Flexibility of coal and gas fired power plants

2017-09-18 Paris, Advanced Power Plant Flexibility Campaign
Dr. Andreas Feldmüller
Content

1  Technical comparison of plant flexibility
2  Plant modernization potentials
3  Modernization show cases
4  Conclusions
Key aspects of flexible power plant operation

1. Hot start-up time
2. Ramp rate
3. Minimum Load
4. Cold start-up time
Operational flexibility of power plants has increased

Example: Lignite-fired power plants

<table>
<thead>
<tr>
<th>Lignite-fired Power Plants</th>
<th>VDE (ETG) April 2012</th>
<th>Agora Energiewende, Fichtner June 2017</th>
<th>Neurath (Germany) (6)</th>
<th>Belchatow (Poland) (1)</th>
<th>Boxberg R (Germany) (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commonly used</td>
<td>State-of-the-art power pl.</td>
<td>Optimization potential</td>
<td>Commonly used</td>
<td>State-of-the-art power plants</td>
<td>Commissioned 1975, modernized</td>
</tr>
<tr>
<td>Average ramp rate [% Pnom per min]</td>
<td>1</td>
<td>2.5</td>
<td>4</td>
<td>1-2</td>
<td>2-6</td>
</tr>
<tr>
<td>Minimum Load [% Pnom]</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>50-60</td>
<td>35-50</td>
</tr>
<tr>
<td>Hot start-up time [min]</td>
<td>360</td>
<td>240</td>
<td>120</td>
<td>240-360</td>
<td>75-240</td>
</tr>
<tr>
<td>Cold start-up time [min]</td>
<td>600</td>
<td>480</td>
<td>360</td>
<td>480-600</td>
<td>290-480</td>
</tr>
</tbody>
</table>

(0) VDE-Studie "Erneuerbare Energie braucht flexible Kraftwerke - Szenarien bis 2020", Autoren ETG-Task Force Flexibilisierung des Kraftwerksparks

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants

(6) RWE AG, Siemens AG, PowerGen Europe 2013

New plants and plant modernizations lead to increasing operational flexibility of the installed fleet!
Flexibility of coal and gas fired power plants - comparison

Minimum Load

<table>
<thead>
<tr>
<th>Simple cycle</th>
<th>Gas</th>
<th>Combined cycle</th>
<th>Hard coal</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum load [% ( P_{\text{nom}} )]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parking load GT 26 ((^{2}))</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>with sequential comb.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Gas**
  - Bouchain (\(^{3}\)) (2016)
  - Fortuna (\(^{4}\)) (2016)

- **Combined cycle**
  - Parking load GT 26 (\(^{2}\)) with sequential comb.

- **Hard coal**
  - Walsum (\(^{1}\)) (2013)

- **Coal**
  - Neurath (\(^{6}\)) (1975\(\rightarrow\)2012)
  - Belchatow (\(^{1}\)) (2011)
  - Boxberg R (\(^{1}\)) (2012)

**Legend**
- Commonly used (\(^{1}\))
- State-of-the-art (\(^{1}\))
- Example
- Modernization (from \(\rightarrow\) to)

**References**
1. Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants
3. GE Power, EDF, PowerGen Europe 2016
4. GAS TURBINE WORLD May - June 2016
5. Siemens references
6. RWE AG, Siemens AG, PowerGen Europe 2013
Flexibility of coal and gas fired power plants – comparison

Ramp rate

<table>
<thead>
<tr>
<th>Type</th>
<th>Gas</th>
<th>Combined cycle</th>
<th>Hard coal</th>
<th>Coal</th>
<th>Lignite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple cycle</td>
<td>Siemens F class (mod in 2016)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined cycle</td>
<td>Siemens F class (mod in 2016)</td>
<td>Walsum (2013)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Commonly used (1)
- State-of-the-art (2)
- Example (3)
- Modernization (from to)

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants
(2) GE Power, EDF, PowerGen Europe 2016
(3) RWE AG, Siemens AG, PowerGen Europe 2013
(4) GAS TURBINE WORLD May - June 2016
(5) Siemens AG, Power Gen Europe 2017
Flexibility of coal and gas fired power plants – comparison

Hot start-up time

<table>
<thead>
<tr>
<th>Hot start-up time [min] or [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>360</td>
</tr>
<tr>
<td>330</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>270</td>
</tr>
<tr>
<td>240</td>
</tr>
<tr>
<td>210</td>
</tr>
<tr>
<td>180</td>
</tr>
<tr>
<td>150</td>
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<tr>
<td>120</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Simple cycle

Gas

Combined cycle

Hard coal

Coal

Lignite

Commonly used (1)  State-of-the-art (1)  Example  Modernization (from → to)

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants
(3) GE Power, EDF, PowerGen Europe 2016
(4) GAS TURBINE WORLD May - June 2016
(8) KMW AG, Siemens AG, Power Gen Europe 2015
Flexibility of coal and gas fired power plants - comparison

Cold start-up time

<table>
<thead>
<tr>
<th></th>
<th>Gas</th>
<th>Combined cycle</th>
<th>Coal</th>
<th>Lignite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple cycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined cycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard coal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lignite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Commonly used (1)
- State-of-the-art (1)
- Example

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants
Content

1. Technical comparison of plant flexibility
2. Plant modernization potentials
   - Example: Hot start-up
   - Example: Ramp rate (frequency response)
   - Example: Minimum load
3. Modernization show cases
4. Conclusions
Hot start-up of a combined cycle power plant

- Improved concept (Hot start on the Fly, a fully integrated and automated start-up process)
- Further potential by increased start-up gradients of GT and ST

Improvement potentials gained from start-up concept, component capabilities and automation
Fast load ramps of steam power plants – frequency support with the water steam cycle

1. Throttling
2. Additional Valve (interstage valve)
3. Condensate Stop
4. HP Heater
5. Fuel Increase
Overall optimization of steam power plant to improve plant frequency support
HP turbine with additional HP valve for peak and part load

- Rated condition: Additional HP valve is closed
- Additional (peak) load: Additional HP valve is open
- Part load: Connected to heater

Main control valves are wide open

Stop valve

HP turbine with additional HP valve to increase
- HP swallowing capacity for frequency response
- Feed water temperature at part load
Controls modernization to reduce minimum load

Minimum Load Reduction

- Use of robust state space controller for unit control
- Adaptation, optimization and setting of lower-level controls for new minimum load level
- Adaptation or addition of control sequences, burner and mill scheduler
- Provision of additional instrumentation where necessary
- Modifications, additions or replacement of original DCS as necessary

- Faster response to increased load demands as unit does not need to be shut down
- Avoidance of unnecessary start-ups and shutdown
Content

1. Technical comparison of plant flexibility
2. Plant modernization potentials
3. Modernization show cases
   - Combined Cycle: Mainz-Wiesbaden
   - Lignite fired: Neurath Units D and E
4. Conclusions
Results at CCPP Mainz-Wiesbaden - Power station 3
Hot start-up time reduced to 27 minutes

- Combined Cycle
- SCC5-4000F
- Multi shaft
- ≈ 440 MW
- Built 2000

- Hot Start on the Fly (HoF) is the standard start up process after overnight stop
- Highly predictable start up time of 27 minutes (+/- 2 minutes)

Reference: PowerGen Europe 2015,
From base to cycling operation - innovative operational concepts for CCPP,
Dr. Andreas Feldmüller & Florian Roehr, Siemens AG,
Thomas Zimmerer, Kraftwerke Mainz-Wiesbaden AG
Results at RWE Neurath Unit D
Load gradient tripled, Minimum load reduced by 40%

- 630 MW, tangential, lignite-fired, built 1975
- Boiler design for base load
- Fuel changed massively compared to design

Reference: PowerGen Europe 2013
A Vision Becomes Reality, One of the most flexible lignite fueled units of the World - Achieved by a DCS Retrofit
Björn Pütz & Thomas Schröck, RWE AG, Annette Barenbrügge & Bernhard Meerbeck, Siemens AG

- Installation of a new robust state-space unit control
- Fully automatic mill shut-on and shut-off
- Optimisation of all subordinated controllers, e.g. air, feedwater, fuel
Content

1. Technical comparison of plant flexibility
2. Plant modernization potentials
3. Show cases
4. Conclusions
Conclusions

- Operational flexibility of power plants has increased in the last years
- New plants and plant modernizations lead to increasing operational flexibility of the installed fleet
- Large improvements could be achieved by plant modernizations
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Details of the references

(0) VDE-Studie "Erneuerbare Energie braucht flexible Kraftwerke - Szenarien bis 2020“, Autoren ETG-Task Force Flexibilisierung des Kraftwerksparks, April 2012

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants

(2) Alstom, Christoph Ruchti, Hamid Olia, Peter Marx, Andreas Ehram and Wes/ey Bauver, Combined cycle plants as essential contribution to the integration of renewables into the grid, VGB PowerTech 9/2011, page 84


(4) GAS TURBINE WORLD May - June 2016, Junior Isles, Block Fortuna sets three world records, page 16-20

(5) Siemens references

(6) PowerGen Europe 2013, Pütz & Schröck (RWE AG), Barenbrügge & Meerbeck (Siemens AG), A Vision Becomes Reality, One of the most flexible lignite fueled units of the World - Achieved by a DCS Retrofit

(7) Power Gen Europe 2017, Eisfeld, Feldmüller, Röhr (Siemens AG), CCPP improvements in a business environment of intermittent power generation

(8) PowerGen Europe 2015, Feldmüller & Roehr (Siemens AG), Zimmerer (Kraftwerke Mainz-Wiesbaden AG), From base to cycling operation - innovative operational concepts for CCPP
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