Advanced Power Plant Flexibility

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Flexible power plants are a major source of flexibility in all power systems
  - Biggest source in several leading countries
  - Key issues: minimum generation levels, start-up times, ramp-rates

Significant barriers hinder progress:
  - Technical solutions not always known
  - Regulation and/or market design frequently favour running ‘flat-out’
  - Contractual arrangements with manufacturers may penalise flexible operating pattern

Campaign to be launched at CEM8

Example North-America
From baseload operation to starting daily or twice a day (running from 5h00 to 10h00 and 16h00 to 20h00)
Source: NREL
(Thermal) power plants as a flexibility option

In the short term: make room while keeping the lights on
In the long term: critical for bridging multi-day periods without VRE
<table>
<thead>
<tr>
<th></th>
<th>Uncertainty</th>
<th>Variability</th>
<th>Location</th>
<th>Modularity</th>
<th>Non-synchronous</th>
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<tr>
<td></td>
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<td>Ramps</td>
<td>Surplus</td>
<td>Scarcity</td>
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<td>Transmission grids</td>
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<tr>
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<td>✘</td>
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<tr>
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<tr>
<td>DSI large-scale</td>
<td>✓</td>
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<td>✓✓</td>
<td>0</td>
<td>✘</td>
</tr>
</tbody>
</table>

Updated from IEA, 2014: The Power of Transformation

Flexible power plants compete with other resources across the full spectrum of flexibility requirements.
Cost-benefit analysis

- Robust information on cycling and retrofit costs are very hard to obtain
- Cited numbers for start-up costs diverge up to factor of ten
- Interventions highly plant specific

Retrofits of existing assets can be a cost-effective tool to enhance system flexibility.
## Retrofits to Improve Flexibility - Real World Cases

### Plant: Neurath 2x630MW  
**Manufacturer:** Siemens

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>Contract</th>
<th>Proven Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Gradient</td>
<td>5 MW/min</td>
<td>12 MW/min</td>
<td>15 MW/min</td>
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<tr>
<td>Minimum Load</td>
<td>440 MW</td>
<td>290 MW</td>
<td>270 MW</td>
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<tr>
<td>Primary Frequency Control (PFC)</td>
<td>18 MW by Turbine Valve Throttling</td>
<td>18 MW by Condensate Throttling</td>
<td>45 MW</td>
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<tr>
<td>Secondary Frequency Control (SFC)</td>
<td>n.a</td>
<td>66 MW</td>
<td>100 mw</td>
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<tr>
<td>Simultaneously PFC+SFC</td>
<td>n.a</td>
<td>18 MW+66 MW</td>
<td>18 MW+75 MW</td>
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<tr>
<td>Efficiency</td>
<td>37%</td>
<td></td>
<td>38.10%</td>
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<tr>
<td>Start-Up Time</td>
<td>4hr and 15min</td>
<td>3hr and 15min</td>
<td></td>
</tr>
</tbody>
</table>

### Plant: Steag Voerde 700 MW  
**Manufacturer:** Siemens

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<thead>
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<tr>
<td>Minimum Load</td>
<td>280 MW (40%)</td>
<td>140 MW (20%)</td>
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</table>
**Power Plant Flexibility- A Comprehensive Approach**

**Unit-wide optimization**
- Optimize load control (“gently” reach temperature and operational limits without violating them)
- Optimize flame conditions
- Optimize fuel supply
- Re-program DCS software
- Train staff

**Make use of digital monitoring**
- Monitor T changes regularly
- Monitor flame conditions
- Monitor catalyst conditions

**System-wide optimization**
- Use advanced optimization software to optimize dispatch
- Make use of any storage capabilities to operate thermal plants more flexibly
- Dynamic DR programs
- Design appropriate markets

**Replace components if needed**
- Use materials designed for thermal cycling
- Use feed water pump designed for cycling
Power System Flexibility Enhancement & 13th FYP in China

- Huge potential of flexible operation ability for thermal power units in China.
- 133GW CHP plants and 86GW condensing power plants will be retrofitted by 2020, which is 20% of the overall capacity of coal power in China. A flexible regulation capacity of 46GW is expected to be achieved.

Source: EPPEI
Regulatory frameworks to incentivise flexibility

• Carrots:
  - Provide incentives to leave the market or reduce market share
  - Allow very high prices during periods of scarcity

• Sticks:
  - Give priority to other generation resources (priority dispatch)
  - Allow very low / negative prices during abundance periods

• ... and other tricks:
  - Consider flexibility potential when nominating must-run units
  - Remunerate new types of services (synchronous inertia, ramping capability)
  - Adjust KPIs for plant operators
Regulatory frameworks to incentivise flexibility

Price volatility – in particular periods of zero or negative prices – strong commercial driver to become more flexible.
Challenges on Reducing min Load in Coal Power Plants

1) **Low flue gas temperature**
   - Low-load operation reduces flue gas temperature
   - Side effect: Poor performance of de-NOx catalyst

2) **Unstable flame**
   - Maintaining flame stability is more challenging during low-load

3) **Thermal stresses**
   - Thermal stresses are caused due to a) frequent cycling and b) unstable flame
   - Power plant life time reduction

4) **Reduced load control options**
   - During low-load the amount of condensate water is reduced
   - Condensate stop control is dying out

5) **Drop in efficiency (expensive operation)**
   - During low-load operation steam volume and pressure are reduced
   - Side effect: Bypass of HP turbine is required → reduced efficiency
Technical Interventions to Reduce min Load in Coal Power Plants

1) **Improving emission levels**
   - Dynamic supervision of conditions in the catalyst

2) **Stabilizing flame temperature**
   - Dynamic measurement of flame conditions in the combustion zone
   - Smart controls: Optimization of all subordinated controllers (e.g. air, fuel, feed water)

3) **Reducing thermal stresses**
   - Dynamic monitoring of components for fatigue
   - Smart controls: Optimized load control for more “gentle operation”
   - Replacement of materials with ones designed for thermal cycling

4) **Improving load control options**
   - Use alternative options:
     - Alternative “fast control handle” is throttling of steam to HP turbine

5) **Improving efficiency**
   - Optimization of all subordinated controllers to improve steam (pressure conditions)
Challenges on Increasing Power Plant Ramp-Rates

1) **Maintaining optimal flame conditions**
   - During fast ramping it is more challenging to maintain optimal conditions in the boiler

2) **Speed of fuel supply**
   - Fast ramping depends on the responsiveness of the fuel supply system

3) **Unstable feed water circulation rate**
   - Changing pump operation during cycling causes water flow disturbances

4) **Thermal stresses**
   - Temperature imbalance between firing and feed water
   - Excessive temperature changes at turbine components
Technical Interventions to Increase Power Plant Ramp-Rates

1) Improving flame conditions
   - Dynamic measurement of flame conditions in the combustion zone
   - Smart controls: Optimization of all subordinated controllers (e.g. air, fuel, feed water)

2) Improving speed of fuel supply
   Optimize mill operation (shift between n to n+1 operation, use good mills for low load, use mills with high content of fine grain coal)

3) Stabilizing feed water circulation rate
   - Design pumps with favorable characteristics for fast cycling

4) Reducing thermal stresses
   - Continuous optimization of control \( = f \) (coal type, summer/winter soot blowing, operator dependence)
   - Smart controls: Optimize operation to reach technical limits without violating them
Challenges on Decreasing Power Plant Start-Up Times

1) Maintaining optimal flame conditions

All challenges related to increased ramp-rates are even more profound during start-up

2) Speed of fuel supply

3) Unstable feed water circulation rate

4) Temperature alarms

5) Distributed control system and turbine controller bottle-necks
   • Many times next-step in a start-up sequence is delayed until a temperature threshold is reached
Solutions to Decrease Power Plant Start-Up Times

1) **Maintaining optimal flame conditions**

All challenges related to increased ramp-rates are even more profound during start-up.

2) **Speed of fuel supply**

3) **Unstable feed water circulation rate**

4) **Temperature alarms**

5) **Distributed control system (DCS) and turbine controller bottlenecks**
   - Many times next-step in a start-up sequence is delayed until a temperature threshold is reached.

Solution: Re-program software; if not possible replace software.