Flexibility replaced efficiency as a technology driver

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Drivers of the power sector – an European perspective

- Security of Supply
- Economy
- Environment

- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010
- 2020

- Capacity
- Availability
- Emissions
- Efficiency
- Flexibility
Consequences of the merit order distortion are lower wholesale prices and less operating hours.
The missing-money-problem

Example Coal-fired Power Plant GKM (all units)

Is the Energy-only market the right market design to stimulate and ensure investments and operation of conventional power plants in the long-term?
The future design concepts are determined by costs, lifetime requirements, efficiency and flexibility. The prioritization of these criteria depends on the value of flexibility.
What does flexibility mean?

Flexibility is more than technology. It comprise aspects from system stability, design, operational concepts to shift organization and personal skills.
Technical flexibility comprises several aspects

**Dynamics**
- high operational gradients (load change rate)
- short ramp-up time for minimal and nominal load
- short minimal stand-still time

**Operational flexibility**
- high number of start-ups and load cycle at reduced life-time consumption
- low minimal load with high efficiency
- uniform high-level efficiency-profile at a wide load range

**Fuel flexibility**
- high plant availability in spite of coal blending and imported coal
- coal treatment technologies and plant modifications (e.g. combustion processes)
- biomass co-firing with a secure supply chain

The flexibility potentials are limited by emission and dew-point values, efficiency and lifetime requirements as well as the minimum steam flow.
Principal measures for flexibilisation of coal fired plants

- **Introduction of the bin (-and feeder) system**
- **Process optimization water/steam system**
- **Optimization conventional combustion**
- **Part load optimization of components**
- **Optimization material concept pressure containing component**

Source: Vattenfall
Dynamics and operational flexibility

Main flexibility contributors are: high load gradients, low minimum load, short ramp-up times

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Hard-coal</th>
<th>Lignite</th>
<th>CCGT</th>
<th>Gas Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load gradient [% / min]</td>
<td>1.5 / 4 / 6</td>
<td>1 / 2.5 / 4</td>
<td>2 / 4 / 8</td>
<td>8 / 12 / 15</td>
</tr>
<tr>
<td>in the load range [%]</td>
<td>40 to 90</td>
<td>50-90</td>
<td>40* to 90</td>
<td>40* to 90</td>
</tr>
<tr>
<td>Minimum load [%]</td>
<td>40 / 25 / 20</td>
<td>60 / 50 / 40</td>
<td>50 / 40 / 30*</td>
<td>50 / 40 / 20*</td>
</tr>
<tr>
<td>Ramp-up time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot start &lt;8 h [h]</td>
<td>3 / 2.5 / 2</td>
<td>6 / 4 / 2</td>
<td>1.5 / 1 / 0.5</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Cold start &gt;48 h [h]</td>
<td>10 / 5 / 4</td>
<td>10 / 8 / 6</td>
<td>4 / 3 / 2</td>
<td>&lt; 0.1</td>
</tr>
</tbody>
</table>

Source: VDE
usual value / state of the art / potential
*as per emission limits for NOx and CO

Thermal power plants are able to significantly contribute to a modern energy system. Technology development is focused on realizing the potentials for flexibility.
Dynamics and operational flexibility

Comparison of flexibility and ramp capacities of state-of-the-art CCGT and lignite-fired power plants

High and fast ramp capabilities are flexible and complement intermittent renewables.

- Operation with two boilers
- Operation with one boiler
- BoA - optimised operation of a lignite-fired power plant.

**Technical measures to increase of operational load gradient:**

→ separation of grinding and combustion, decreasing wall-thickness and aligned component design

**Technical measures to reduce the minimal load:**

→ increase of numbers of mills, optimization of grinding process and optimized combustion process (e.g. flame detection)
Dynamics and operational flexibility

Example Coal-fired Power Plant GKM (Unit 8)

Start-up diagram, Unit 8 at GKM

Live steam flow in %

Time in minutes

- Blue line: Hot < 8 h
- Red line: Hot > 8 h < 48 h
- Green line: ColdStart > 48 h

- 0 Min. to 105 Min.
- 105 Min. to 150 Min.
- 190 Min.
Reduction of minimum load

Typical technical measures:

→ **Boiler**
  - Low minimum load thus low thermal firing capacity
  - Increase of numbers of mills
  - Optimization of grinding and combustion process
  - Installation of tilting burners
  - Switch to 1-mill operation

→ **Water Steam Cycle**
  - Minimum feedwater flow
  - Boiler temperature profile

→ **Turbine**

→ **Flue Gas Cleaning**

→ **Auxiliaries**
  - Minimum load of pumps, fans and other aux.equipm.
  - Protection systems (I&C)
## low-load operation: Basic considerations

<table>
<thead>
<tr>
<th>Typical challenges</th>
<th>Problem</th>
<th>Solution</th>
<th>Technical measure</th>
</tr>
</thead>
</table>
| Flame stability and flame detection                    | Flame pulsation and blow-off                 | ▪ Modify burner operation  
▪ Modify burner  
▪ Support burners (oil/gas)  
▪ Additional flame detectors | ▪ Improve fuel to air ratio  
▪ Increase mixture and swirl  
▪ Reduce cooling air flows  
▪ Change pulverization  
▪ install flame holder rings |
| Thermal firing capacity per burner level                | Mill minimum load                             | ▪ Ensure minimum coal content in burner fuel/air flow  
▪ Ensure equal coal dust distribution to burners  
▪ Reduce cooling air flows  
▪ Improve positioning accuracy of air control flaps | ▪ Reduce cooling air flows  
▪ Avoid leaking air flaps  
▪ Modification of characteristic curves of flap drives and more accurate flow and position measurements |
| Stable and equal distribution of feed water in evaporator | Over-heating and excessive tension in boiler tubes | ▪ Check for design buffer in minimum feedwater flow  
▪ Use circulation mode |                                                                                          |
| Boiler temperature profile changes                      | High temperature gradients in thick-wall components and turbine | ▪ Minimize temperature changes  
▪ Check turbine ventilation protection | ▪ Improve/extend measurements in water/steam cycle  
▪ Optimize mode change procedure between once-through and circulation operation |
| Higher dosing of NH3 in SCR due to low flue gas temperature (~ < 280 °C) | NH3 slip Fouling/corrosion                   | ▪ Additional flue gas re-heating  
▪ Improve dosing control | ▪ Eco-Bypass water- or flue gas side  
▪ Use higher burner level  
▪ Use higher air ratio |
| FGD separation ratio                                    | Residual time of droplets decreases          | ▪ Increase L/G ratio | ▪ Improve pump operation scheme |

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VGB PowerTech e.V.,FOLIE 14
1-Mill-operation: where to look at

Online mill monitoring:

- Reduce minimum load
  Advanced diagnostic and management system to reduce mill load
  Target: 15 - 20%

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<tr>
<td>COAL FINENESS MONITORING</td>
</tr>
<tr>
<td>Validation completed with good results</td>
</tr>
<tr>
<td>COAL FLOW UNBALANCE MONITORING</td>
</tr>
<tr>
<td>Validation completed with acceptable results</td>
</tr>
</tbody>
</table>

VIBRATION MONITORING

- Stress-tests, aimed at simulating mill malfunctioning events successfully performed

PRIMARY AIR FLOW MONITORING

- Advanced measurement system installed and successfully validated

Additional flame detectors:
1-Mill-operation  RDK Karlsruhe, Germany

Operation at minimum technical load by change from two to one mill in service

Source: RWE/Alstom
Fuel flexibility

Imported coal

Coal blending

Biomass co-firing

Challenges:

→ high plant availability in spite of changing fuels
→ necessity of plant upgrades and technological modifications (e.g. combustion, FGC)
→ secure supply chain (e.g. for biomass)