Improving the Flexibility and Efficiency of Gas Turbine-based Distributed Power Plant

Mike Welch
Siemens Industrial Turbomachinery Ltd.
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Contents

- Introduction
- Decentralised Power
- Addressing the Energy Trilemma with Flexible Decentralised Power
  - Cost of Energy
  - Security of Supply
  - Environment
- Conclusions
Introduction

The Energy Trilemma

- Growing demand for affordable electricity
- Modern society requires security of power supplies
- Need to limit impact of power generation on both the local and global environment

- **Focus on only one area can cause problems**
- High penetration of intermittent renewables has created security of supply and price problems
- Change in operational requirements of fossil fuel power
Introduction

Changing Operational Needs

- Rapid changes in fossil fuel power generation output caused by non-despatchable intermittent renewables
- Power plant designed for base load having to operate as mid-merit or peaking plant
- Part-load operation of centralised fossil plant or maintained as spinning reserve
- ‘Clean’ natural gas fossil fuel generation under cost pressures
- Security of supply risks, increased emissions
- Water constraints
Introduction

Changing considerations for future Power Plant design

Flexibility
- Fast Response
- Frequent Cycling
- Fuel Switching

Fossil Power Generation needed
Decentralised Power

Decentralised Power can help address the challenges of the Energy Trilemma

- Located close to load demand centres
  - Reduced transmission losses
  - Connected to distribution network
  - Frequency and voltage support
  - Can satisfy a local heat demand

- Multiple units
  - Increased availability
  - Enhanced operational range
  - High efficiency across wide load range
  - Minimised environmental footprint
  - Low initial investment
    - Easy expansion
Siemens Gas Turbine Portfolio for Decentralised Power

Heavy-duty gas turbines
- SGT5-8000H
- SGT5-4000F
- SGT5-2000E
- SGT6-8000H
- SGT6-5000F
- SGT6-2000E

Industrial gas turbines
- SGT-800
- SGT-750
- SGT-700

Aeroderivative gas turbines
- Industrial Trent 60
- Industrial RB211
- Industrial 501-K

With Rolls-Royce aeroderivative technology

Power Generation / Mechanical Drive
Addressing the Energy Trilemma with Decentralised Power

Price of Energy

- High Energy Efficiency
- Competitive Installed Costs
- Compact Modular Packages
  - Small footprint, ease of future expansion
- Low maintenance and plant manpower costs
  - Core exchange principal
- Fast start-up possibilities with no maintenance penalties
  - No EOH on Industrial Trent aero-derivative
- Low cost fuel potential
- Low waste disposal
  - Lube oil & water treatment chemicals
Addressing the Energy Trilemma with Decentralised Power

Price of Energy

- Use of Opportunity Fuels to reduce costs
  - US$0.50/ MMBTU ≈ US$2 million / year for a 50MW class gas turbine
- Wide range of potential fuels, even in DLE combustion systems
- Can show environmental benefit too
  - Reduced flaring
  - Ethane or propane to replace diesel

7.7MW tri-fuel gas turbine installed in a cogeneration plant in the USA

Siemens Gas Turbine Solution

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Page 10 October 2016

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### Addressing the Energy Trilemma with Decentralised Power

#### Price of Energy: Pulse Load Operation

<table>
<thead>
<tr>
<th>100MW Power Plant</th>
<th>ICE</th>
<th>CC ICE</th>
<th>Trent DLE OC</th>
<th>Trent DLE CCGT</th>
<th>Trent + ORC</th>
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<tbody>
<tr>
<td><strong>Full Load Net Efficiency</strong></td>
<td>%</td>
<td>44</td>
<td>49.2</td>
<td>41.87</td>
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<tr>
<td><strong>Start-up time</strong></td>
<td>Mins</td>
<td>5</td>
<td>50</td>
<td>10</td>
<td>40</td>
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<tr>
<td><strong>Shut-down time</strong></td>
<td>Mins</td>
<td>1</td>
<td>20</td>
<td>5</td>
<td>20</td>
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<tr>
<td><strong>O&amp;M costs (2000 hrs/yr operation)</strong></td>
<td>$/MWh</td>
<td>5.5</td>
<td>5.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Start-up costs</strong></td>
<td>$/MW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

![Chart showing the price of energy for Pulse Load Operation with different power plants and operating times.](chart.png)
Addressing the Energy Trilemma with Decentralised Power

Security of Supply

- Potential to connect to Grid at Distribution level
- Voltage and frequency support to avoid the need for load shedding
- Multiple units: high station availability / low maintenance downtimes
- Black start and multi-fuel capability
- Low starting power
  - Potential to combine with energy storage solutions
- Fast start and cycling capability

99.5% Start Reliability
Addressing the Energy Trilemma with Decentralised Power

Security of Supply

Also Step Load possibilities for Gas Turbines for decreased time to full load

* Ultra fast start requires specific pre-start conditions to be met

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Addressing the Energy Trilemma with Decentralised Power

Environment

- High Efficiency across wide load range through multiple units
- Low combustion emissions across wide load range and on start-up
  - NOx, CO, UHC, Methane Slip
- Water-free CCGT potential
  - Organic Rankine Cycle
  - Supercritical CO₂
- Reduced construction times through modularity
- Compact Footprint
- Biogas, syngas and hydrogen fuel potential
Addressing the Energy Trilemma with Decentralised Power

Environment

- Growing concern over impact of methane emissions to atmosphere

- Several studies in Marine applications on using LNG as fuel

- Methane slip reduces CO$_2$ benefit of LNG compared to diesel or HFO

- 9MW spark ignition gas engine with typical 5g/kWh methane slip at full load is > 1 tonne/hour CO$_2$ eq.
  - Methane slip increases as load decreases: typically 40g/kWh at 25% load

Comparison of combustion emissions in mg/Nm$^3$ from a 4MW class gas engine and small gas turbines (gas engine data from Waukesha 16V275GL data sheet)
Conclusions

Gas Turbine-based Decentralised Power can play a major role in the future of Power Generation

- Flexibility to meet Market requirements
- Applicable for any power output needs
- Helps address the Energy Trilemma
  - Affordable cost of energy
  - Secure supplies
  - Minimised environmental footprint
- Support for Grids with high penetration of Intermittent Renewables
- Combined with other technologies to maximise operational flexibility
- Non-fossil fuel potential
Thank you for your attention!

Mike Welch
Industry Marketing Manager
Siemens Industrial Turbomachinery Ltd.

Waterside South
Lincoln, United Kingdom

Phone: +44 (1522) 584000
Mobile: +44 (7921) 242234

E-mail: welch.michael@siemens.com

siemens.com/power-gas