Introduction to cross-border capacities – economic and technical characteristics

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Lecture outline

• Characteristics of electricity transmission
  ‣ Network losses
  ‣ Service quality
  ‣ Physical vs. commercial flow

• Role of interconnectors – economic considerations

• Capacity allocation methods
  ‣ Administrative
  ‣ Explicit, NTC based auctions
  ‣ Market coupling
  ‣ Flow-based auctions

• CBC investment
Characteristics of electricity transmission

- Electricity transmission is a natural monopoly
  - Transmission and distribution tariffs are regulated
- Electricity transmission capacities are limited
  - Congestion management is needed
- Between countries transmission capacities are usually more constrained
  - These lines have been planned due to security reasons and not to commercial aim
- Electricity follows physical rules, not commercial arrangements in the transmission network
  - Commercial transactions and physical flows are often decoupled
Network losses

- **Network losses dependent on:**
  - On voltage level: higher voltage level means less losses
  - Length: the longer route means higher losses
  - Lower in underground cable

- **Transmission losses:**
  - ~2-4 % of the generated electricity

- **Distribution losses:**
  - Technical and commercial losses (not billed or not paid)
  - 4-9 % of the generated electricity
Service quality

<table>
<thead>
<tr>
<th>Name</th>
<th>Short Form</th>
<th>Units of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Average Interruption Duration Index</td>
<td>SAIDI</td>
<td>Minutes per customer per year</td>
</tr>
<tr>
<td>System Average Interruption Frequency Index</td>
<td>SAIFI</td>
<td>Interruptions per customer per year</td>
</tr>
<tr>
<td>Customer Average Interruption Duration Index</td>
<td>CAIDI</td>
<td>Minutes per interruption</td>
</tr>
<tr>
<td>Energy Not Supplied</td>
<td>ENS</td>
<td>GWh</td>
</tr>
</tbody>
</table>
Characteristics of electricity flow

Network is the aggregation of nodes and lines. Nodes include generation and consumption, while in the lines flow the electricity.

Kirchhoff’s 1st (Current) Law: The current flow into any point (node) in a circuit equals the current flow out.

Kirchhoff’s 2nd (Voltage) Law: Kirchhoff’s Voltage Law states that power flowing from node A to node B on a network distributes itself along all parallel paths between the two points, roughly in inverse proportion to the impedance/resistance of each path.
PTDF (Power Transfer Distribution Factor) matrix

<table>
<thead>
<tr>
<th>Commercial</th>
<th>Physical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-&gt;B</td>
</tr>
<tr>
<td>A-&gt;B</td>
<td>0.7</td>
</tr>
<tr>
<td>A-&gt;C</td>
<td>0.3</td>
</tr>
<tr>
<td>B-&gt;C</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

Consumption: 1
Production: 1
A real PTDF matrix: 100 MW electricity export from HU to AT
Different types of electricity flows

Source: ACER
Average unscheduled flow indicator, 2015 (MW)

Source: ACER, 2016
Physical vs. commercial flows

Physical flow

Commercial flow

Difference of net commercial and net physical flows almost zero

Source: MAVIR, 2017-03-03
Role of interconnectors – economic considerations
Congestion pricing example

What is the price of cross border transmission capacity right?
Trade – price equalisation

Country A

Import

Country B

Export

Price

Price

$P_A$

$P_B$

$P_e$

$Q_A$

$Q_B$
Consumer surplus (CS):

Consumer surplus is the difference between the maximum price a consumer is willing to pay and the actual price they do pay.
Consumer surplus 2

Country A

Import

Country B

Export

Price

\( P_A \)

\( P_e \)

\( P_B \)

\( Q_A \)

\( Q_B \)

\( D \)

\( S \)

\( CS_2 \)
Why interconnections are important? I.

- The picture shows a simulated European Electricity Market (for 2014)
- Yearly baseload prices and commercial trade (boxes) flows are (arrows) depicted
- Average baseload prices vary between 40-70 €/MWh
Why interconnections are important? II.

• Yearly baseload prices and commercial trade (boxes) flows are (arrows) depicted – Zero tarde assumptions!

• In some countries price goes down, e.g.
  • RO: 51-> 45
  • BG: 52-> 44
  • CZ: 49-> 44
  • BiH: 54-> 30

• In some countries extreme high prices can be visible
  • HU: 55->234
  • SR: 55->676
  • MK: 56->126

• In these countries demand curtailment is needed
ROLE of TSOs

• They are the responsible parties for building up new cross-border connection lines.

• How they could be made interested to reduce congestions – which will reduce their congestion rents?

• Classic economic problem: deliver a **public good**, where the main responsible to deliver the good is not incentivised - or even negatively affected!

• EU answer:
  ▪ Congestion rents must be used to develop CBC lines, where congestion occurs
  ▪ There is also a planned 10% rule, where national CBC capacities must be increase to reach at least 10 % of production by 2020.
  ▪ PCI process as well to help these developments
  ▪ ENTSO-E 10 year development plan
  ▪ Possibility to build up commercial line – where for some years the fundamental rule of third party access can be lifted – so all user will pay, even if no congestion exists (e.g. Eastlink line)
EU regulation: congestion rent must go to network development or lowering transmission tariffs:

Source: ACER MMR 2016, ENTSO-E
**10 % rule for 2020?**

- Most SEE countries have no problem with the rule they inherited rather strong connections with the neighbours
- But lines are old, many needs replacement
- EU members Greece and Romania are rather week in this sense

<table>
<thead>
<tr>
<th>Country</th>
<th>CBC/generation capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>48%</td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>30%</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>11%</td>
</tr>
<tr>
<td>Greece</td>
<td>9%</td>
</tr>
<tr>
<td>Croatia</td>
<td>55%</td>
</tr>
<tr>
<td>Kosovo*</td>
<td>na</td>
</tr>
<tr>
<td>Montenegro</td>
<td>167%</td>
</tr>
<tr>
<td>Macedonia</td>
<td>36%</td>
</tr>
<tr>
<td>Romania</td>
<td>6%</td>
</tr>
<tr>
<td>Serbia</td>
<td>44%</td>
</tr>
</tbody>
</table>
Capacity allocation methods
Usual way to determine available cross-border transmission capacity

- **Total transfer capacity (TTC)**: The maximum possible exchange between two compatible areas.
- **Transmission Reliability Margin (TRM)**: Security margin which copes with uncertainties.
- **Net Transfer Capacity (NTC)**: Maximum possible exchange between two areas taking into account uncertainties, thus $\text{NTC} = \text{TTC} - \text{TRM}$.
- **Already Allocated Capacity (AAC)**: The total amount of allocated transmission rights prior to auctioning.
- **Available Transmission Capacity (ATC)**: The remaining part of NTC, which is auctioned to market participants. $\text{ATC} = \text{NTC} - \text{AAC}$.

*(The definitions are based on ENTSO-E terminology.)*
DE TSO can accept 800 MW; DKe only 585 MW; the latter one can be distributed.
Only in implicit and flow based auctions you can buy electricity with one contract, by explicit methods you buy electricity and transmission rights separately – inefficient!
„Use it or loose it” principle

- Long term CBC auctions
- Day-ahead CBC auctions
- Scheduling

- Can be used in intraday trading (if possible)

If those rights, which are allocated in previous auctions are not „scheduled” then loose it
Administrative allocation methods

• First come, first served
  ▷ If no congestion exist
  ▷ Intraday market

• Pro rata
  ▷ Cross border capacity rights are allocated according to the bid
  ▷ E.g.:
    • Total ATC – 75 MW;
    • Two market player:
      – Company „A” bid: 50 MW
      – Company „B” bid: 100 MW
    • Allocated capacity right
      – Company „A”: 25 MW
      – Company „B”: 50 MW
  ▷ Not commonly used, because of strategic behavior
    • Company „A” would like to win 50 MW, but its bid is 200 MW in order to win 50 MW
Explicit NTC based allocation method I.

• Bilateral
  ‣ Two capacity rights are needed to import/export
    – E.g.: If a trader would like to export from Ukraine to Hungary, then capacity right is needed from UA TSO and HU TSO as well
  ‣ Separate: 50-50 % allocated by the neighboring TSOs in separate auction(s)

• Common/joint
  ‣ One TSO allocated the full capacity
  ‣ Distribution of revenues: 50-50 %

<table>
<thead>
<tr>
<th>Border</th>
<th>Yearly</th>
<th>Monthly</th>
<th>Daily</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT-HU</td>
<td>PC</td>
<td>PC</td>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>BG-GR</td>
<td>PC</td>
<td>PC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BG-RO</td>
<td>PC</td>
<td>PC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GR-IT</td>
<td>BIL</td>
<td>BIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR-HU</td>
<td>BIL</td>
<td>BIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HU-RO</td>
<td>PC</td>
<td>PC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HU-SK</td>
<td>PC</td>
<td>PC</td>
<td>PC</td>
<td></td>
</tr>
</tbody>
</table>

BIL: Bilateral (separate NTC calculation)
PC: Partially coordinated (common calculation, but not all affected borders are considered)

Yearly and monthly cross border auctions in SEE in 2015 (MMR 2016)
Explicit NTC based allocation method II.

- Co-ordinated
  - Three or more TSOs organize common auctions
  - More efficient allocation
  - E.g.: Central Allocation Office
Implicit auctions

Explicit auction

- Product (kWh)
- Cross Border capacity

Implicit auction

- Product + CB capacity

- Lower risk
- Higher utilization rate
- Help the market integration
CZ-SK-HU Market coupling

Figure 16: Price convergence between the Czech Republic, Hungary and Slovakia – July 2010 to December 2012 (%)

Launch of trilaterial MC

Source: Platts, OKTE and HUPX (2013) and ACER calculations
Flow-based auctions

1. Step: Determine the reference flow (without flow-based auctions), and the technical limit of a given line

2. Step: determine the PTDF matrix

<table>
<thead>
<tr>
<th>Physical</th>
<th>A-&gt;B</th>
<th>A-&gt;C</th>
<th>B-&gt;C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-&gt;B</td>
<td>0.7</td>
<td>0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>A-&gt;C</td>
<td>0.3</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>B-&gt;C</td>
<td>-0.3</td>
<td>0.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

3. Step: Bidding

<table>
<thead>
<tr>
<th>Trader</th>
<th>From</th>
<th>To</th>
<th>Quantity (MW)</th>
<th>Price (€/MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A</td>
<td>B</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>2.</td>
<td>B</td>
<td>A</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>3.</td>
<td>A</td>
<td>C</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>4.</td>
<td>C</td>
<td>B</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

4. Step: Impacts of the bid to the physical flows

5. Step: Reduce the congestion in border A-C
- 1. trader or 3. trader can decrease it;
- 3. trader bid is cheaper -> curtail to 58 MW instead of 60 MW

6. Step: 1. trader and 3. trader pays 50 €/MW, because they cause the congestion
# Summary of CBC auctions

<table>
<thead>
<tr>
<th>Type of Auction</th>
<th>Frequency of auction</th>
<th>Cooperation of TSOs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NTC based auction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First come first served</td>
<td>Intraday</td>
<td>Weak</td>
</tr>
<tr>
<td>Pro rata</td>
<td>Complementary tool</td>
<td>Weak</td>
</tr>
<tr>
<td>Bilateral explicit auction</td>
<td>Daily/monthly/yearly</td>
<td>Weak/medium</td>
</tr>
<tr>
<td>Common explicit auction</td>
<td>Daily/monthly/yearly</td>
<td>Medium</td>
</tr>
<tr>
<td>Co-ordinated auction</td>
<td>Daily/monthly/yearly</td>
<td>Strong</td>
</tr>
<tr>
<td>Bilateral implicit auction</td>
<td>Daily</td>
<td>Strong</td>
</tr>
<tr>
<td>Implicit multilateral</td>
<td>Daily</td>
<td>Strong</td>
</tr>
<tr>
<td><strong>Flow-based auction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explicit auction</td>
<td>Daily</td>
<td>Very strong</td>
</tr>
<tr>
<td>Implicit auction</td>
<td>Daily</td>
<td>Very strong</td>
</tr>
</tbody>
</table>
And where do we stand with CBC development in Europe?
Cross-border investments in Europe till 2012

NTC values for a selection of 23 interconnectors

EU27 Consumption growth
NTC/physical capacities 2015

- Although many incentives exist to increase NTC to physical capacity ratio, some region lags behind
- National interest of self-sufficiency frequently undermine overall economic welfare
- In SEE this ratio is the lowest in ENTSO-E!

<table>
<thead>
<tr>
<th>HVAC/HVDC</th>
<th>Region</th>
<th>Tradable capacities (MW)</th>
<th>Physical capacities (MVA)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>NORDIC</td>
<td>6,164</td>
<td>13,242</td>
<td>46.5%</td>
</tr>
<tr>
<td></td>
<td>BALTIC</td>
<td>1,431</td>
<td>4,010</td>
<td>35.7%</td>
</tr>
<tr>
<td></td>
<td>CWE</td>
<td>7,352</td>
<td>26,930</td>
<td>27.3%</td>
</tr>
<tr>
<td></td>
<td>SWE</td>
<td>3,687</td>
<td>11,638</td>
<td>31.7%</td>
</tr>
<tr>
<td></td>
<td>CSE</td>
<td>12,104</td>
<td>42,016</td>
<td>28.8%</td>
</tr>
<tr>
<td></td>
<td>CEE</td>
<td>7,493</td>
<td>31,873</td>
<td>23.5%</td>
</tr>
<tr>
<td></td>
<td>SEE</td>
<td>2,403</td>
<td>14,884</td>
<td>16.1%</td>
</tr>
<tr>
<td></td>
<td>UK-I</td>
<td>3,303</td>
<td>3,500</td>
<td>94.4%</td>
</tr>
<tr>
<td>HVDC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BALTIC</td>
<td>913</td>
<td>1,000</td>
<td>91.3%</td>
</tr>
<tr>
<td></td>
<td>CSE</td>
<td>384</td>
<td>500</td>
<td>76.7%</td>
</tr>
<tr>
<td></td>
<td>NORDIC</td>
<td>4,741</td>
<td>6,130</td>
<td>77.3%</td>
</tr>
</tbody>
</table>

Source: ACER MMR 2016, ENTSO-E
Summary

• Difficulties in determining NTCs – this has high impacts on trade and on consumer prices as well! Regulatory issues are serious, as consumers, producers will be significantly affected!
• Distributional effects are always to be considered! Multi-agent decision making is required!

• Low incentives on TSOs to develop CBC – but EU rules promote its further development:
  ▶ PCI and PECI process
  ▶ 10 % rule for 2020
  ▶ Rules on the use of congestion rents!
THANK YOU FOR YOUR ATTENTION!

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