FTR Allocations to Ease Transition to Nodal Pricing: An Application to the German Power System

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Outline

• Introduction
• Optimization models
• FTR Allocation in a Three-Node Network
• FTR Allocation for the German Power System
• Conclusions
Introduction

• Increasingly accepted that nodal pricing is most efficient way of operating a power system
• Major obstacle: implied distributional impacts from a change from uniform to nodal prices
• Generators in low-price and loads in higher-price zones might lose out with new pricing system
• A successful element of implementation of nodal pricing has been the parallel allocation of FTRs
• *Initial* allocation of FTRs: highly disputed element of market liberalization processes
Introduction

• Initial provision of FTRs boils down to sharing the pie among various market participants
• NYISO: early implementation of an FTR market to deal with “grandfather” contracts
• New Zealand: nodal prices date back to 1989, FTRs were not immediately implemented
• Australia: zonal pricing system developed that has complicated the initial allocation of FTRs
• Europe: lack of nodal prices makes unlikely that revenue-adequacy for FTR allocations is met
Introduction

• Develop model to explore how initial free allocation of FTRs (at the time of transition to nodal pricing) is designed

• Three node network: analyze effects of different modalities to allocate FTRs

• Models for uniform pricing, nodal pricing and for optimal allocation of FTRs

• Simplified FTR allocation methods available in practice. We compare across them

• Application to the German power market
Optimization Models

- Three optimization models.
- **First model**: current German electricity market clearing approach with a uniformly priced national spot market, and subsequently congestion management based on curative power plant redispatch.
- **Second model**: follows idea of nodal pricing and combines the economic dispatch of power plants and optimal operation of the physical transmission network.
Optimization Models

• Models differ in the way congestion in the transmission network is handled
• Uniform pricing model uses curative methods, whereas preventive congestion management is applied in the nodal pricing model
• **Third model**: deals with allocation of FTRs to market participants based on results of the uniform and nodal pricing market models
• Feasibility and the revenue adequacy of the FTR allocation are checked out
Uniform Pricing Model

**Market Clearing**

\[
\min_G \sum_{p,t} m_c G_{p,t} \]
\[
\sum_n d_{n,t} - \sum_p G_{p,t} - \sum_n g_{n,t}^{RES} = 0
\]
\[
0 \leq G_{p,t} \leq g_p^{max}
\]

**Congestion Management**

\[
G_{UP}^G_{DOWN}, \Delta \min \sum_{p,t} m_c (G_{p,t}^{UP} - G_{p,t}^{DOWN})
\]
\[
d_{n,t} - \sum_{p \in A(n)} (g_{p,t} + G_{p,t}^{UP} - G_{p,t}^{DOWN}) - g_{n,t}^{RES} - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0
\]
\[
0 \leq G_{p,t}^{UP} \leq g_p^{max} - g_{p,t}
\]
\[
0 \leq G_{p,t}^{DOWN} \leq g_{p,t}
\]
\[
\left| \sum_I h_{l,n} \Delta_{n,t} \right| \leq p_l^{max}
\]
\[
\Delta_{n',t} = 0
\]
Nodal Pricing Model

\[
\min_G \sum_{p,t} mc_p G_{p,t}
\]

\[
d_{n,t} - \sum_{p \in A(n)} G_{p,t} - g_{n,t}^{\text{RES}} - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0
\]

\[
0 \leq G_{p,t} \leq g_p^{\text{max}}
\]

\[
\left| \sum_l h_{l,n} \Delta_{n,t} \right| \leq p_l^{\text{max}}
\]

\[
\Delta_{n',t} = 0
\]
FTR Allocation Model

- Two approaches for initial allocation FTRs.
  - First approach allocates FTRs to conventional and renewable generators based on historical production.
  - Second approach relies on installed generation capacities to determine the amount of FTRs.

- On the demand side, FTRs are allocated relative to consumption given the total amount of FTRs allocated to generation.

- For both allocation approaches, we explore different levels or amounts of total FTRs.
FTR Allocation Model

\[
\min_{\Delta} \varepsilon
\]

\[
\sum_{n} FTR_n^D - \sum_{n} FTR_n^{RES} - \sum_{p} FTR_p^G = 0
\]

\[
FTR_n^D - FTR_n^{RES} - \sum_{p \in A(n)} FTR_p^G - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0
\]

\[
cr_t^{TSO} - \sum_{p} (price_{slack,t} - price_{A(n),t}) FTR_p^G - \sum_{n} (price_{slack,t} - price_{n,t}) FTR_n^{RES}
\]

\[- \sum_{n} (price_{n,t} - price_{slack,t}) FTR_n^D = 0
\]

\[
\left| \sum_{t} h_{l,n} \Delta_{n,t} \right| \leq p_{l}^{max}
\]

\[
\Delta_{n',t} = 0
\]
FTR Allocation in a Three-Node Network

Characteristics
- Time periods: t1, t2
- Generation: p1, p3
- Load: n2, n3
- Equal line characteristics
- Line capacity unlimited except for line n1-n3 = 50 MW
Summary of market participant’s revenue, costs, and surplus in different pricing regimes

<table>
<thead>
<tr>
<th></th>
<th>Uniform pricing</th>
<th>Nodal pricing</th>
<th>Surplus change including socialized transmission surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>0</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>Costs</td>
<td>3800</td>
<td>2600</td>
<td>--</td>
</tr>
<tr>
<td>Surplus</td>
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<td>-2600</td>
<td>+2200</td>
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<tr>
<td>n3</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>0</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>Costs</td>
<td>7600</td>
<td>7800</td>
<td>--</td>
</tr>
<tr>
<td>Surplus</td>
<td>-7600</td>
<td>-7800</td>
<td>+1800</td>
</tr>
<tr>
<td><strong>Generation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>6150</td>
<td>2150</td>
<td>--</td>
</tr>
<tr>
<td>Costs</td>
<td>2150</td>
<td>2150</td>
<td>--</td>
</tr>
<tr>
<td>Surplus</td>
<td>4000</td>
<td>0</td>
<td>-4000</td>
</tr>
<tr>
<td>p3</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
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<td>5250</td>
<td>--</td>
</tr>
<tr>
<td>Costs</td>
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<td>5250</td>
<td>--</td>
</tr>
<tr>
<td>Surplus</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>1350</td>
<td>3000</td>
<td>--</td>
</tr>
<tr>
<td>Cost</td>
<td>4050</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>Surplus</td>
<td>-2700</td>
<td>3000</td>
<td>Socialized to load</td>
</tr>
</tbody>
</table>
FTR allocation based on installed capacity

FTR allocation based on production

Change of market participant’s surplus between uniform and nodal pricing considering different initial FTR allocation regimes in the three-node setting.
### FTR Allocation for the German Power System

<table>
<thead>
<tr>
<th>Case</th>
<th>Surplus change in MEUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer (high solar)</td>
<td>0.00</td>
</tr>
<tr>
<td>Winter (low wind)</td>
<td>-1.00</td>
</tr>
<tr>
<td>Winter (high wind)</td>
<td>2.00</td>
</tr>
</tbody>
</table>

#### Change of surplus between uniform and nodal pricing

- **Demand**
- **Generation**
- **RES Generation**
FTR allocation based on installed capacity  

<table>
<thead>
<tr>
<th>Summer (high solar)</th>
<th>Winter (low wind)</th>
<th>Winter (high wind)</th>
</tr>
</thead>
</table>

- **Surplus change in MEUR**
  - -0.2 to 0.2
  - -0.15 to 0.15
  - -0.1 to 0.1
  - -0.05 to 0.05
  - 0

- **Allocated FTRs in MW**
  - 50000
  - 100000
  - 150000

FTR allocation based on production

<table>
<thead>
<tr>
<th>Summer (high solar)</th>
<th>Winter (low wind)</th>
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- **Surplus change in MEUR**
  - -0.2 to 0.2
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  - 0

- **Allocated FTRs in MW**
  - 50000
  - 100000
  - 150000

Change of market participant’s surplus between uniform and nodal pricing considering different initial FTR allocation regimes (Blue: load; Red: conventional generation; Green: renewable generation)
Average change in surplus of demand in the high wind winter week under production-based allocation approach.
FTR allocation based on installed capacity

FTR allocation based on production

Histogram of average nodal surplus changes in the high wind winter week with capacity-based (left side) and production-based FTR allocation (right side)
Conclusions

• Major challenge for implementation of nodal pricing is the distributional impact of price changes facing generation and load in different locations of the system

• Implementation of nodal pricing accompanied with free allocation of FTRs to market participants to mitigate distributional effects

• In a three node network allocation in proportion to annual production volume allows to better compensate the distributional impact than allocation in proportion to installed capacity
Conclusions

• Modeling in the German power system with full nodal representation:
  – FTR allocation can mitigate almost all distributional effects for the demand side, and a large share for conventional generation
  – For intermittent renewables the allocation of FTR obligations can mitigate fewer of the distributional effects
  – This points to the need of more complex FTR designs

• Further assessment of numerical results