SGT-700 DLE combustion system extending the fuel flexibility

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Content of presentation

- SGT-700 introduction
- Fuel system & combustion design
- Test results with different fuels
- SGT-700 fuel range
- Operational experience
- Summary
Traditionally DLE-systems have only been used on standard natural gases & non-DLE combustion has been used on more reactive (ethane, propane, hydrogen) and non-reactive (nitrogen, CO). This is changing:

- New regulations are requiring *less emissions* (which means DLE-systems).
- New regulations are *restricting* the possibility to *flare-off* non desired fuels
- Different processes are *producing more non-standard fuels* (such as shale gas and PDH)
- Hydrogen may be used as "energy storage"

This means; Rapid changes of fuel supplies desired in order to accept different feeds from processes and the possibility to utilize different sources and/or suppliers.

Therefore a continuous development and mapping of the SGT-700 possibilities has been prioritized during the last couple of years.

**The fuel capabilities of the SGT-700 including is now been further extended**
DLE Fuel flexibility of SGT-700
Siemens gas turbine portfolio

Heavy duty gas turbines

50 Hz
- SGT5-8000H - 400 MW
- SGT5-4000F - 307 MW
- SGT5-2000E - 172 MW

60 Hz
- SGT6-8000H - 296 MW
- SGT6-5000F - 242 MW
- SGT6-2000E - 114 MW

Industrial and aero-derivative gas turbines

50 Hz
- Ind. Trent 60 - 54 to 66 MW
- SGT-800 - 48 to 53 MW
- SGT-750 - 37 / 38 MW
- SGT-700 - 33 / 34 MW
- Ind. RB211 - 27 to 34 MW

50 or 60 Hz
- SGT-600 - 24 / 25 MW
- SGT-500 - 19 / 19 MW
- SGT-400 - 13 to 14 MW / 13 to 15 MW
- SGT-300 - 8 / 8 MW
- SGT-200 - 7 / 8 MW
- SGT-100 - 5 / 6 MW
- Industrial 501 - 4 to 6 MW

Power Generation / Mechanical Drive

Industrial
- SGT-800
- SGT-750
- SGT-700
- Ind. Trent 60
- SGT-600
- SGT-500
- SGT-400
- SGT-300
- SGT-200
- SGT-100
- Industrial 501

Aero-derivative
- Siemens gas turbines

Heavy duty 60 Hz
- SGT5-8000H
- SGT5-4000F
- SGT5-2000E
- SGT6-8000H
- SGT6-5000F
- SGT6-2000E

Heavy duty 50 Hz
- SGT-800
- SGT-750
- SGT-700
- Ind. Trent 60
- SGT-600
- SGT-500
- SGT-400
- SGT-300
- SGT-200
- SGT-100
- Industrial 501
### DLE Fuel flexibility of SGT-700

**SGT-700, Industrial gas turbine**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service introduction year</td>
<td>2003</td>
</tr>
<tr>
<td>Units sold to date</td>
<td>72</td>
</tr>
<tr>
<td>- PG/MD</td>
<td>45/27 units</td>
</tr>
<tr>
<td>- Total fleet hours</td>
<td>&gt; 1 200 000</td>
</tr>
<tr>
<td>Lead Package hours</td>
<td>&gt; 82 000</td>
</tr>
<tr>
<td>Fleet Availability</td>
<td>98.4%*</td>
</tr>
<tr>
<td>Fleet Reliability</td>
<td>99.7%*</td>
</tr>
<tr>
<td>Start reliability</td>
<td>97.1%*</td>
</tr>
<tr>
<td>MTBF</td>
<td>4 842h*</td>
</tr>
</tbody>
</table>

### Data at ISO conditions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet</td>
<td>15°C</td>
</tr>
<tr>
<td>CC</td>
<td>1188 °C Mixed</td>
</tr>
<tr>
<td>Outlet</td>
<td>533°C</td>
</tr>
<tr>
<td>Exh. flow</td>
<td>95 kg/s</td>
</tr>
<tr>
<td>Output</td>
<td>32.8/33.7 MW(el/s)</td>
</tr>
<tr>
<td>Efficiency</td>
<td>37.2% / 38.2% (el/s)</td>
</tr>
</tbody>
</table>

*Figures based on a 12 month rolling average
Including GT, package, E&C and driven equipment.
DLE Fuel flexibility of SGT-700
The challenges

SGT-700 has only one burner/combustor configuration – due to its simple design, it can be utilised in many different applications. The envelope is continuously stretched by theoretical & practical tests as well as site feed-back.

A high turbine inlet temperature is desirable in order have a high gas turbine efficiency, but:

- The flame needs to be cold in order to not produce NOx
- The flame needs to be hot in order to not produce CO/UHC

Different fuels have different issues:

- Low reactive fuels: flame out & instability
- High reactive fuels: flash-back & over-heating
DLE Fuel flexibility of SGT-700
Patented burner principles, Simple design

2nd generation DLE, SGT-600

3rd generation DLE, SGT-700

Combustion air
Gas fuel stage 2
Gas fuel stage 1
Liquid fuel
Gas fuel stage 2
Atomization nozzle
Gas injection ports

Flame

Main gas
Pilot gas pipe
Film air holes
Pilot gas holes

Compressor air
Pilot and main oil (in tip)

Central gas
Combustion mixture at burner outlet
### DLE Fuel flexibility of SGT-700

#### SGT-700, Industrial gas turbine

<table>
<thead>
<tr>
<th>Turbine</th>
<th>Power (MW)</th>
<th>Combustion system</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGT-500</td>
<td>19</td>
<td>2(^{\text{nd}}) Generation DLE&lt;br&gt;Non-DLE</td>
</tr>
<tr>
<td>SGT-600</td>
<td>25</td>
<td>2(^{\text{nd}}) Generation DLE&lt;br&gt;3(^{\text{rd}}) Generation DLE&lt;br&gt;Non-DLE</td>
</tr>
<tr>
<td>SGT-700</td>
<td>33</td>
<td>3(^{\text{rd}}) Generation DLE</td>
</tr>
<tr>
<td>SGT-750</td>
<td>37</td>
<td>4(^{\text{th}}) Generation DLE</td>
</tr>
<tr>
<td>SGT-800</td>
<td>50.5</td>
<td>3(^{\text{rd}}) Generation DLE</td>
</tr>
</tbody>
</table>

All Finspong (Sweden) Gas Turbines comes with **DLE as standard** due to its reliable and cost effective design.

SGT-600/700/800 have the same burner design.

Older engines (SGT-500/600) also have conventional as an option (which is not available for SGT-700/750/800)
DLE Fuel flexibility of SGT-700
Uncomplicated DLE control

- Factory calibration of each burner with fixed orifice (no moving parts) in order to have even flow distribution to all burners
- Only 2 fuel control valves required – one for each manifold (main & pilot)
- Operational control by two parameters: total fuel flow and split between main and primary
- Pros:
  + Simple, less expensive than conventional
  + No staging between burners allows rapid load changes and load rejection
  + Stable, no mapping or tuning required after commissioning
  + Insensitive to ambient conditions
Test stand utilized for fuel flex tests. Full load engine test possible to perform on all burners as well as single burner test.

Checking: flame-out/flash-back; combustion dynamics; emissions; temperatures
DLE Fuel flexibility of SGT-700

N₂/Low-WI verification combined with rapid changes

High Nitrogen content and rapid Wobbe Index change.

40% (vol) of Nitrogen shifted to 100% standard natural gas.

Wobbe Index increases 80% in 2 min with stable load. Standard hardware and control utilized. Slight increase of NOx during shifting – then back to original level.
DLE Fuel flexibility of SGT-700
H₂-verification combined with load changes

Load changing with constant H₂-flow
Altering the load between 10 and 27 MW with a constant feed of H₂ results in between 50 and 75% (vol) H₂-content

Nox-emissions shown vs H₂-content;
Up to approximately 45% H₂-content there is almost no consequence on Nox (<10%). Above this H₂-level the Nox will be more affected.
DLE Fuel flexibility of SGT-700
Pictures from H₂-operation

Pictures of burner in combustor when operating at 30 MW load with increasing amount of H₂ in fuel.
SGT-700 Fuel Flexibility
Acceptable fuel composition

- Uncomplicated combustion system without staging
- Load rejection capability
- On-load fuel-changeover capability
- Dry low emissions capability on gas and liquid fuel
- WI-range 25-80MJ/Nm³

<table>
<thead>
<tr>
<th>Gas Fuel Constituents</th>
<th>New mole %</th>
<th>Previous mole %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane, CH₄</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Ethane, C₂H₆</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Propane, C₃H₈</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Butanes and heavier alkanes, C₄+</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Hydrogen and carbon monoxide, H₂ + CO</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Inerts, N₂/CO₂</td>
<td>40/30</td>
<td>40/30</td>
</tr>
<tr>
<td>H₂S</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
DLE Fuel flexibility of SGT-700
PDH-plant with varying fuel composition

Example of one SGT-700 installation in a PDH-plant in China with extremely high (and rapid) variance of fuel composition over time.
In commercial operation for one year
DLE Fuel flexibility of SGT-700
Component status after 8000hrs of operation

Combustion chamber; Burner; First inlet guide vane (nozzle)

Pictures taken from the Chinese PDH-unit after 8000 hrs of operation with extremely high variations on fuel composition.
Components does not show any deviating findings – components fit for purpose
DLE Fuel flexibility of SGT-700

Summary

• The Medium Sized (15-50MW) Siemens Gas Turbines developed in Finspong have for the last 15 years only included **DLE-design** which includes the **SGT-700**

• **Simple DLE-design & fuel system** which allows for high fuel flexibility and reliability.

• The applicable **fuel composition is continuously stretched** – from testing in test bed and operational feed-back from site.

• The latest revision includes extending the limits
  
  • **Ethane** content to **100%** (from 50%);
  
  • **Propane** content to **100%** (from 50%)
  
  • **Hydrogen** content to **50%** (from 15%)
  
  • **Wobbe Index 25-80 MJ/Nm3**

• **Variating composition** over time **accepted**

• PDH-plant **inspection shows component fit for purpose**
Thank you for your attention!