 years of Steam Turbine manufacturing
- 150th Gas Turbine manufactured
- OSP™ concept launch
- Total Technological Independence
- Global leading OEM of GT and ST
- 2016
- 2014
- 2012
- 2010
- 2007
- 2005
- 1995
- 1991
- 1962
- 1923
- 1853

- 2016
- Acquisition of Alstom advanced HDGT technology and Assets
- Global leading OEM of GT and ST

- 2014
- Incorporation of Joint Ventures with Shanghai Electric Company

- 2012
- 100 years of Steam Turbine manufacturing

- 2010
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- 2007
- OSP™ concept launch

- 2005
- Total Technological Independence

- 1995
- First Combined Cycle Power Plant based on Ansaldo Energia GT

- 1991
- Ansaldo Energia established

- 1962
- First supercritical 600 MW Power Plant

- 1923
- First Power Plant

- 1853
- Giovanni Ansaldo & Co. established

- 2016
- Acquistion of Alstom advanced HDGT technology and Assets
- Global leading OEM of GT and ST
## New Equipment Portfolio

**Heavy Duty Gas Turbine Performance**

<table>
<thead>
<tr>
<th>Model</th>
<th>Output / Efficiency</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT36-S5</td>
<td>500 MW / 41.5%</td>
<td>50 Hz</td>
</tr>
<tr>
<td>GT36-S6</td>
<td>340 MW / 41%</td>
<td>60 Hz</td>
</tr>
<tr>
<td>GT26</td>
<td>345 MW / 41%</td>
<td>50 Hz</td>
</tr>
<tr>
<td>AE94.3A</td>
<td>310 MW / 39.8%</td>
<td>50 Hz</td>
</tr>
<tr>
<td>AE94.2A</td>
<td>185 MW / 36.2%</td>
<td>50 Hz</td>
</tr>
<tr>
<td>AE64.3A</td>
<td>78 MW / 36.3%</td>
<td>50 / 60 Hz</td>
</tr>
</tbody>
</table>

GT gross performance including once-through-cooler contribution where applicable.

100% Methane, ISO conditions, duct and auxiliary losses excluded.

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Ansaldo’s H-Class Gas Turbine: GT36

- 15 stage compressor (4 vanes variable)
- CPSC can combustor
  - 12 cans (60Hz)
  - 16 cans (50Hz)
- 4 stage turbine

<table>
<thead>
<tr>
<th></th>
<th>GT36 S5 (50Hz)</th>
<th>GT36 S6 (60Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SC</strong></td>
<td><strong>CC 1+1</strong></td>
<td><strong>SC</strong></td>
</tr>
<tr>
<td>Power, MW</td>
<td>500</td>
<td>340</td>
</tr>
<tr>
<td>Efficiency, %</td>
<td>41.5</td>
<td>41.0</td>
</tr>
</tbody>
</table>
GT36 Gas Turbine Evolution

GT26 Sequential Combustion
• 23 years of reliable reheat technology proven in F-class fleet

GT36 CPSC features
• Sub 25vppm NOx & CO
• Turn Down < 30% GT load
• Gaseous Fuel Flexibility: Wobbe Index: 31-50MJ/m₃
  Up to 18% molar C₂+ hydro-carbons with H₂ fuel doping capability
• Dual fuel capability with distillate Oil#2 and online fuel changeover
• Hot gas path inspection 13 days

Technology evolution of existing product portfolio using in-house knowhow
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CPSC Operating Principle

…and comparison to a generic axially staged combustion system

Premixed 1\textsuperscript{st} stage combustion

Axial Staged

CPSC NO\textsubscript{x} advantage

CPSC mixes all fuel and all air together before sequential auto-ignition

Mixer Exit Temperature, MET

Combustor exit remaining temperature spread

Short residence time combustion and CPSC flame hotspots avoided

Peak temperature for axially staged combustor

B: Burner
M: Mixer
C: Combustor
A: Air
F: Fuel

Axial Staged
**GT36 CPSC Combustor**

**Key Components**

**First Stage, (FS)**
- Gas and oil startup & premix burner & combustor
- Ansaldo F-class low NOx low turndown technology
- Capacity adapted to GT36 combustor
- High degree of identical or similar components to F-class design

**Sequential Burner (SB)**
- Reheat burner for emission and turndown performance (low residence time)
- Direct evolution of GT26 SEV burner design and fuel injector technologies
- Multi point (dual) fuel injection with high concentration of vortex generators for improved mixing
- Integrated thermo-acoustic damping features
- Optimized for low combustor exit temperature spread

**Dilution Air Mixer**
- Multi row mixer with nozzles configured for uniform inlet profile to sequential burner
- Regulates MET* range for optimum SB performance
- Utilized experience from silo combustor designs of legacy BBC/ABB/Alstom gas turbines

**Sequential Liner (SL)**
- Sequential combustor and interface to turbine
- Leveraged PSM Ansaldo can transition duct expertise and design portfolio
- Thermally free movement to reduce stresses
- High-temperature alloy with improved creep strength and durable dense vertically cracked TBC

* MET: Mixer Exit Temperature
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## Combustor Design Procedure

### Validation vehicle applicability versus technical risks

<table>
<thead>
<tr>
<th>Validation Vehicles</th>
<th>CFD and Analytical Tools</th>
<th>Water channel (LDA, PIV, LIF)</th>
<th>Flow bench</th>
<th>Atmospheric Tests</th>
<th>High Pressure Tests</th>
<th>Combustor Removal Test</th>
<th>GT36-S6 Engine Test Center</th>
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<tbody>
<tr>
<td>Component lifetime</td>
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<tr>
<td>Combustor operation and performance</td>
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<td>✓</td>
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<td>Transferability of results</td>
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<td>Fuel distribution system</td>
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<td>Fuel manifold (internal fuel distribution)</td>
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<tr>
<td>Can to can scatter</td>
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<td></td>
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</tbody>
</table>
GT36

Combustor – Confirmation of correlation and transferability Rig-to-Engine

High Pressure Combustor Test Rig

- Test rig based validation was a key element of the GT36 burner development
- Full scale rig testing performed since 2013

GT36 in Birr Test Power Plant

- Transferability to engine operation confirmed for the first (Premix) and the second stage (Sequential).
- Correlation of operation window, pulsation and emission as expected
- Operating range emissions confirmed
- Metal temperature readings transferable
High Pressure CPSC Gas Operation

Combustor and flame Images (viewed facing upstream)

Low load: Sequential burner off

Part load: Sequential burner ignited

Full load: Sequential burner at max firing
GT36 Gas Turbine
Test Power Plant in Birr, Switzerland

- GT36 Test Engine located in Birr, Switzerland and operational since 2016.
- Engine instrumented with > 3000 instruments, with > 500 rotating parts instrumentation.
- Extended performance testing completed for design and off-design conditions.
- Engine test results confirm design performance targets.
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GT36 Test Engine Validation
Validation completed on April 12, 2017

- Start-up and shut-down testing performed
- Grid synchronization and electricity export functional
- Hot- and cold-start performance verified
- Loading gradients confirmed
- Full load operation and mapping confirms design

### Performance:
- P [MW]
- η [%]
- TIT [°C]
- TAT [°C]
- m [kg/s]
- p [bar]

### Emission:
- NOx [vppm]
- CO [vppm]

### Operability:
- OPC [-]
- Turndown [%]

Engine in Operation, picture taken from outside enclosure
GT36 successfully completed the first phase of the comprehensive validation program

The first GT36 Unit, Ansaldo Energia’s H-Class gas turbine model, has successfully completed the first phase of the comprehensive validation program at the Birr Test Power Plant in Switzerland.

The test power plant is a full scale simple cycle power station, built in 2015/2016, that can be used for the operation and validation of the fully instrumented engine under real power plant conditions, because the power is dispatched to the Swiss Power Grid.

The tests fully confirm the high performance, low emissions over the entire load range, and resulting very wide operation window of this engine.

The test program included stress testing of the two stages of the sequential combustion system, part and full load mapping, transient operation and performance testing. The validation engine is equipped with more than 3,000 measurement points, including a telemetry system which transfers more than 500 measurements from the rotating parts.

Full engine validation is an integral part of the development of Ansaldo Energia’s new turbine. The thorough validation process includes design validation with engineering tools, component validation, full engine validation and, finally, field monitoring.

The GT36’s combustion system has already been tested as single component in a combustor test rig, at full size and under full massflow, at the DLR (the German Aerospace Center) in Cologne since 2013.

The test results reported for the GT36-S6 (60Hz rating) confirmed power output above 340 MW at 41% efficiency. In combined cycle this corresponds to performance exceeding 500 MW at 61.3% net efficiency in ISO conditions and 720 MW at 61.5% efficiency for the GT36-S5 (the 50Hz scaled version).

The unique characteristics of the GT36 provide a very useful response to power market requirements today and in the future, where combined cycle plants need to offer high efficiency coupled with high operational flexibility, because power output has to follow the fluctuating needs of the grid in order to compensate and back-up generation using intermittent renewable sources.
A new generation is born

New products.
New technologies.
New service capabilities.

Ansaldo Energia: a global player in the power generation market.