Workshop on Power Grid Interconnection in Northeast Asia

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INTERNATIONAL PERSPECTIVES ON POWER GRID INTERCONNECTIONS
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Global primary energy use

Source: IIASA, WEC

Sources: unipede; Statistical panorama 1997
Energi- og elektrisitets intensitet i amerikansk industri

Energy Intensity

Electricity's Share

[Graph showing energy intensity and electricity's share from 1890 to 1990]
World electricity generation sources
World generation capacity

[Diagram showing the growth of global generation capacity from 1995 to 2020, with lines representing gas, solid fuels, hydro, oil, nuclear, and other renewables.]
Massive transfer of hydro electricity to population centres (Source ABB)
Factors contributing to benefits

• Non coincidental peak load (Example: the England-France interconnection)
• Merit order investments, i.e. the cheapest projects first.
• Scale economy. Large projects have often low unit cost but are too large for the local market.
• Operational benefit (merit order loading)
• Lower total investment.
• Lower total reserve requirement (which contributes to lower investment).
• Use of hydro as a cheap FCR (Frequency Control Reserve).
• Load following.
Benefit of hydro thermal interconnection

- Two categories of hydro generation systems:
  - Capacity constrained systems.
  - Energy constrained systems.
- Thermal systems are always energy constrained.
- There is always a benefit in connecting an energy constrained system to a capacity constrained.
- The hydro system can provide low cost reserves.
- The same for load following capabilities.
- The hydro system relies on a highly variable and stochastic inflow of water.
Rate of efficiency for different hydro turbines

- Kaplan turbine
- Pelton turbine
- Propeller turbine
- Slow Francis turbine
- Fast Francis turbine

<table>
<thead>
<tr>
<th>Turbine Type</th>
<th>Efficiency (η)</th>
</tr>
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<tbody>
<tr>
<td>Kaplan</td>
<td>0.8</td>
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<tr>
<td>Pelton</td>
<td>0.6</td>
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<td>Propeller</td>
<td>0.4</td>
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<tr>
<td>Slow Francis</td>
<td>0.2</td>
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<tr>
<td>Fast Francis</td>
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</table>
Load profile covered by hydro and thermal generation

Production [MW]

Load profile

Hydro production from storage

Thermal production to fill up hydro storage

Hour

Production

Coal

Nuclear
Simulated generation in Norway over 50 hydrological years

Total production (hydroelectric + gas + small-scale district heating) 108.4 TWh/year

Hydropower 107,800 TWh/year

Import 1,326 TWh/year

Export 4,140 TWh/year

Spill over into maintenance 0.940 TWh/year

Fast power 101,700 TWh/year

Random power 2,992 TWh/year

Small-scale district heating 0.617 TWh/year
Benefit of hydro–thermal exchange
Deregulation has serious impact on regional interconnections

- Interconnections increase the competitive pressure
- Interconnections affect market prices.
Principle for price calculation

Price

Balance

Purchase

Sale

Turnover

MW
Spot and wholesale contract prices before deregulation

Price [øre/kWh]

- Long Term Marginal Cost
- Contract price Statkraft
- Spot price
Spot and wholesale contract prices after deregulation

Source: Norsk Kraftmegling
Simulated and observed spot prices in Nord Pool

Price [NOK/MWh]


Real spotprice
Simulated spotprice
Case: Single transmission line between two areas

Surplus

\[ \text{Supply A} \]

\[ \text{Deficit} \]

\[ \text{Demand A} \]

\[ \text{Demand B} \]

Price \( p_A \) [NOK/MWh]

\[ \text{Supply B} \]

\[ \text{Demand B} \]

Price \( p_B \) [NOK/MWh]
Congestion fee
Consequences for different participants
The Baltic Ring Project
DC connection England - France

2000 MW
Interchange capacities in Scandinavia
Interconnection Columbia - Venezuela
Energy recourses in the GMS region

- Hydro power in Yunnan
- Hydro power in Myanmar
- Hydro power in Lao PDR
- Coal in Yunnan
- Lignite Lao PDR
- Gas in Myanmar and Malaysia