A new approach of distributed power generation

Dr. Thorsten Krol
Content

• Introduction
  • Market description
  • Operational analysis

• Discussion of various solution options
  • Modernization of existing power plants
  • New Installations
    • Centralized power generation
    • De-centralized power generation

• Reference cases for new installations
Operational market driver

1. Grid stability – country overview

2. Wind in Energy mix

3. No. of redispatches p.a. in local grid

4. Profit situation LGT-driven power plants

* Projection from available data Apr. 1st – Dec. 2013

** Data from Jan. – Jul. 31st, 2015

Example profit situation of large GT-driven power train

<table>
<thead>
<tr>
<th>Year</th>
<th>Positive CSS</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>84.9 %</td>
<td>7.437 h</td>
<td>6.053 h</td>
<td>36.3 %</td>
<td>19.7 %</td>
<td>20.7 %</td>
</tr>
<tr>
<td>2011</td>
<td>69.1 %</td>
<td>6.053 h</td>
<td>3.180 h</td>
<td>1.726 h</td>
<td>1.813 h</td>
<td></td>
</tr>
</tbody>
</table>
## Differences in operating regimes

<table>
<thead>
<tr>
<th>Operations statistics</th>
<th>Base load operation conventional</th>
<th>Base load operation renewable</th>
<th>Peak load operation renewable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations in capability diagram</td>
<td><img src="image1" alt="Active power" /></td>
<td><img src="image2" alt="Active power" /></td>
<td><img src="image3" alt="Active power" /></td>
</tr>
<tr>
<td>active power share</td>
<td><img src="chart1" alt="Pie chart" /></td>
<td><img src="chart2" alt="Pie chart" /></td>
<td><img src="chart3" alt="Pie chart" /></td>
</tr>
</tbody>
</table>

### Active power

- **Thermal rotor limit**
- **Power factor**
- **Thermal stator winding limit**
- **Step iron limit**
- **Steady state limit**

### Operation in capability diagram

- **< 60%**
- **60% - 90%**
- **> 90%**

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Page 4 September, 2015 VGB-Kraftwerke 2015 Wien Dr. T. Krol AL=N; ECCN=N
Differences in operating regimes

<table>
<thead>
<tr>
<th>Operations statistics</th>
<th>Base load operation conventional</th>
<th>Base load operation renewable</th>
<th>Peak load operation renewable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load changes and change rate</td>
<td><img src="image1.png" alt="Chart" /></td>
<td><img src="image2.png" alt="Chart" /></td>
<td><img src="image3.png" alt="Chart" /></td>
</tr>
</tbody>
</table>
| Operations summary | • >7000 operating hours  
• Defined loading points in power diagram  
• Low number of starts and load changes | • >7000 operating hours  
• Defined loading points in power diagram  
• Low number of starts and high number of load changes | • <1000 operating hours  
• Operation in power diagram on demand  
• Low number of starts and highest number of load changes |
Changes in Power Markets: Centralized Power Generation

Generation

Transmission & Distribution

Consumption
Gas Turbine Modernizations  
Operational Flexibility

<table>
<thead>
<tr>
<th>Combined Cycle Start Up</th>
<th>Frequency Sensitive Mode and Frequency Restoration Reserve</th>
<th>Peak Load &amp; Grid Support</th>
<th>Minimum Load Improvement</th>
<th>Shut Down and Restart Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Turbine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast GT Start Up with Hot-Start-On-The-Fly</td>
<td>GT Load Gradient Increase within IGV actuation range</td>
<td>Turn Up &amp; (Fast) Wet Compression</td>
<td>Part Load Upgrade &amp; Extended Turn Down</td>
<td>Shut Down Gradient &amp; Reduced GT Cool Down Time</td>
</tr>
<tr>
<td>Steam Turbine</td>
<td>(Advanced) Hot-Start-On-The-Fly</td>
<td>EOH counter, (load change) Stress controller</td>
<td>multiple measures to reduce wetness &amp; thermal fatigue</td>
<td>Parallel shut down</td>
</tr>
<tr>
<td>Generator</td>
<td>Turninggear Operation, Frequent starting</td>
<td>Operation in load following regime</td>
<td>Power increase of generators</td>
<td>Generator Efficiency in Power Train</td>
</tr>
</tbody>
</table>

Geneva - generator

Standard Operation Line

Flex Operation Line

Base Load (P*)
Changes in Power Markets:
Centralized Power Generation

Generation 

Transmission & Distribution 

Consumption
**Advanced 50Hz F-Class gas turbine**

**SGT5-4000F**

- **Gross power output**: 307 MW*
- **Gross Efficiency**: 40 %*
- **Gross Heat rate**: 9001 kJ/kWh
- **Exhaust mass flow / temp.**: 723 kg/s / 579 ºC*
- **Weight**: 312000 kg

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**Combined Cycle Package i.e. 1S**

- **Net power output**: 445 MW
- **Net efficiency**: 58.7 %
- **Net heat rate**: 6133 kJ/kWh
- **Number of gas turbines**: 1
- **Pressure / Reheat**: Triple / Yes

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* @ ISO conditions, 50mbar backpressure
Changes in Power Markets:
Centralized Power Generation

Generation

Transmission & Distribution

Consumption
IPPS - Gas Turbine power plants
Stable efficiency in a wide load range with multiple GTs

Performance EconoFlex6™

Long term experience of Turbines
→ SGT-800
→ SST-900

Robust technology
→ High reliability

Best serviceability
→ Highest Power plant availability

Focus on customer needs
→ High flexibility

EconoFlex6™

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Output, MW net*</td>
<td>425 MW</td>
</tr>
<tr>
<td>Net efficiency*</td>
<td>56.2 %</td>
</tr>
<tr>
<td>Power within 10 minutes*</td>
<td>286 MW</td>
</tr>
<tr>
<td>Minimum load, % / MW*</td>
<td>10% / 42 MW</td>
</tr>
<tr>
<td>Ramp rate, MW / min*</td>
<td>73 MW/min</td>
</tr>
</tbody>
</table>

* @ ISO conditions, 50mbar backpressure
Changes in Power Markets: New centralized vs. decentralized Power Generation
Changes in Power Markets:
New centralized vs. decentralized Power Generation

**Generation**

- CG dominated
- DG dominated

**Transmission & Distribution**

- Reduction of system losses
- System losses in Europe
- Source: IEA

**Consumption**

- Lower generation efficiencies still economic
- Lower investments in grid while slightly higher investment in generation
- additional profit options by CoGen and local grid stabilization

**System losses in Europe**

- 0% - 3%
- 3% - 6%
- 6% - 9%
- 9% - 12%
- >12%
## Product range

### Power Band

<table>
<thead>
<tr>
<th>Power Generation</th>
<th>SGT-100 5.4 MW</th>
<th>SGT-200 6.8 MW</th>
<th>SGT-300 7.9 MW</th>
<th>SGT-400 13.4 MW</th>
<th>SGT-500 19.1 MW</th>
<th>Ind. RB211-G62 (27.2 MW)</th>
<th>Ind. RB211-GT61 (32.1 MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven for Power Generation and Cogeneration</td>
<td>Fuel flexibility, Fast start time</td>
<td>Operates on a wide range of fuels</td>
<td>Excellent steam rising capability</td>
<td>Burns heavy fuel (HFO) oil and crude oil</td>
<td>High simple cycle efficiency</td>
<td>Low maintenance, high availability</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packages</th>
<th>SGT-100 Package</th>
<th>SGT-200 Package</th>
<th>SGT-300 Package</th>
<th>SGT-400 Package</th>
<th>SGT-500 Package</th>
<th>Ind. RB211-Package</th>
<th>Ind. Trent - Package</th>
</tr>
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</tbody>
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### Packages

- SGT-100 Package
- SGT-200 Package
- SGT-300 Package
- SGT-400 Package
- SGT-500 Package
- Ind. RB211-Package
- Ind. Trent - Package

- SGT-600 Package
- SGT-700 Package
- SGT-750 Package
- SGT-800 Package

### Product Range

- **Ind. 501-K**
  - 3.9 - 5.7 MW
  - Fuel flexibility, Fast start time

- **SGT-200**
  - 6.8 MW
  - Compact design, Operates on various fuels

- **SGT-300**
  - 7.9 MW
  - Operates on a wide range of fuels

- **SGT-400**
  - 13.4 MW
  - Excellent steam rising capability

- **SGT-500**
  - 19.1 MW
  - Burns heavy fuel (HFO) oil and crude oil

- **Ind. RB211-G62**
  - (27.2 MW)

- **Ind. RB211-GT61**
  - (32.1 MW)

- **Ind. RB211-GT62**
  - (27.2 MW)

- **Ind. RB211-GT62**
  - (29.8 MW)

- **Ind. Trent DLE**
  - (54.0 MW)

- **Ind. Trent WLE**
  - (65.6 MW)

- **SGT-700**
  - 32.8 MW
  - Fuel flexibility: LNG, FLNG, Upstream

- **SGT-750**
  - 37.0 MW
  - Low maintenance, high availability

- **SGT-800**
  - 47.5/50.5/53 MW
  - Proven, high efficiency

### Proven for Power Generation and Cogeneration

- Compact design, Operates on various fuels
- Excellent steam rising capability
- Burns heavy fuel (HFO) oil and crude oil

- High simple cycle efficiency
- Low maintenance, high availability

### Fuel flexibility

- LNG, FLNG, Upstream
- Burns heavy fuel (HFO) oil and crude oil

### High simple cycle efficiency

- Fast start and restart capability
- High simple cycle efficiency

### Proven, high efficiency

- Fast start and restart capability
- High simple cycle efficiency
Technology leader with best gas turbines technology designed for your needs

Flexibility by combination of leading technologies

**Aero-derivative gas turbines (ADGT’s)**
- Long term proven technology
- Fixed and floating applications

**Industrial gas turbines (IGT’s)**
- Focus on industrial and electrical power generation

Best solution for your needs in
- industrial,
- CoGen, and
- Combined Cycle applications with high potential in reliability, life cycle, efficiencies, flexibility (part load efficiency, load change rate, parking load, etc.)

Significant increase of flexibility by combining leading technologies
# Delimara (Malta)
## Reliable CCPP with high efficiencies

## Project Summary

<table>
<thead>
<tr>
<th>Project</th>
<th>Delimara</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>ElectroGas, Malta</td>
</tr>
<tr>
<td>Application</td>
<td>205 MW&lt;sub&gt;e&lt;/sub&gt; LNG-fired power plant</td>
</tr>
<tr>
<td>Technology</td>
<td>3 x SGT-800 Gas Turbines, 3 x HRSG and 1 x SST-900 Steam Turbine</td>
</tr>
<tr>
<td>Start</td>
<td>2014</td>
</tr>
</tbody>
</table>
| Complete | Summer 2016 for Open Cycle  
End 2016 for Combined Cycle |
| Challenge |  
- Governmental change out of heavy fuel oil towards LNG  
- Reliable power generation for 50% of Malta’s electricity demand |
| Solution |  
- Combined cycle power plant based on 3 x 1 configuration delivers 205MW<sub>e</sub> with high efficiency and low emissions also at part load operation  
- High performance in high ambient air temperatures by inlet air cooling system using chilling power from LNG regasification process |
| Benefits |  
- Reduced level of air pollution and fuel consumption in country  
- Low power generation costs  
- Reliable technology with high availability |
## Bayonne Energy Centre – Gas-fired power plant

### Utility

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<tr>
<td><strong>Benefits</strong></td>
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### Summary

1. **Modernize existing Power Plants**
   - Extend life time and usage of existing and payed off assets
   - Enhanced operational flexibility to meet new operating conditions
   - High mass of inertia remains in grid for frequency stabilization
   - Low investment costs

2. **New LGT Power Plant centralized**
   - Optimized for customers with high power demand
   - Highest full load efficiencies
   - Utilization of existing distribution grids
   - Lowest investment per MW installed

3. **New SGT Power Plant centralized**
   - Utilization of existing distribution grids
   - Highest availability
   - High operational flexibility

4. **New SGT Power Plants decentralized**
   - Maximum operational flexibility optimized for local demand in grid
   - Directly embedded into Smart Grid
   - CAPEX can be spread over time
   - Short installation time
   - High availability
Thank you for your attention!
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