GE Gas Power Systems (gas turbine) fuel capabilities

P. Glaser, J. Goldmeer, M. Knapczyk, P. Pastecki

October 13, 2016
Economically available fuels vary by region

North America
- Natural gas
- Shale gas
- Process gas

Latin America
- Natural gas
- LNG (import)
- Biofuels
- LPG

Europe
- Natural gas
- LNG (import)
- Biofuels

Middle East & N. Africa
- Natural gas
- Crude oil
- Lean methane
- Sour gas

Sub-Saharan Africa
- Natural gas
- Crude oil
- Heavy liquids

India
- Natural gas
- Refinery off-gas
- Naphtha

China
- Natural gas
- Heavy liquids
- Steel mill gases
- Shale gas

Southeast Asia
- Natural gas
- LNG
- Lean methane
- Sour gas

Customers require fuel flexible power generation solutions
Experience with alternative fuels

<table>
<thead>
<tr>
<th>Liquid fuels</th>
<th>Gaseous fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>Natural gas</td>
</tr>
<tr>
<td>Marine gasoil</td>
<td>LNG</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>H₂ blends</td>
</tr>
<tr>
<td>Light cycle oil</td>
<td>Ethane</td>
</tr>
<tr>
<td>Naphtha</td>
<td>LPG / Propane</td>
</tr>
<tr>
<td>Condensate</td>
<td>Flare gas and associated gas</td>
</tr>
<tr>
<td>Ethanol / Methanol</td>
<td>Coal bed methane</td>
</tr>
<tr>
<td>Kerosene / Jet fuel</td>
<td>Lean methane</td>
</tr>
<tr>
<td>Butane</td>
<td>Refinery/process off gas</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Arabian Super Light crude oil</td>
</tr>
<tr>
<td>Dimethyl ether (DME)</td>
<td>Light crude oils</td>
</tr>
<tr>
<td>Arabian Super Light crude oil</td>
<td>Light crude oils</td>
</tr>
<tr>
<td>Dimethyl ether (DME)</td>
<td>Heavy fuel oil</td>
</tr>
<tr>
<td>Arabian Super Light crude oil</td>
<td>Arabian Super Light crude oil</td>
</tr>
<tr>
<td>Light crude oils</td>
<td>Sour gas</td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td></td>
</tr>
</tbody>
</table>

GE offers comprehensive fuels solutions for power generation applications
## Gas turbine fuel capability

### Aero and Industrial gas turbines

<table>
<thead>
<tr>
<th>Gas turbine</th>
<th>LM2500(1)</th>
<th>LM6000(1)</th>
<th>LMS100(1)</th>
<th>6B.03</th>
<th>7E.03, 9E.03, 9E.04</th>
<th>13E2</th>
<th>6F.01</th>
<th>6F.03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustor</td>
<td>DLE</td>
<td>DLE</td>
<td>DLE 2</td>
<td>DLN 1/1+</td>
<td>DLN 1/1+</td>
<td>AEV</td>
<td>DLN 2.5</td>
<td>DLN 2.6</td>
</tr>
<tr>
<td>Simple cycle output (MW)</td>
<td>23.8-37.1</td>
<td>45 - 57</td>
<td>108-117</td>
<td>44</td>
<td>91/132/145</td>
<td>203</td>
<td>52</td>
<td>82</td>
</tr>
<tr>
<td>NOx (ppm) @15% O₂</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>4</td>
<td>15</td>
<td>15</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Min Turndown (% load)</td>
<td>50%</td>
<td>25%, 50%</td>
<td>50%</td>
<td>50%</td>
<td>35%</td>
<td>70%</td>
<td>40%</td>
<td>52%</td>
</tr>
<tr>
<td>Wobbe Variation (%)</td>
<td>± 20%</td>
<td>± 20%-25%</td>
<td>± 20%</td>
<td>&gt; ± 30%</td>
<td>&gt; ± 30%</td>
<td>± 10%</td>
<td>± 10%</td>
<td>+10%, -15%</td>
</tr>
<tr>
<td>Ethane (vol %)</td>
<td>~30-35%</td>
<td>~15-24%</td>
<td>~15%</td>
<td>100%</td>
<td>100%</td>
<td>~23%</td>
<td>~25%</td>
<td>~15%</td>
</tr>
<tr>
<td>Propane (vol %)</td>
<td>~35%</td>
<td>~15-24%</td>
<td>~15%</td>
<td>~100%</td>
<td>~100%</td>
<td>~23%</td>
<td>~15%</td>
<td>~15%</td>
</tr>
<tr>
<td>H₂ (vol %)</td>
<td>~5%</td>
<td>~5%</td>
<td>~5%</td>
<td>~30-32%</td>
<td>~30-32%</td>
<td>~5%</td>
<td>~0%</td>
<td>~5%</td>
</tr>
<tr>
<td>Inert (vol %) (CO₂, N₂)</td>
<td>~50%</td>
<td>~25-30%</td>
<td>~15%</td>
<td>~40%</td>
<td>~40%</td>
<td>~20%</td>
<td>~5%</td>
<td>~15%</td>
</tr>
</tbody>
</table>

Note 1 - There are multiple configurations available for GE’s Aeroderivative gas turbines as well as the 13E2, and the values presented in this table are representative of the capability of the specific gas turbine model. Actual performance and capability are site and fuel specific.
**Gas turbine fuel capability**

*Utility scale gas turbines*

<table>
<thead>
<tr>
<th>Gas turbine</th>
<th>9F.04</th>
<th>9F.06</th>
<th>7F.05</th>
<th>7F.06</th>
<th>9HA.01</th>
<th>9HA.02</th>
<th>7HA.01</th>
<th>7HA.02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustor</td>
<td>DLN 2.6+</td>
<td>DLN 2.6+</td>
<td>DLN 2.6+</td>
<td>DLN 2.6+</td>
<td>DLN 2.6+ AFS</td>
<td>DLN 2.6+ AFS</td>
<td>DLN2.6+ AFS</td>
<td>DLN2.6+ AFS</td>
</tr>
<tr>
<td>Simple cycle output (MW)</td>
<td>281</td>
<td>342</td>
<td>232-241</td>
<td>270</td>
<td>429</td>
<td>519</td>
<td>280</td>
<td>346</td>
</tr>
<tr>
<td>NOx (ppm) @15% O₂</td>
<td>15</td>
<td>15</td>
<td>5-12</td>
<td>9</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Min Turndown (% load)</td>
<td>35%</td>
<td>38%</td>
<td>44 - 46%</td>
<td>30%</td>
<td>30%</td>
<td>30%</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>Wobbe Variation (%)</td>
<td>± 15%</td>
<td>± 15%</td>
<td>± 7.5%</td>
<td>± 7.5%</td>
<td>± 15%</td>
<td>± 15%</td>
<td>± 10%</td>
<td>± 10%</td>
</tr>
<tr>
<td>Ethane (vol %)</td>
<td>~25%</td>
<td>~25%</td>
<td>~25%</td>
<td>~25%</td>
<td>~25%</td>
<td>~25%</td>
<td>~25%</td>
<td>~25%</td>
</tr>
<tr>
<td>Propane (vol %)</td>
<td>~35%</td>
<td>~25%</td>
<td>~35%</td>
<td>~25%</td>
<td>~35%</td>
<td>~35%</td>
<td>~25%</td>
<td>~25%</td>
</tr>
<tr>
<td>H₂ (vol %)</td>
<td>~5%</td>
<td>~5%</td>
<td>~5%</td>
<td>~5%</td>
<td>~5%</td>
<td>~5%</td>
<td>~5%</td>
<td>~5%</td>
</tr>
<tr>
<td>Inert (vol) % (CO₂, N₂)</td>
<td>~15%</td>
<td>~15%</td>
<td>~30%</td>
<td>~15%</td>
<td>~15%</td>
<td>~15%</td>
<td>~15%</td>
<td>~15%</td>
</tr>
</tbody>
</table>
Aeroderivative gas turbine fuel capability: heating value rate of change study
Fuel heating value variation – customer site data

- Three hour survey of gas fuel at customer site (actual fuel composition is the dark line)
- Fuel LHV increased by ~ 20 BTU/scf during this time

Gas chromatograph data (heavy light blue line) lags behind the actual fuel composition change
Rapid fuel heating value changes
Comparing gas chromatograph to GE algorithm

Baseline case
- Rate of change of fuel LHV exceeds GC response time
- Increased risk of potential combustor operational issues until GC data catches up to fuel composition

GE fuel tracking algorithm
- Algorithm tracks changes in fuel LHV, even with fast rates of change
- This algorithm limits potential risk of operational issue during rapid fuel heating value shifts
Rapid fuel heating value changes
Comparing gas chromatograph to GE algorithm

Baseline case
- Instances with LHV rate of change faster than GC can measure
- Increased risk of potential operational issues (Red zones)

GE fuel tracking algorithm
- Algorithm tracks changes in fuel LHV, even with fast rates of change
- Reduces potential risk of operational issues

Algorithm based on fuel property data tracks rapid fuel changes, limiting potential risk of operational issues

Copyright, General Electric Company, 2016; All Rights Reserved.
Heavy-duty gas turbine fuel capability case studies
Case study: *Refinery gas blending*

- GE’s fuel-flexible DLN1 combustion technology enables customers to use a variety of fuels, including refinery gas
- DLN combustion technology allows for lower NOx emissions without the need for diluent injection
- Validated with more than 10,000 fired hours at a site using a refinery gas that is a blend of hydrogen and hydrocarbons

“GE Power Generation Services’ solution helped us to increase plant efficiency and reduce our environmental footprint, supporting our goals to produce cleaner energy and meet the region’s increasingly stringent emissions requirements”

– Antonio Berlanga, Operation Manager, Compañía Española de Petróleos (CEPSA)
Case study: hydrogen blending

- A US based customer requested the capability to allow blending of \( \text{H}_2 \) and natural gas
- GE provided the fuel blending system and updated the gas turbine control system
- Successful field operation blending (up to 5% \( \text{H}_2 \)) with natural gas on a set of 7F.03 gas turbines configured with DLN 2.6 combustion system
- These units have accumulated over 80,000 fired hours on blended fuel
Case study: Non-methane hydrocarbons

- Refinery application in large US metropolitan area. Butane used as a start-up and back-up fuel on set of four 7E.03 gas turbines
- Customer converting Frame 5 and 6B.03 gas turbines for continuous 100% load operation on propane
- Gas turbine site in the US blending ethane and natural gas

GE’s gas turbines are all capable of operating on a blend of natural gas and ethane. Many of these are also capable of operating on 100% ethane or LPG
Case study: light crude in a F-class gas turbine

- 120 hour field test successfully performed on a 7F.04 gas turbine in Saudi Arabia; First F-class DLN combustion system to operate on crude oil

GE now has 15 7F gas turbines in Saudi Arabia that have operated on ASL. This fleet will grow to 33 gas turbines once other plants awarded to GE start commercial operation.
Summary

• Shifts in availability and economics of traditional fuels are creating interest in new fuels for power generation

• GE’s aeroderivative and heavy-duty gas turbines are capable of operating on a wide variety of fuels supporting a variety of powergen applications