ANSALDO ENERGIA EXPERIENCE ON FUEL FLEXIBILITY

"Shale Gas Revolution: opportunità e sfide per l'industria italiana nel mondo"

Alessia Bulli
SUMMARY

• Introduction: Ansaldo Energia
• Shale Gas: a new opportunity
• AEN experience on fuel flexibility
• Conclusions
• Introduction: Ansaldo Energia

• Shale Gas: a new opportunity

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• Conclusions
ANSALDO ENERGIA GROUP

Ansaldo Energia is Italy’s largest supplier, installer and service provider for power generation plants and components.

References as per Dec. 2013
COMPANY PRODUCTS AND SERVICES

Open and Combined Cycles Power Plants

Thermal Power Plants

Equipment: Gas Turbines, Steam Turbines and Turbogenerators

Service on AEN installed fleet (OEM)

Service on third party installed fleet (OSP™)

References as per Dec. 2013
Installed power worldwide
> 180,000 MW
in more than 90 Countries

- Open Cycle
- Combined Cycle
- Thermal
- Cogeneration
- Geothermal
- Solar Power
- Wind Power
- Hydroelectric
- Waste to energy

References as per Dec. 2013
## GAS TURBINE PORTFOLIO

### Models and Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Power [MW]</th>
<th>Class</th>
<th>Reliability</th>
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<tbody>
<tr>
<td>AE64.3A</td>
<td>75</td>
<td>F</td>
<td>&gt; 98%</td>
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<tr>
<td>AE94.2</td>
<td>185</td>
<td>E</td>
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<tr>
<td>AE94.2K</td>
<td>170</td>
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<td>310</td>
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Ansaldo Energia independent technology

Widely proven models

References as per Dec. 2013
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Shale Gas: a new opportunity

Conventional gas e Shale gas

- Porous and permeable rocks
- Deposits of contained dimensions
- Constant production but less long-lived
- Higher productivity (up to 70%)

- Clays
- Very large deposits
- Production decreases rapidly after an initial peak but long-term
- Lower productivity (up to 30%)
# Shale Gas: compositions

## Shale gas major components before processing

<table>
<thead>
<tr>
<th>Component</th>
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<th>Site 1</th>
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<td>0.3</td>
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<td>2.7</td>
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<tr>
<td>Nitrogen</td>
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<td>0.3</td>
<td>0.3</td>
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<td>0.1</td>
<td>7.9</td>
<td>1.5</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Total inerts ((\text{CO}_2+\text{N}_2))</td>
<td>2.0</td>
<td>0.5</td>
<td>0.4</td>
<td>1.2</td>
<td>0.5</td>
<td>4.9</td>
<td>9.3</td>
<td>1.8</td>
<td>3.4</td>
<td>3.7</td>
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<tr>
<td>TOTAL</td>
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<td>100.0</td>
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AEN experience on fuel flexibility

AE64.3A Low BTU gas --- GT balance

Low LHV gas (down to 19 MJ/kg)

Combustion chamber

Fuel mass flow: LBTU gas = 2.6 NG

Compressor

Pressure ratio: 18.6 with LBTU gas (18 with NG)

ISSUES:
- Compressor characteristic curve changes

ACTIONS:
- Check loads compared to NG operation
- Surge margins check

Secondary Air System

Secondary Air Flows check and rotor axial thrust
Experimental data with gas LHV 19 MJ/kg:

- $m_{\text{fuel}}$
- $m_{\text{air}}$

Ignition with low BTU gas only

Premix on

FSNL
AEN experience on fuel flexibility

AE 94.2

AE 94.2K

AE 94.3A

AE 64.3A
AEN experience on fuel flexibility

AE 94.2

BASIC DESIGN: Natural Gas and fuel oil

NATURAL GAS → PREMIX MODE

NOx emissions < 25 ppm

FUEL OIL → DIFFUSION MODE

A basic solution foresees the operation only in diffusion mode, very easy and flexible but with higher NOx emissions

WITH WATER INJECTION

NOx emissions < 42 ppm

Another possible solution is to adopt the PREMIX mode, this allows to save a large amount of demi water

NOx emissions < 75 ppm dry

Nowadays more than 80 AE94.2 gas turbines are equipped with a dual fuel system
AEN experience on fuel flexibility

AE 94.2

BASIC DESIGN: NAPHTA OPERATION

All types of fuel change over possible and tested:

HSD \iff naphtha
HSD \iff natural gas
Naphtha \iff natural gas

Mixed operation (naphtha - gas) experienced:

• combustion stability
• load range: 50% - base load
• with water injection \implies achievement of NOx emissions
AEN experience on fuel flexibility

AE 94.2

AE 94.3A

AE 94.2K

AE 64.3A
### AE 94.2K: SYNGAS OPERATION

**Power Plant**

<table>
<thead>
<tr>
<th></th>
<th>ISAB Energy Priolo</th>
<th>Elettra GLT Servola</th>
<th>EniPower Ferrera E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Power (GT/CC)</td>
<td>2x162 MW / 516 MW</td>
<td>1x110 MW / 170 MW</td>
<td>1x 166 MW / 255 MW</td>
</tr>
<tr>
<td>Equivalent Operating Hours (EOH)</td>
<td>Unit 1: 137188 Unit 2: 109975</td>
<td>102226</td>
<td>74870</td>
</tr>
<tr>
<td>Fuel Loading</td>
<td>0- 100% BL</td>
<td>40 - 100% BL</td>
<td>0 - 100% BL</td>
</tr>
<tr>
<td>NOx, CO emissions [ppm]</td>
<td>75/10 ppm</td>
<td>30/10 ppm</td>
<td>25/10 ppm</td>
</tr>
<tr>
<td>GT/CC efficiency [%]</td>
<td>34.5/48.9</td>
<td>32.3/47.2</td>
<td>36.0/50.1</td>
</tr>
</tbody>
</table>

**AEN experience on fuel flexibility**

**AE94.2K**

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## AEN experience on fuel flexibility

### AE 94.2K: SYNGAS OPERATION

<table>
<thead>
<tr>
<th></th>
<th>ISAB Energy (I)</th>
<th>Elettra GLT Servola (I)</th>
<th>EniPower Ferrera E. (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feedstock</strong></td>
<td>Asphalt</td>
<td>Steel mill process gas</td>
<td>Asphalt</td>
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<tr>
<td><strong>Gasification</strong></td>
<td>Texaco</td>
<td>-</td>
<td>Shell</td>
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<tr>
<td><strong>Natural Gas Integration (as thermal Input to Gas Turbine)</strong></td>
<td>0%</td>
<td>45-49%</td>
<td>0-35%</td>
</tr>
<tr>
<td><strong>Fuel Gas Temperature</strong></td>
<td>195 °C</td>
<td>260 °C</td>
<td>190 °C</td>
</tr>
<tr>
<td><strong>Fuel Gas Pressure</strong></td>
<td>22 barg</td>
<td>20 barg</td>
<td>22 barg</td>
</tr>
<tr>
<td><strong>H₂/CO ratio</strong></td>
<td>0.95 - 1.05</td>
<td>0.09 - 0.99</td>
<td>0.55 - 0.92</td>
</tr>
<tr>
<td><strong>Fuel Gas Comp. [% vol.]</strong></td>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>H₂</td>
<td>31.25</td>
<td>9.03</td>
<td>9.56</td>
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<tr>
<td>CO</td>
<td>29.78</td>
<td>16.25</td>
<td>9.61</td>
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<tr>
<td>H₂O</td>
<td>34.59</td>
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<td>N₂</td>
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<td>CO₂</td>
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<tr>
<td>CH₄</td>
<td>0.13</td>
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<td>20.73</td>
</tr>
<tr>
<td>C₂+</td>
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<td>0.53</td>
<td>0.54</td>
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<tr>
<td><strong>LHV [MJ/Nm³]</strong></td>
<td>7.2</td>
<td>8.67</td>
<td>10.21</td>
</tr>
</tbody>
</table>
AEN experience on fuel flexibility

AE 94.2

AE 94.2K

AE 94.3A

AE 64.3A
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AE 94.3A

OFFGAS OPERATION

Properties
• Higher Stoichiometric Combustion Temperature
• Higher Flame Speed
• Smaller Volumetric Heating values

• Pre-Ignition
• Flash Back risk in Premix Mode
• Higher NOx emissions
• Combustion Dynamics

<table>
<thead>
<tr>
<th>Fuel Properties</th>
<th>CH₄</th>
<th>H₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHV [MJ/kg]</td>
<td>50.3</td>
<td>119.9</td>
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<tr>
<td>LHV [MJ/Nm³]</td>
<td>33.9</td>
<td>10.2</td>
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<tr>
<td>Flame speed in air [cm/s]</td>
<td>43</td>
<td>350</td>
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<tr>
<td>Stoich. Comb. Temp. [K]</td>
<td>2227</td>
<td>2370</td>
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<tr>
<td>Density [kg/Nm³]</td>
<td>0.72</td>
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<tr>
<td>Specific heat [kJ/kg K]</td>
<td>2.18</td>
<td>14.24</td>
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<tr>
<td>Flammability limits [%]</td>
<td>5-15</td>
<td>4-75</td>
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</table>
AEN experience on fuel flexibility

**AE 94.3A OFFGAS OPERATION**

- Reliable dual fuel operation with same combustion system
- Different settings for OG-NG and NG only operation
- 70%-100% Load allowable on OG-NG operation

- 15% H₂ max → part load operation
- 11% H₂ max → high load operation
- Negligible effect on NOx emissions
## Shale Gas: compositions

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<tr>
<td>Total inerts (CO₂+N₂)</td>
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AEN experience on fuel flexibility

AE 94.3A

Effects of gas change

- Combustion stability

- Emissions

Installation of a calorimeter for a fast reaction on combustion parameters
Fast changes in gas composition could affect the combustion dynamics, in terms of flame stability. In order to prevent humming phenomena due to gas switch it is better to have a fast reaction in control system corrections, so that combustion parameters can be set up in the proper way.

**Fast changes in gas composition**

**Base load:** high combustion thermal input

**Load ramps:** high pilot gas thermal input

With the installation of a calorimeter a fast reaction of the control system on combustion parameters can be achieved.
Combustion stability at high load

Comparison of combustion stability for different gas composition → variation in frequencies
Emissions @ minimum load

Emissioni CO & NOx vs. CH4

- NOx [mg/Nm^3]
- CO [mg/Nm^3]
- PTG [MW]

% CH_4 increasing
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The **SHALE GAS** represents an important opportunity for the Italian energy market.

To catch this chance it is necessary to adapt the gas turbines operation with a fuel having a very variable composition.

**Ansaldo Energia**, thanks to its extensive experience on **FUEL FLEXIBILITY**, has shown to be ready to exploit this opportunity on its entire fleet, with control philosophies capable of handling sudden variations in the composition of the gas.
Thank you for your attention

Alessia.Bulli@aen.ansaldo.it