Electricity transmission: Investment

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Readings


Investment
Which is the objective?

To ensure that all transmission facilities that are “justified”, i.e., meet a prescribed social welfare efficiency criterion (which must account both for economic & quality of supply considerations) are
- built at optimal times
- properly operated & maintained
at minimum cost
The “regulatory test”
What is a “justified” investment?

- Investment optimality according to traditional regulation:
  "Invest in network assets only while the additional network investment cost is still smaller than the additional saving in system operation costs (generation costs, loss of supply)"

- This definition is consistent with the one adequate for a context of competition:
  "Invest so that the net aggregated benefits (once network charges are included) of all network users (i.e. generators & consumers) are maximized"

- Technical reliability rules have to be met in any case, although it is preferable that they are incorporated into the cost / benefit function

The “golden rule” in both centralized & competitive frameworks (1)

- Traditional framework: Maximize global social welfare
  \[ \text{Max } \{U(D) - FG - VG - CT\} \]  \quad (1)
  
  \( U(D) \): utility for the demand D
  \( FG \): generation fixed costs
  \( VG \): generation variable costs
  \( CT \): transmission total costs
The “golden rule” in both centralized & competitive frameworks (2)

- Open market framework:
  \[ PD = IG + CT \]  \hspace{1cm} (2)
  - PD: payments by consumers (at wholesale level)
  - IG: revenues of generators (once they have paid their transmission charges)
  - CT = IVT + CCT (optionally) \hspace{1cm} (3)
  - IVT: “variable” transmission revenues (from application of nodal energy prices to consumers & generators)
  - CCT: complementary charge (assuming that transmission is regulated so that its total costs are fully recovered)

The “golden rule” in both centralized & competitive frameworks (3)

- Open market framework (continuation):
  Rearranging equation (2):
  \[ PD - IG - CT = 0, \]
  which can be introduced in (1):
  \[ \text{Max } \{ (U(D) - PD) + (IG + CT) - FG - VG - CT \} \]
  & then
  \[ \text{Max } \{ (U(D) - PD) + (IG - FG - VG) \} = \]
  \[ = \text{Max } \{ \text{net benefit of consumers} + \text{net benefit of generators} \} \]
  as we wanted to prove
A useful property

- An economically justified network investment under traditional network expansion rules
  
  \[ \text{network investment cost} < \text{savings in operation costs} \]
  
  will increase the net benefit of

  **Generators:** income from nodal prices – operation costs – network charges
  
  **Consumers:** utility – cost of purchasing electricity – network charges

  if the residual network cost is allocated pro rata of the economic benefits of each network user

The “regulatory test” in practice

- A fully convincing “regulatory test” is missing in practice
  
  - to verify that a proposed investment is justified or even that it is the “optimal” one within a set of proposed network reinforcement options
  
  - the current predominant criterion in Europe & most of US is to comply with prescribed security criteria (*some countries have mandatory “Grid Codes”*) & to eliminate network bottlenecks

- Some countries specifically include the criterion of economic efficiency, but it is not clear how this is applied (*or if it is actually applied*)
Physical components for the transmission function (1)

- Transmission lines
  - Overhead lines & underground cables (AC & DC)

- Elements for connexion, voltage transformation & operation
  - Bus bars
  - Transformers
  - Phase-shifters
  - Breakers
  - Disconnect switches
  - Insulators

Physical components for the transmission function (2)

- Protection components
  - Automatic breakers
  - Lightning arresters
  - Protection relays

- Metering & control components
  - Voltage & current transformers
  - Telemetering & telecontrol

- Reactive power control
  - Capacitors
  - Reactances
  - SVCs (Static voltage compensators)
  - FACTS, in general
**Investment**

**Nature of transmission costs**

*Actual transmission network costs*
- Infrastructure costs
  - investment capital costs
  - operation & maintenance costs

*Costs incurred because of the existence of the network*
- Ohmic losses (generation costs)
- Costs of redispatch that are incurred to eliminate violations of transmission constraints (generation costs)
- Some of the costs of ancillary services
  - reactive power / operating reserves / black start capability

*System Operation & transmission are different activities (although sometimes they are performed by the same firm)*

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**ACRONYMS OF TECHNOLOGIES**

- FACTS: Flexible Alternating Current Transmission System
- FSC: Fixed Series Capacitor
- GIL: Gas Insulated Line
- HTC: High Temperature Conductor
- HTS: High Temperature Superconductor
- HVDC: High Voltage Direct Current
- OHL: Overhead Line
- PMU: Phasor Measurement Unit
- PST: Phase Shifting Transformer
- SMES: Superconducting Magnetic Energy Storage
- SSSC: Static Synchronous Series Compensator
- STATCON: Static Condenser
- SVC: Static VAR Compensator
- TCSC: Thyristor Controlled Series Compensator
- UPFC: Unified Power Flow Controller
- WACS: Wide Area Control System
- WAMS: Wide Area Monitoring System
- XLPE: Cross-linked Polyethylene
Transmission costs
(a sample, based on regulated standard costs in Spain, 2002)

- Fixed costs of network facilities (M stands for "million")
  - Lines & substations
    - 400 kV 2 Circuit Duplex: 0,288 M€/km
    - 400 kV 1 Circuit Duplex: 0,182 M€/km
    - 220 kV 2 Circuit: 0,168 M€/km
    - 220 kV 1 Circuit: 0,108 M€/km
    - Substations: 1.8 M€/bay 400 kV
    - Control center: about 4.8 M€

- Operation & maintenance costs
  - 400 kV: 3.350 €/circuit/km/year
  - 220 kV: 1.940 €/circuit/km/year

Transmission vs. total costs
(case example: Spain)

- Total regulated transmission costs in 2002:
  - 582 M€
    - 347 M€ for REE
    - 235 M€ for the other transmission owners

- Total electricity supply cost 12000 M€
  - In this case transmission costs amount to less than 5% of total electricity costs
  - However, in some countries the percentage may reach up to 20%
Determination of transmission network costs

- Dilemma: Remunerate according to the actual incurred costs or trying to reflect the current marginal investment costs
- Answer depends on who is really responsible for the development of the network
  - If the transmission firm is "active", then the remuneration must refer to an efficient & well adapted network & economic incentives should depend on the actual contribution to quality of supply, losses & congestion costs, i.e. "performance"
  - If the transmission firm is "passive", then the remuneration must refer to the actual network & incentives must just depend on the availability of the network equipment (*)
- Specific regulation is needed for network assets that are used for non-electrical activities

(*) Some additional “mild” incentives can make sense

Determination of transmission costs

Investment costs

- Alternatives of evaluation of the "rate base"
  - From the present market value (potential to generate income): it happens to depend on regulated tariffs
  - From the historic (accounting) cost (ignores technological change, but it matches incurred costs with revenues)
  - From some "replacement value"
    - "depreciated replacement cost, DRC": present cost of the assets that today would provide the same service as the existing assets
    - "optimized depreciated replacement cost, ODRC": present cost of the assets of an optimal network for the present needs
    - "optimized deprival value, ODV": minimum loss that a business would suffer if it were deprived of the asset = min{market value, ODRC}
- The rate of return on capital
  - Weighted average of debt and equity, each one according to its rate of return according to its risk
**Determination of transmission costs (cont.)**

- Costs of O&M / management costs
  - percentage (after benchmarking with comparable efficient utilities) of the rate base

- Particular case: The cost of new investments
  - Preferable: assign by auction ➞ pay the winner bid
  - If facility is built by coalition of users just for their own use ➞ regulated value is not needed
  - In general use standard costs as guidance

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**Alternative approaches to regulation of transmission investment**
Investment in new facilities
Approaches

1. System Operator proposes reinforcement plan, to be authorized by regulator. Construction of lines:
   A. Compulsory (all lines) & assigned by competitive bidding or to incumbent
   B. Non compulsory for some (all) lines & left to risk investors to build & negotiate remuneration with network users or regulator

2. A private company is awarded the transmission license and is regulated as a monopoly: subject to grid code; remuneration based on some price control scheme (e.g. RPI-X)

3. Coalitions of network users proposes reinforcements, to be authorized by regulator; regulated remuneration of total costs; construction is assigned by competitive bidding

4. Risk investments: same as above, but coalition bears total costs & regulated remuneration covers partial costs

5. Merchant lines (remuneration based on transmission market value)

Investment in new network facilities
Approaches (comments)

1. **SO + Regulator:** (A) May result in overinvestment if regulator fails to set limits in the authorization process & (B) underinvestment if risk investors do not show up

2. **Private licensed company:** May result in underinvestment unless very careful incentive schemes are implemented

3. **Coalitions of network users:** Only lines with clear beneficiaries will be built. May be a complement to 1

4. **Risk investments:** Same as 3, but more acute. Good to promote investment in underdeveloped networks

5. **Merchant lines:** Cannot be trusted to develop a sound network, since transmission revenues from nodal prices in a well developed network will grossly under recover transmission costs. May be a complement to 1 or 2
Option 1.A
System Operator + Regulator

- Regularly, the System Operator must propose a plan for reinforcements of the transmission network
  - after taking into consideration (justified) any proposals made by the network users
- Regulatory authorities approve the plan & authorize construction of individual new facilities
- Construction, operation & maintenance of each facility are allocated in a competitive auction
  - pay as bid to winner
  - limited duration of contract; auction for the next period?
  - set availability targets for each facility & penalties (credits) according to the actual performance
- May be complemented by options 3, 4 & 5

Option 1.B
System Operator + Regulator

- Regularly, the System Operator must propose a plan for reinforcements of the transmission network
  - after taking into consideration (justified) any proposals made by the network users
- Regulatory authorities approve the plan & authorize construction of individual new facilities
- Construction, operation & maintenance as in 1.A except for some lines that are left to risk investors
  - who can negotiate remuneration & other terms of contract with potential beneficiaries of the line or with regulator
- Concern: “justified” lines may not be built
Option 2: Private firm & global regulated remuneration

- A private company is awarded the transmission license and regulated as a monopoly
  - Must follow prescribed design requirements (grid code)
  - Incentives to meet performance targets (warning: separate clearly from incentives to System Operator)
  - Global remuneration (RPI-X) for the complete network, while taking into account
    - actual new investments
    - economic lives & depreciation of existing investments
    - economic health of transmission company
    - expected efficiency improvements
- Concern: incentives to under-invest. It is more difficult to estimate the costs for the period than to approve a plan & pay for the facilities actually built

Option 3
Users have the initiative (A & B)

- Initiative of proposal of network reinforcements corresponds to coalitions of network users
  - OPTION A: coalition builds & pays the reinforcement, which needs authorization from regulator
  - OPTION B: after a quasi-judiciary process (coalitions pro & against, evaluation by system operator) regulator decides whether reinforcement is justified or not.
    If justified, it is built under competitive bidding
    - pay as bid to winner
    - limited duration of license; auction for the next period
    - set availability targets & penalties (credits) according to performance
    - charge cost to all users with general allocation method
Option 4
Users have the initiative (C)

- OPTION C: risk investments
  Quasi-judicial process as in option B
  If the reinforcement is found justified:
    - the proprietary coalition is selected (a specific auction procedure is followed)
    - assign construction by competitive bidding
    - apply regulated tariffs (attenuated, according to the line utilization) to all network users
    - financial rights on the congestion rents of the reinforcement ("firm transmission rights") are given to its owners

Option 5
Merchant lines

- Basic idea: Regulate the transmission activity as any other competitive business → merchant lines
  - Remuneration comes from congestion rents
    - Network capacity may even be bid in a short-term market (possible with DC lines)
  - Firm Transmission Rights (FTRs), may be seen not only as a risk hedging mechanism, but also as an incentive for investment
- Difficulties:
  - insufficiency (in general) of market driven revenues
  - high exposure to risk
  - reliability lines
  - potential for market power abuse
Session 15
Module E.3

Electricity transmission: Access
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Study material

- Transpower New Zealand, “Financial transmission rights”, 2001 <An excellent tutorial text>
- For another excellent, but more advanced text (not required): “Integrating European Electricity Markets”, 2009, go to http://www.iefe.unibocconi.it
Readings


Regulation of transmission services

ACCESS

Part of the material for this module was originally compiled by Alberto Pototschnig (Energy Markets International & advisor to the Florence School of Regulation, FSR) in his courses at the FSR
Access
What is the objective?

- To ensure nondiscriminatory access to all network users
- Thus, transparent & equitable rules must be used for
  - authorization of connection to the grid
  - allocation of limited transmission capabilities

How to assign priorities for access?

- There is a diversity of situations
  - Requests to connect to the network
  - Solve local network constraints
  - Solve generalized network constraints
Requests of connection to the grid

Principles of access (1 of 4)
Requests of connection to grid

- Access for generators or consumers may only be restricted because of lack of network capacity
  - reinforce network if justified whenever possible
  - offer alternative connection points if proposed ones are not feasible
- Consumers have the right to be supplied at the requested point, but cannot displace prior consumers
- Different criteria may be applied to generators
  - a) same as for consumers
  - b) right to be connected at any point, even if in conflict with existing generators for the use of limited network capacity
Principles of access (2 of 4)

Requests of connection to grid

◆ The objectives of connection charges is the recovery of costs of connection infrastructure (\& perhaps reinforcements)
  • to an appropriate extent, considering benefits to other grid users
  • in this way providing (some) locational signals

◆ Connection costs depend on
  ➢ distance from the existing network
  ➢ capacity of the required connection
  ➢ configuration of the (local) network

Principles of access (3 of 4)

Requests of connection to grid

◆ Alternative charging approaches for connection assume different degrees of contribution to the cost of dedicated facilities and of network reinforcement (\& therefore of socialisation of these costs)
  ➢ No charges ➔ all connection costs are socialised
  ➢ Shallow charges ➔ connection charges cover the cost of dedicated facilities (and possibly the cost of reinforcements in the local area); costs of (other) reinforcements are socialised
  ➢ Deep charges ➔ connection charges cover the cost of dedicated facilities and of all network reinforcements
Principles of access (4 of 4)

Requests of connection to grid

- Reinforcements related to a new connection may benefit existing grid users as well
- Dedicated facilities for a new connection may benefit future connections
  - these facilities may become common to several grid users
  - the SO may decide to oversize these facilities
- No simple rule for definition of connection charges
  - Connection of small grid users may be generally charged on a shallow basis (according to standardised values/criteria)
  - Cost-related connection charges for large grid users and for non-standard connections (e.g. very distant locations from the existing network)

Solution of **local** network constraints
How to assign access priorities?

Local network constraints

- Market mechanisms versus regulated methods
  - MARKET
    - If the conditions exist for competition: the market rules must avoid introducing excessive risks for generators & consumers
      - Separated bids for the daily market & to solve network constraints
  - REGULATED
    - More appropriate for those situations where the market does not seem to be possible
    - This requires to transfer the knowledge on costs (at least in general terms) to the regulator & to reach a reasonable agreement

Management of generalized network constraints
How to assign access priorities? (1 of 4)

**Generalized network constraints**

Principles for allocation of limited network capacity

- Use, whenever possible, market mechanisms that do not discriminate any network users
- Do not allow long-term capacity reservations to result in market dominance
  - allocate firm capacity with market mechanisms
  - set upper limits to the fraction of capacity that can be auctioned
  - do not allow any single agent to control a large fraction of the auctioned capacity
  - unused capacity must be available for any buyer
  - possible ad hoc treatment of existing long term contracts

How to assign access priorities? (2 of 4)

**Generalized network constraints**

- A diversity of solution schemes in the short-term, very dependent on the specific context
  - Nodal prices *(pioneer use in several countries in South America, in the Central American Market, widely used in US ISOs)*
  - Zonal prices or market splitting or implicit auctions *(Scandinavia, Italy, ERCOT initially; extensions of this scheme could be used to cover more than one centrally dispatched system)*
  - Redispatch &/or counter-trading *(these are solutions more internal to a market, or in simple configurations with two markets; less market-oriented)*
How to assign access priorities? (3 of 4)

*Generalized network constraints*

- There is also the possibility to use different types of **long-term** contracts
  - Explicit auctions
    - Financial vs. physical rights
    - Point-to-point rights versus flowgates
  - Associated issues
    - Pre-existent contracts: compatibility with the market
    - Market power: limitations in the allocation rules
    - Rights that are linked to new generation investments

How to assign access priorities? (4 of 4)

*Generalized network constraints*

- More sophisticated schemes are needed in **regional** markets
  - Centralized vs. Loosely coordinated vs. Basically independent
    - The Central American Electricity Market (*nodal pricing, N+1 markets, centralized dispatch of international trade*)
    - The EU Internal Electricity Market (*lack of global coordination; several tight sub-regional markets; attempts to tighter coordination, e.g. flow-based market coupling*)
    - The US ISOs / RTOs (*still very rudimentary coordination among them*)
Details on methods for network constraint management

The basic considered approaches

- Full nodal pricing
- Zonal pricing
  - Network congestion results in economic islands, with different market prices
- Redispatch & countertrade
  - System Operator decides the optimal redispatch / counter flow that eliminates the congestion
- Auctions of network capacity
  - The congested capacity is offered for auction & only the winners can execute their transactions (explicit & implicit implementations are possible)
Nodal versus zonal prices

- Network congestions result in economic islands with different market prices → if distinct zones can be defined & prices are averaged within each one → zonal prices
- These prices cause changes in generation & demand → any network constraint violations are removed
- The congested line generates some income: (transported energy) x (difference in prices between the two ends of the line)

Redispatch / counter-trade

- **Redispatch**: The System Operator, using economic & technical information from the power system, decides the optimal dispatch that solves the congestion (i.e. eliminates any constraint violation)
  - The extra cost of the redispatch should be assigned to those agents that have the responsibility for it
- **Counter-trade**: (similar to redispatch) The SO decides to apply a physical transaction in the opposite direction so that the constraint violation is eliminated
Network capacity contracts (1 of 4)

- These are risk hedging contracts that try to reduce or to eliminate economic risks that network congestions may cause in bilateral transactions
  - Loss of income if a generator is removed from dispatch because of network congestions
  - Price volatility that is caused by network congestions
  - Physical impossibility to perform the transaction
- Variants: physical vs. financial / line-based (flowgates) or node to node (or zone to zone)

Network capacity contracts (2 of 4)

Explicit capacity auctions

- Nodal or zonal prices are not required; compatible with any organization of the wholesale market
- Prior to the energy market, the limited capacity is auctioned to the agents affected by the congestion
  - Network capacity & energy market are artificially separated
  - (Conceptually) an implicit auction (resulting in nodal or zonal prices) would be superior
- Only the winning transactions (in the auction) may physically take place
- The auction generates some income
  (transported energy) x (auction price for that transaction)
Network capacity contracts (3 of 4)

- Remember that the market value (based on differences of nodal prices) of a network capacity contract once built (over the economic life of the asset) is in general much less than the total cost of the corresponding transmission capacity.
- Network transmission contracts have to adapt to any mechanism of congestion management that has been adopted:
  - if zonal prices are used → FTRs must cover the price differential between the entry & exit nodes
  - if auctions are used → FTRs are a particular form of explicit auctions

Network capacity contracts (4 of 4)
Firm transmission rights (FTRs)

- FTRs are “contracts for differences” of the type Quantity Q x (nodal price k – nodal price j)
- Well designed FTRs have very useful properties
  - Simultaneous feasibility → Revenue adequacy
- FTRs may increase market power problems
- It is important to understand the differences & coincidences of FTRs & physical transmission contracts
  - In the spot market
  - In emergency situations