Peruvian Transmission Model

Pedro Sanchez
March, 2004
Road Map

- Peru
- Peruvian Power Sector Reform
- Market Regulation
- Private Sector Participation
- Lessons Learned
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Peru At A Glance

- Population: 25.7 million
- Surface area: 1,285.2 thousand sq. km
- GDP: 53.9 billion US$
- GNP per capita: 2,100 US$
Peruvian Power System

- Installed capacity: 5,900 MW
- Generation: 22,000 GWh
- Number of customers served: 3.6 million
- Transmission installed capacity
  - 220 KV lines: 5500 km
  - 220 kV SS: 4000 MVA
  - 138 kV lines: 2400 km
  - 138 kV SS: 1500 MVA
Market

Energy Sales by Type

- Residential: 55%
- Industrial: 26%
- Commercial: 15%
- Public Lighting: 4%
PTS
Road Map

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<table>
<thead>
<tr>
<th>Action</th>
<th>92</th>
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<td>Tariff Adjustment</td>
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<td>BOOT's</td>
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<td>Distribution</td>
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<td></td>
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<tr>
<td>Privatized</td>
<td>41%</td>
<td>72%</td>
<td>60%</td>
<td></td>
<td></td>
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<tr>
<td>New developments</td>
<td>11%</td>
<td>0%</td>
<td>40%</td>
<td></td>
<td></td>
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<td>State owned (*)</td>
<td>47%</td>
<td>28%</td>
<td>0%</td>
<td></td>
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</table>

* : 34% is owned by a National Pension Fund
Access Ratio (%)
Number of Customers

The chart shows the increase in the number of customers from 1990 to 2002. The number of customers has steadily increased from 0.00 in 1990 to approximately 4.00 in 2002.
Distribution Losses (%)
Tariffs

![Graph showing Tariffs from 1995 to 2002. The graph compares two categories: Reg. and Market. The Reg. category shows a decreasing trend with a peak around 1996. The Market category remains relatively stable.](image-url)
Investment (kUS$)
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System Operator (COES)

- **Organization**
  - Board of Directors (2T, 7G)
  - Operations Director (Dedicated team)
  - Funded by G’s and T’s

- **Decision Making process**
  - Core decisions: unanimous
  - Other: majority
  - Discrepancies are solved by arbitration
System Operation

- **System Operator (COES)**
  - Short, medium, and long term planning.
  - On line coordination

- **On line operation: Gencos & Transcos**

- **National Dispatch Center. (Transco)**

- **Least Cost dispatch**

- **Transactions based on marginal costs**
Transmission Regulation

- Transmission is a separate activity
- Concession are awarded by the Government
- Transcos cannot trade
- Open Access (Capacity, Tolls are regulated)
- Term of concessions
  - New assets: BOOTs for 30 years + 3 construction
  - Existing assets: Concession for 30 years.
Transmission Services Pricing (1)

- **Main System**
  - Individual beneficiaries cannot be identified
  - High Voltage
  - Bidirectional flow

- **Secondary Systems**
  - Beneficiaries identified: Gencos, Discoms, or Large Customers)
Transmission Services Pricing (2)

- **Costing**
  - Investment: Annuity (12%, 25 years, Adapted Investment (AI))
  - O&M: 3% of AI

- **Tariff**
  - Tariff = Costing / KW (Demand)

- **Who Pays:**
  - MS: All generators based on their capacity
  - SS: Beneficiaries
Planning

- Indicative Planning
  - Investment
- Specific Investments
  - ISO
  - Transcos
  - Users
- New expansion: BOOT’s
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General approach

- BOOT’s: Initial experience
- Concession of entire transmission system
BOOT’s (1)

- Privatization background
- Output based Schemes
- Tariff: Defined for 30 years
- General Regulations
- No PPA
BOOT’s (2)

- Prequalification process
- Contract Negotiation
- Proposal
- Closing
Concession

- General regulations
- Tariff: defined for 30 years
- Principal systems
- Secondary systems
## Results

### Peruvian Transmission Private Projects

<table>
<thead>
<tr>
<th>Bidders</th>
<th>Mantaro Socabaya</th>
<th>Reforzamiento Sur</th>
<th>Oroya Carhuamayo - Paragsha Derivacion Antamina</th>
<th>ETECEN-ETESUR</th>
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<td>National Grid</td>
<td>Red Electrica del Sur</td>
<td>Red Electrica del Sur</td>
<td>ISA</td>
<td>ISA</td>
</tr>
<tr>
<td>ENEL</td>
<td>ISA</td>
<td>ISA</td>
<td>ISA</td>
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<tr>
<td>Transmantaro</td>
<td>Transmantaro</td>
<td>Transmantaro</td>
<td>ISA</td>
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</tr>
<tr>
<td>No of bidders</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Winner</td>
<td>Transmantaro</td>
<td>Red Electrica del Sur</td>
<td>ISA</td>
<td>ISA</td>
</tr>
<tr>
<td>Base Price (US $ Million)</td>
<td>300.00</td>
<td>92.50</td>
<td>71.81</td>
<td>229.59</td>
</tr>
<tr>
<td>Winning price (US $ Million)</td>
<td>179.18</td>
<td>74.48</td>
<td>65.41</td>
<td>261.99</td>
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<tr>
<td>Reduction</td>
<td>60%</td>
<td>81%</td>
<td>91%</td>
<td>114%</td>
</tr>
</tbody>
</table>
Road Map

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Lessons learned

- BOOT’s are an effective way to promote new investment in transmission
- Regulation has to be redefined
- Pricing issues
- New investment
Peruvian Transmission Model

Pedro Sanchez
March, 2004
Transmission Expansion in PJM
Lessons Learned from a Fully Developed Network

presented by
Jim Barker
for
The World Bank Energy Week 2004
March 9, 2004
Washington, DC
Overview

- Key lessons: Slide 3
- PJM background: Slides 4-10
- Regulatory authority: Slide 11
- Current role of PJM & planning process: Slides 12-14
- Evolution of the network: Slides 15-17
- Case studies in delay: Slides 18-19
- Incremental expansion: Slides 20-21
- Summary of lessons: Slide 22

NOTE: This is a very simplified and abbreviated summary; it is only the tip of the iceberg.
Key lessons for developing countries

- Transmission rights of way (way leaves) will be very scarce; obtain for the distant future
- Economic expansion of transmission based on:
  - Delivery of generation to serve firm load obligation
  - Sharing diversities of emergencies by interconnecting generators and systems of generators
- Need regulatory regime to facilitate:
  - Siting, environmental and land use approvals
  - Adequate cost recovery
Membership:
~ 240 Members
100+ Transmission Service Customers

3/3/2004

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strategic solutions for the electricity industry
Pennsylvania-New Jersey-Maryland (PJM): Additional Background

- PJM does NOT own transmission
  - transmission controlled and expanded under terms of contract between transmission owners and PJM

- Scope of transmission controlled by PJM
  - varies according to member, may include 69 kV
  - includes network (meshed grid) and radial connections of load and generation

- Pool formed over 75 years ago – 1927: 3 members
- 7 years experience with open access
- 5 years experience with centralized planning
PJM: Technical considerations

• Technical issues for consideration when comparing PJM to other networks and markets

• Static capacitors are typically installed close to load in order to provide compensation where needed
  – in contrast to Dominican Republic system which tries to meet reactive requirements from generation over the transmission network; uneconomic use of network
PJM: Technical considerations

• PJM network capable of sustaining loss of a single circuit on a double circuit tower without using emergency ratings (first contingency (N-1) reliability criteria)
  – many developing countries not capable of meeting such criteria

• PJM has adequate reserve generating capacity: 19%
PJM: Market overview

- PJM administers:
  - financially binding Day Ahead (DA) and financially and physical binding Real Time (RT) energy markets
  - capacity market to meet capacity obligation
  - allocation and auctions of Fixed Transmission Rights (FTR) as mechanism for hedging congestion
  - settlement system using locational marginal prices for DA and RT markets

- Physical and financial bi lateral contracts operate in parallel with markets administered by PJM
PJM: Transmission pricing overview

- PJM administers transmission tariff to recover capital and operating cost for transmission owners
- Transmission tariff is a zonal tariff
  - each transmission owner’s system is a zone
  - 12 zones plus a non zone charge for network integration service
- Transmission owners may request PJM to file for an increase in their zonal transmission tariff
- PJM recognizes the need for recovery of transmission expansion costs to “be consistent with individual state retail rate conditions and requirements.”
Regulatory authority

• Siting/environmental: determined by federal legislation
  – administered by States, localities, Corps of Engineers, and other agencies

• Economic: determined by federal legislation AND by State legislation
  – federal legislation governs *wholesale* transactions and *transmission* tariffs for *privately* owned utilities, but *not* in Texas, Alaska, Hawaii
    • administered by Federal Energy Regulatory Commission (FERC)
    • FERC determines rate of return and rate design
  – state legislation governs bundled *retail* tariffs
    • administered by state regulatory commissions
Role of PJM: transmission expansion

• “Old” world: before unbundling under FERC order 888
  – vertically integrated member utilities planned transmission for reliability and energy delivery
  – plans coordinated among members
  – negotiated allocation of costs for joint ownership projects

• “New” world: functional (NOT corporate) unbundling of member utilities
  – PJM established independent planning capability
Transmission expansion planning

- PJM plans expansion of the network as necessary to meet reliability criteria and to accommodate new generation and load
- Expansion for reliability assigned to transmission owner in zone in which facilities are required
- Increases in nodal marginal clearing prices indicate cost of congestion due to system constraints and potential need for transmission, load response, or generation to relieve congestion
- Participants or non participants (merchants) may propose additions to respond to congestion pricing signals in the energy market
Default transmission provider

• PJM determines cost allocation according to principle that beneficiaries should pay
  – generators pay for connection costs and reinforcements or additions to the network
  – zonal loads pay for costs according to determination by PJM as to the benefit
  – all cost allocations subject to approval by Federal Energy Regulatory Commission (FERC)

• FERC has required PJM to act as provider of last resort (default provider) to relieve economic congestion
  – PJM assigns contracting obligations and allocation of costs
  – Open issue remains: if State regulator does not permit recovery of costs – Transmission Owner could refuse to build.
Evolution of the network

- A view from the bottom up: start in Washington, D.C.
  - 1900: load within Washington isolated with load, generation/load islands within the city
  - 1906: load combined and served from one plant, multiple units
  - 1933: Washington and Baltimore systems interconnect to share generation reserves (reliability)
  - 1965: Washington (Potomac Electric Power Co. (PEPCO)) system interconnects with Virginia and Western Maryland systems: 450 MW capacity benefit
500 kV network: the role of joint ownership

• 500 kV network developed over 30 years; some key dates
  – early ’60s: jointly owned mine mouth (pit head) generating plant (Keystone) in coal fields of western Pennsylvania and associated 500 kV transmission system to deliver energy to load in the east
  – late ’60s 500 kV lines associated with Peach Bottom nuclear plant
  – early ’70s: 500 kV associated with Conemaugh plant in western Pennsylvania
500 kV expansion (continued) –

– mid ’70s: PEPCO interconnects at 500 kV- not joint ownership, justified based on reserve sharing
– Late ’70s/early ’80s eastern 500 kV system expanded
– 500 kV ties established to systems to west, north and south
– 1994: Washington 500 kV loop completed after 18 years from initial application for approval
Delays in expansion

• In early ’70s, study of potential for expanding at voltage higher than 500 kV concluded that low probability of acquiring right-of-way at any transmission voltage

• Early ’80s: west-east transfer limited economic purchases from the west, but
  – essentially no new 500 kV rights-of-way over last 20 years

• Proposed west-east transmission defeated due to New Jersey regulatory rejection of GPU request to include costs in base rates; also extensive intervener opposition (environment, labor unions, etc.)
Obstacles to expansion: Brighton-High Ridge line case study

- Need for 500 kV loop around Washington identified in early ’70s; critical reliability
- 1976: initial filing for approval of line to close 500 kV loop
  - Maryland regulator approved line after four years of hearings and deliberations (1980)
  - Regulatory decision appealed by interveners to State courts; decision affirmed in 1985
  - Disputes between State and Howard county over siting jurisdiction
    - Issues in interventions: environmental, health (electromagnetic fields (EMF))
- 1994: commercial service
Techniques for expansion: existing right of way

- PJM added 2,900 MVAR of capacitors at 230 kV and at 500 kV
  - West-east transfer capability for economic imports increased by 1,000 MW
  - Ownership shared among members of pool
- Other examples
  - Pennsylvania Power & Light built double circuit 500 kV structures, initially energized at 230 kV
  - “Shave” ground from under center of span to allow for increased expansion of conductor and thermal loading
Potential for expansion: 360 MW to 1,000 MW

- Over 15 years of rapid load growth, PEPCO expanded transfer capability from 360 MW per 230 kV circuit to 1,000 MW per circuit
- Key factor was to buy Right-of-Way: over 80 meters wide
- Transfer constraint was thermal ratings of conductors
- Incremental investment steps:
  - Single circuit towers with initial conductors: 795 mcm = 360 MW per circuit (assumes zero impedance)
  - Rebuild to form double circuit towers with 1590 mcm conductors
  - Rebuild to provide two 1590 mcm conductors per phase = 1,000 MW capability per circuit
Summary of lessons for developing countries

- Regulatory regime should be clear and minimize potential for jurisdictional disputes: economic & environmental regulation
  - avoid US problems of inconsistencies and disputes between federal and local regulation
  - limit ability of vested interests to erect obstacles to transmission expansion which is in the public interest

- Regulation to:
  - insure that transmission owners receive adequate return to promote investment for (a) reliability and (b) economy
  - insure that transmission owners examine all reasonable options and weigh long term benefits
  - allow incremental increase in initial investments to facilitate accommodation of long term load growth
“Smart” transmission systems –
the possible use of new technology

Dr. Dejan J Sobajic
EPRI
March 9, 2004
Recognition of the Need for “Smart” Grid Infrastructure

• President Bush, Feb 23, 2002, Radio Address:
  – “America can’t meet tomorrow’s energy needs with yesterday’s infrastructure.”

• Energy Secretary Abraham, May 8, 2002, releasing the National Transmission Grid Study:
  – “America’s electricity infrastructure is ill equipped to sustain our country’s needs today, and wholly insufficient to handle the growth in demand that is projected over the next few decades.”

• National Academies Report “Making the Nation Safer: The Role of Science and Technology in Countering Terrorism”:
  – Recommends technology be developed “for an intelligent, adaptive power grid”
Tomorrow’s Grid – Prerequisites

• Reliability – First!
• Symmetric market design
• Clear operational responsibilities
• Restrict operations in “N-1” space
• Integrated generation & transmission planning
Tomorrow’s Grid – Technology Solutions

- **“Smart”**: With sensors & system wide information processing
- **“Flexible & Resilient”**: An intelligent network w/ real-time monitoring & control
- **“Self Healing”**: Capable of predicting or immediately containing outages w/ adaptive islanding & fast isolation or sectionalizing
- Established Standards: Enabling “plug & play” distributed resources and digital appliances & devices
Integrated Energy & Communications System Architecture
Infrastructure Systems for On-Line Trade, Security and Control

OASIS

ISN

CC-RTU

WAMS

Trade Data Net

GI D/ API

Security Data Net

Control Data Net

HF Dynamic Data Net

Transmission Reservation
Congestion Management
Ancillary Services

Transaction Information System

PRA
DTCR
DSA
VSA
TRACE

PSAPAC
TRELSS

Integrated Substation Diagnostics
RCM
MMW

FACTS Controllers
Event Recording and Diagnostics
Stabilizer Tuning

Integrated Substation Diagnostics

CIM
Visualize critical information from raw data

- **Example:** Community Activity Room (CAR)
  - Displays the limits of power market activities imposed by constraints on the underlying power system
  - Locates system bottlenecks
  - Suggests combinations of net power import and export to avoid congestion
  - Promotes integration of system reliability and market efficiency
Blackout Prevention, Mitigation & Control

- **Phase 1**: 2 – 4 years
- **Phase 2**: 3 – 10 years
- **Phase 3**: 7-15 years
Activities Underway

- EPRI Electricity System Framework for the Future - ESFF
- EPRI Power Delivery & Markets – Roadmap
- EPRI Reliability Initiative I & II
- Consortium for Electricity Infrastructure for Digital Society - CEIDS
- Infrastructure Security Initiative – ISI
- CIM Extensions for Market Data – CME
- Advanced Market Design Initiative - AMD
- North American Electricity Infrastructure Monitoring System – NESEC
For More Information

Please contact:

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Transmission in the Nordic Countries

Nils-Henrik M. von der Fehr
University of Oslo
DET NORDISKE TRANSMISSIONSNET
The transmission grid in the Nordic countries
## General Facts

<table>
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<th>Finland</th>
<th>Norway</th>
<th>Sweden</th>
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<tr>
<td>Area, 1000 km²</td>
<td>43</td>
<td>338</td>
<td>324</td>
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<td>Population, mill.</td>
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<td>5,2</td>
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<td>GDP per capita, USD</td>
<td>31 889</td>
<td>25 288</td>
<td>42 889</td>
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<td>Installed capacity, MW</td>
<td>12 632</td>
<td>16 866</td>
<td>27 960</td>
<td>32 223</td>
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<td>Generation, GWh</td>
<td>37 260</td>
<td>71 938</td>
<td>130 591</td>
<td>143 361</td>
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<td>Electricity consumption per capita, kWh</td>
<td>6 519</td>
<td>16 127</td>
<td>26 871</td>
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Source: Nordel Annual Report 2002
# Generation and Consumption, GWh

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<td>Nuclear</td>
<td>0</td>
<td>21 443</td>
<td>0</td>
<td>65 572</td>
<td>87 015</td>
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<td>Thermal</td>
<td>32 349</td>
<td>39 793</td>
<td>783</td>
<td>11 185</td>
<td>84 110</td>
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<td>Other renew.</td>
<td>4 879</td>
<td>66</td>
<td>76</td>
<td>558</td>
<td>5 579</td>
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<td><strong>Total</strong></td>
<td><strong>37 260</strong></td>
<td><strong>71 938</strong></td>
<td><strong>130 591</strong></td>
<td><strong>143 361</strong></td>
<td><strong>383 150</strong></td>
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<td>Import</td>
<td>9 047</td>
<td>14 577</td>
<td>5 330</td>
<td>20 108</td>
<td>49 062</td>
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<td>Export</td>
<td>11 102</td>
<td>2 654</td>
<td>15 003</td>
<td>14 750</td>
<td>43 509</td>
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<tr>
<td><strong>Consumption</strong></td>
<td><strong>35 205</strong></td>
<td><strong>83 861</strong></td>
<td><strong>120 918</strong></td>
<td><strong>148 719</strong></td>
<td><strong>388 703</strong></td>
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Source: Nordel Annual Report 2002
## Transmission

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<th>Norway</th>
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<tr>
<td>400 kV AC/DC, km</td>
<td>1 346</td>
<td>4 062</td>
<td>2 144</td>
<td>11 067</td>
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<tr>
<td>220-300 kV AC/DC, km</td>
<td>504</td>
<td>2 403</td>
<td>5 639</td>
<td>4 628</td>
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<td>110-150 kV, km</td>
<td>3 954</td>
<td>15 300</td>
<td>10 470</td>
<td>15 000</td>
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### Interconnector capacity, MW

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<td>from Denmark</td>
<td>-</td>
<td>0</td>
<td>1 040</td>
<td>2 640</td>
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<tr>
<td>Finland</td>
<td>0</td>
<td>-</td>
<td>100</td>
<td>1 830</td>
</tr>
<tr>
<td>Norway</td>
<td>1 040</td>
<td>120</td>
<td>-</td>
<td>5 155</td>
</tr>
<tr>
<td>Sweden</td>
<td>2 680</td>
<td>2 230</td>
<td>4 455</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Nordel Annual Report 2002
Organisation of Transmission

- Vertical separation
  - generation
  - transmission
  - distribution
  - supply
- National TSOs
  - own most of the high-voltage transmission networks
  - responsible for system operations
- Extensive co-operation between the TSOs
  - Nordel
NordPool

- Voluntary market exchange
  - spot market for physical trade
  - various markets for long-term financial contracts
- Jointly owned by the TSOs
  - however, independently operated
- Accounts for approx. 20% of total transactions
- Market splitting
  - tool for handling transmission constraints
  - regional sub-markets with (potentially) different prices
System Operation

- Responsibilities
  - national TSOs
  - no need to balance within national borders

- Balancing and regulation services
  - market based
  - short and long run contractual arrangements
  - constraints: market splitting and/or counter trade

- International co-operation
  - integrated regulation market
  - settlements at national level
Transmission Tariffs (Norway)

- **TSO subject to revenue cap**
  - in principle, TSO bears risk (of excessive costs)
  - in practice, fully protected (also; state owned)

- **Regulation of tariff structure**
  - location-specific (point) tariffs
  - variable (energy-related) elements
  - fixed (capacity-related) elements

- **Variable tariff elements**
  - localised transmission losses evaluated at market prices
  - implicit charge on congested lines (spot price difference between deficit and surplus regions)
Transmission Investment (Norway)

- TSO responsible for planning and investment
  - projects allocated on basis of competitive bidding
- Regulatory oversight
  - expansions require concessions (cf. revenue cap)
  - semi-independent national regulator
  - ultimate decision rests with the government
- TSO’s incentives for grid expansion
  - obligation to ensure system security
  - essentially fully covered against risk
- Moderate investments in recent years
  - inherited over-capacity from pre-reform era
Interconnection

- Expansion based on bilateral agreements
  - TSOs (cf. Nordel)
  - regulators (cf. FNER Forum for Nordic Energy Regulators)
  - governments (cf. Nordic Council of Ministers)

- Planning and investment
  - Nordic Grid Master Plan
  - negotiated sharing of costs

- Moderate investments in recent years
  - increasing extent of congestion (although not serious)
  - general view that new investment would increase efficiency
  - tension between cost efficiency and market efficiency
Nordel

- Body for co-operation between Nordic TSOs
  - gradually developed since long before recent reform era
  - chairmanship rotates

- Objectives
  - efficient and harmonised Nordic electricity market
  - contact and co-operation with market players (the ‘Market Forum’)

- Tasks
  - system development and rules for network dimensioning
  - system operation, security, reliability, exchange of information
  - principles of transmission pricing and pricing of ancillary services
  - international co-operation
  - contacts with organisations and regulatory authorities
  - preparing and disseminating information
Conclusion

- Tight regulation
  - tariff structure and revenues/costs
  - investment subject to concession
- Open process
  - consultation with affected parties (or their representatives)
- Extensive collaboration
  - Nordel and FNER
  - tradition of Nordic co-operation based on consensus
- Challenge: further integration
  - transmission planning and system operations
  - regulation at the Nordic level
  - facilitating development of the market (market power)