Nodal and Zonal Market Clearing

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Outline

Impact of market design on day-ahead operations

Impact of market design on real-time operations
- Real time as a market versus real time as a service
- European balancing operations
- Active network management
DAY-AHEAD OPERATIONS
Efficient Decisions in Day-Ahead and Real-Time Operations

Short-term operational efficiency depends on

(i) Efficient **irrevocable** day-ahead decisions

(ii) Real-time **coordination**
Market Design Matters in Turning on the Right Generators in Day-Ahead

- Zonal models can result in **infeasible** power flows (e.g. starting up cheap coal)

- Power flows can be made feasible in real time, but it is costly, e.g.
  - reduce production of coal
  - start up combined cycle gas turbines

=> operating costs that could be avoided

Source: [Aravena, 2017]
Estimate of Day-Ahead Inefficiencies in Central Western Europe

<table>
<thead>
<tr>
<th>Policy</th>
<th>Day ahead (M€/year)</th>
<th>Real time (M€/year)</th>
<th>Total (M€/year)</th>
<th>Efficiency losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodal</td>
<td>11,248</td>
<td>534</td>
<td>11,818</td>
<td>-</td>
</tr>
<tr>
<td>Flow-based</td>
<td>10,458</td>
<td>1,963</td>
<td>12,420</td>
<td>602 M€/year</td>
</tr>
<tr>
<td>zonal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATC-based</td>
<td>10,470</td>
<td>1,949</td>
<td>12,419</td>
<td>601 M€/year</td>
</tr>
<tr>
<td>zonal</td>
<td></td>
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</tr>
</tbody>
</table>

Source: [Aravena, 2019]

**Conclusion:** Day-ahead generator on/off decisions have significant *real-time* economic implications
REAL-TIME OPERATIONS

Real time as a market versus as a service
Real-time dispatch procedures
Active network management
Real Time as a Market Versus Real Time as a Service

• US view
  ▶ Real time: spot market
  ▶ Day ahead: forward market

• European view
  ▶ Day ahead: spot market
  ▶ Real time: a service that supports balancing

• Implication of EU view: balancing responsible parties (BRPs) should remain balanced from day ahead to real time

RT renewable supply > DA renewable forecast
(i) Should the BRP stay in balance, or
(ii) Should the power be exported?

Source: [Aravena, 2017]
# Real-Time Operations

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimization-based</td>
<td>Yes</td>
<td>Not necessarily (e.g. Belgium: no, France: ?)</td>
</tr>
<tr>
<td>Coordination of balancing &amp; congestion management</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>System operator coordination</td>
<td>Interface scheduling</td>
<td>Move towards coordinated balancing (MARI, PICASSO)</td>
</tr>
<tr>
<td>Active network management</td>
<td>Not much (e.g. PJM)</td>
<td>Extensive (e.g. France, Netherlands switches 3x/day (?))</td>
</tr>
</tbody>
</table>
Example: Texas Real-Time Operations

**ERCOT real-time dispatch (source: [ERCOT-RTM])**
## Efficiency of Real-Time Operations

**Conclusion:** Coordination and optimization can have a major impact on real-time cost

*Indicative results based on a single snapshot of Central Western Europe system*

<table>
<thead>
<tr>
<th></th>
<th>Inter-SO coordination?</th>
<th>Optimization in real time?</th>
<th>Real-time cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong></td>
<td>yes</td>
<td>yes</td>
<td>163,721</td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td>no</td>
<td>yes</td>
<td>888,578</td>
</tr>
<tr>
<td><strong>Option 3</strong></td>
<td>no</td>
<td>no</td>
<td>1,670,110</td>
</tr>
</tbody>
</table>
Active network management (ANM): bus-bar/line switching …

• ANM practice in the US
  ► Significant R&D efforts (ARPA-E)
  ► Current view: ANM mostly reactive (contingency response)
  ► Switching in practice: limited (?)
  ► Interference with financial transmission rights market

• ANM practice in Europe
  ► ANM is extensive in Europe, a chicken-and-egg question
  ► ANM is Central Western Europe is coordinated by the CORESO organization [Han, 2015]

