Introduction to cross-border capacities – economic and technical characteristics

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SEERMAP Network Training
December 14-16, 2016
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
  ‣ Where do we stand?
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>

**Diagram:**

- **Service quality**
  - **Voltage quality**
  - **Continuity of supply**
    - **Distribution system**
      - **Long interruptions**
      - **Short interruptions**
    - **Transmission system**
      - Planned
      - Unplanned
  - **Commercial quality**

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

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

Kirchhoff’s 2\textsuperscript{nd} (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>A-&gt;B</td>
<td>A-&gt;B: 0.7</td>
</tr>
<tr>
<td>A-&gt;C</td>
<td>A-&gt;B: 0.3</td>
</tr>
<tr>
<td>B-&gt;C</td>
<td>A-&gt;B: -0.3</td>
</tr>
</tbody>
</table>

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

Source: ACER
Average unscheduled flow indicator, 2014 (MW)

Source: ACER, 2015
Physical vs. commercial flows

- Physical flow:
- Commercial flow:
- Difference of net commercial and net physical flows almost zero

Source: MAVIR, 2016-12-10
Role of interconnectors – economic considerations
Congestion pricing example

What is the price of cross border transmission capacity right?
Trade – price equalisation
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
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
    - CZ: 49->44
    - BiH: 54->30
    - MK: 56->126
  - In some countries extreme high prices can be visible
    - HU: 234
    - AL: 1975
    - 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?
- 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)
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>
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</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>
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</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 \( NTC = TTC - TRM \).

**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. \( ATC = NTC - AAC \).

*The definitions are based on ENTSO-E terminology.*
DE TSO can accept 800 MW; DKe only 585 MW; the latter one can be distributed.

Source: ENTSO-E
Bridge example – Erzsebet bridge of Budapest
Flows on a bridge

• Flow on the bridge depends on many factors:
  • What are the connecting roads?
  • What is the main driving direction?
  • What time of the week/day you are driving?
  • Is there an accident on the bridge?
• Similar constraints occur at the CBC lines:
  • Congestions, allocating some capacities, outages, non planned flows….
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

If those rights, which are allocated in previous auctions are not "scheduled" then loose it.

Can be used in intraday trading (if possible).
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%
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 (%)

Source: Platts, OKTE and HUPX (2013) and ACER calculations

Launch of trilateral MC
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>
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<tr>
<td></td>
<td>A-&gt;B</td>
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<td>B-&gt;C</td>
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<td>0.3</td>
<td>-0.3</td>
<td></td>
</tr>
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<td>0.7</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>B-&gt;C</td>
<td>-0.3</td>
<td>0.3</td>
<td>0.7</td>
<td></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>NTC based auction</th>
<th>Frequency of auction</th>
<th>Cooperation of TSOs</th>
</tr>
</thead>
<tbody>
<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
Aggregated NTC – 2010-2015

Source: ACER MMR 2015, ENTSO-E
EU regulation: congestion rent must go to network development or lowering transmission tariffs:

Source: ACER MMR 2015, ENTSO-E
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>F-UK-I</td>
<td>3,303</td>
<td>3,500</td>
<td>94.4%</td>
</tr>
<tr>
<td>HVDC</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!

• 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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