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To cite this version:

Vincent Rious. An operational and institutional modular analysis of Transmission and System Operator. 5th Conference on Applied Infrastructure Research, Oct 2006, Berlin, Germany. pp.1-38. hal-00218135

HAL Id: hal-00218135

https://hal-supelec.archives-ouvertes.fr/hal-00218135

Submitted on 25 Jan 2008

An operational and institutional modular analysis of Transmission and System Operator

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Abstract

As far as the management of the power flows on a transmission network is concerned by externality, Transmission and System Operators (TSOs) are externality market designers, and so can be studied thanks to a modular analysis grounded on Wilson [2002], Brunekreeft *et al.* [2005] and Glachant *et al.* [2005]. Since TSOs are institutional entities, the design of each module that they implement are constrained by compatibility requirement or "weak institutional complementarity" (Pagano [1993], Aoki [2001]) from their governance structure. The governance structure of TSOs is set by transmission ownership unbundling, governmental energy policy and political economy. Our paper develops such a framework and such an argumentation. Then, although the economic theory specifies a unique arrangement – that we will call "ideal first-best TSO" – to manage efficiently a power transmission network, we can understand why there is such a diversity of TSO arrangements and of heterogeneous results among TSOs. Our comparison between the "ideal first-best TSO" and two reference TSOs, PJM and NGC concludes that some network management schemes may be inefficient compared to an "ideal first-best TSO". But these schemes may be relatively satisfactory regarding the institutional context that frames their design especially as regulation may limit inefficiency.

JEL codes: L5, L29, L33, D61, D62

Keywords: electricity, Transmission and System Operator, governance, modularity, institutional complementarity

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The opinions expressed here are the sole responsibility of the author.

I. INTRODUCTION

As far as the management of power flows is concerned, a Transmission and System Operator (TSO) must achieve three main missions: the short-run externality management, the long-term management and development of the network (Brunekreeft *et al.* [2005]) and the coordination with neighbouring TSOs to deal with border effects (Glachant *et al.* [2005]). Economists and engineers know quite well how to manage efficiently a power transmission network and how to provide network signals that involve an efficient reaction of the network users. Implementations of short-run efficient signals were proposed (Caramanis *et al.* [1982], Schweppe *et al.* [1988]) and were applied on several power markets (Argentina, Chile, New Zealand or some Northeast states of the USA) or recommended on others (FERC [1999], EC [2004]). Long-term locational network signals are applied under a pragmatic way in quite a limited number of network areas. The regulation of the transmission natural monopoly always raises some issues. But at least what lead to an inefficient development of the network is quite well known (Pérez-Arriaga *et al.* [1995], Green [2003]). The coordination between neighbouring Transmission and System Operators is said to be not very demanding at least for the short-run management of network externality (Cadwalader *et al.* [1999], Marinescu *et al.* [2005]). Some coordination agreements are near implementation in the USA (MISO-PJM [2004], MISO-PJM-TVA [2005]). Therefore, an ideal TSO can be imagined from the most efficient implementations of these three missions.

Nevertheless, some reference TSOs such that PJM or NGC are not ideal TSOs. The transmission governance structure imposes a “weak institutional complementarity” (Pagano [1993], Aoki [2001]) between implementations of TSOs’ missions, that is to say compatibility requirements between implementations of TSOs’ missions. This transmission governance structure mainly relies on transmission ownership unbundling from incumbents. The transmission governance structure accounts for the difference between an ideal TSO and real TSOs.

We show that a TSO as a power flow externality market designer can be studied thanks to a modular analysis framework. The modules are the three missions mentioned above and the TSO’s governance structure. We show also that the transmission governance structure accounts for the diversity of arrangements of Transmission and System Operators and their inhomogeneous results.

Our paper is organised as follow. In section II, we show that the design of TSO's missions can be studied within a modular analysis framework, following the same modular philosophy as Wilson [2002]. The implementations of three missions-modules are surveyed by comparing them through their level of internalisation of externality of power flows in price mechanisms, without any prejudices of performances or compatibilities. In section III, the governance structure of transmission completes this framework. It introduces "institutional complementarity" between the operational modules. In section IV, the two reference TSOs, PJM and NGC, with quite opposite features will be studied thanks to our modular analysis framework and an analysis of institutional complementarity between operational modules. We will then be able to understand why there are such heterogeneous results between TSOs.

II. A MODULAR ANALYSIS FRAMEWORK

As market designers, the management of externality by TSOs can be characterised thanks to a common modular analysis framework similar to the Wilson's [2002] one. Our common analysis framework presents the following modules that stand for the three main missions of TSOs: the short-run management of network externality, the long-term development of the transmission network infrastructures (Brunekreeft *et al.* [2005]) and the management of border effects between control areas (Glachant *et al.* [2005]). The implementations of each module are differentiated thanks to their level of internalisation of externality. These solutions are presented under the assumption that the TSO and the regulator are benevolent, efficient and well coordinated. It is then possible to design an ideal first best TSO by summing up the most efficient option of each module. Even if this arrangement is never reached in reality, it is a benchmark for comparisons of TSOs' performances as for the management of power flows.

II. A. THE SHORT-RUN MANAGEMENT OF NETWORK EXTERNALITY

The first mission of a TSO as a network manager is the management of the short-run externality (mainly congestion and losses) on a power transmission network to ensure a short-run adequacy between generation and consumption while respecting the network constraints. This mission is called "System Operation". There exist different solutions with various levels of integration between the system operation and the energy market to internalise network externality.

The efficient sharing of the network capacity as a scarce resource is a well-known and addressed issue in the restructured electricity industry. Schweppe *et al.* [1988] demonstrate that an efficient constrained dispatch could be computed thanks to a nodal pricing system considering network externality as constraints of the market clearing. One generally considers only congestion and losses and seldom includes voltage constraints (Caramanis *et al*. [1982]). A nodal pricing gives an energy price per node indicating where it is preferable to generate or to consume one more megawatt taking into account both network losses and network limitations. The price differential between nodes linked to the externality generates a merchandise surplus for the TSO, also called congestion rent in the DC lossless approximation[1] (see Figure 1). The network limitations prevent the optimal dispatching from reaching the maximum of social surplus free of externality. It results a deadweight loss, a social cost also called congestion cost in the DC lossless approximation.

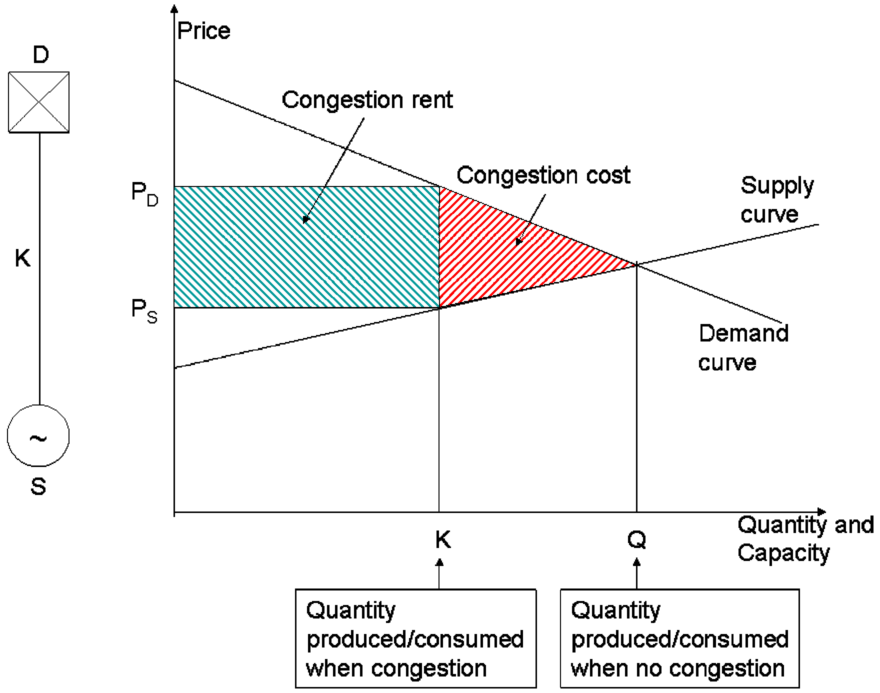

Figure 1 Graphical representation of nodal pricing on a congested two-node network

The redispatch scheme separates the externality management from the energy market (see Figure 2). In this case, the energy market assumes there is no network loss or constraint and all the market participants are paid and charged the system marginal price (SMP). Some generators or

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[1] The more used approximation, namely DC approximation consists in considering only the real power and in approximating the behaviour of the network to be linear. In this case, only the congestions constraint the nodal pricing.

consumers are "constrained on" (and paid P_{on}) in the import node and while others are "constrained off" (and pay P_{off}) in the export node by the TSO after the market clearing to manage network externality. The subsequent redispatch cost is born by the TSO for the short-run operation. It is generally socialised to the long-term in the use of the network tariff. Only the redispatched units know that there are network constraints.

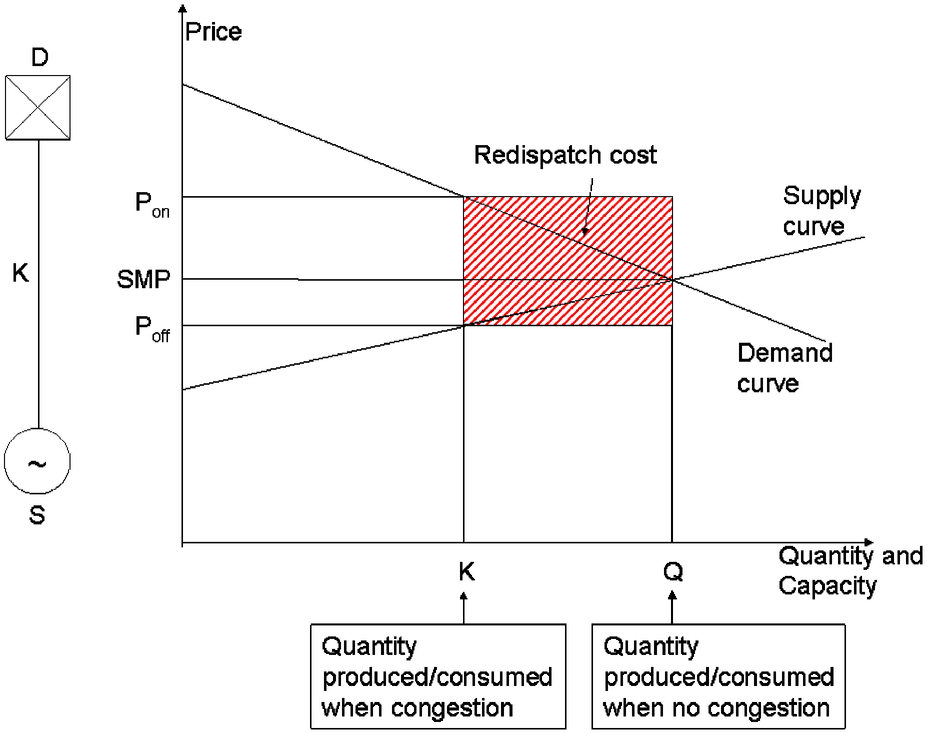

Figure 2 Graphical representation of redispatch scheme on a congested two-node network

Each externality can be independently managed thanks to a different management scheme. For instance, nodal pricing can only internalise congestion while losses (and voltage constraints) are socialised. Similarly, one can manage an externality with different management schemes depending on its amplitude. For instance, zonal pricing mixes the two previous schemes (Bjørndal-Jørnsten [2001], Ehrenmann-Smeers [2005]). The main congestions are treated thanks to a nodal pricing on an aggregated zonal network while the temporary congestions are managed thanks to redispatch and their costs are socialised.

Some forward hedging tools have been designed to hedge locational price volatility on nodal and zonal systems (Hogan [1992]). These forward contracts are generally called Financial Transmission Rights (FTR). Their owners receive a part of the congestion rent based on the price differential between a sink node and a source node.

To conclude, the different solutions to manage externality on a power transmission network can be summed up as follow:

Chart 1 Externality management schemes classified by level of integration between the system opertion and the energy market and by level of socialisation of the cost of system operation

Externality management schemes	Level of integration between the system operation and the energy market	Level of socialisation of the cost of system operation
Nodal pricing	High	Low
Zonal pricing	Medium	Medium
Redispatch	Low	High

II. B. THE LONG-TERM DEVELOPMENT OF THE TRANSMISSION NETWORK

The second mission of a TSO as a network manager is the long-term development of the transmission network. The short-run externality management informs the TSO and the network users on the network constraints. Despite these constraints, the TSO must ensure an adequacy between consumption, generation and network capacity while allowing for an efficient joint investment of the network and of the network users. Consequently, this mission of the TSO is a two-part one. First, the TSO that is assumed to be benevolent will invest to make the social cost decrease. Secondly, the short-run signals when they are public data are necessary but never sufficient to guide the location of the network users. And the merchandise surplus collected by the TSO from the System Operation never recovers the whole cost of transmission. The lumpiness and economies of scale of the network infrastructures generate these two insufficiencies (Pérez-Arriaga *et al.* [1995], Joskow-Tirole [2005]). The short-run signals must be completed by long-term locational signals through network tariffs (Green [2003]). These network tariffs then also complete the TSO's revenues and allow to recover its investments costs (Pérez-Arriaga & Smeers [2003]).

Economies of scales and lumpiness make transmission a natural monopoly (see Rious [2006] for more details). The transmission investments decisions must so be centralised to be efficient (Joskow-Tirole [2005]). Depending on the response of the network users to the short-run and long-term locational signals and the evolution of the load and generation patterns, the benevolent TSO arbitrates between on the one hand the social costs noticed from the short-run operation and anticipated from the connection requests and on the other hand the costs of network investments.

Other things equal, this process is equivalent to a social welfare maximisation (Pérez-Arriaga – Smeers [2003]).

We present the three main methods to allocate the network charges: the deep cost allocation method, the shallow cost allocation method and the zonal tariff. Of course, intermediary methods are possible. There is no ideal theoretical solution to define this tariff and to allocate the network charges but only pragmatic methods that internalise more or less of network externality and so are more or less incentive (Hiroux [2005]). Accommodation capacities can complete these allocation methods.

Under the "deep" cost allocation method, "connection assets" and "network upgrades" are attributed to the network users that trigger the investments through a connection tariff.

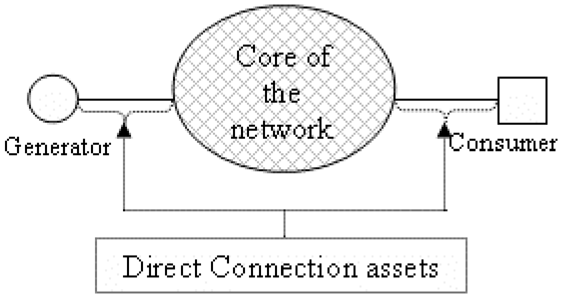

Figure 3 Distinction between connection assets and reinforcement assets in the core of the network

This method is controversial because the network costs that are associated to the lumpiness of the transmission line capacity are individually allocated to the network users. Besides, it is a one-way internalisation since the network users whose connection generates positive externalities are not rewarded.

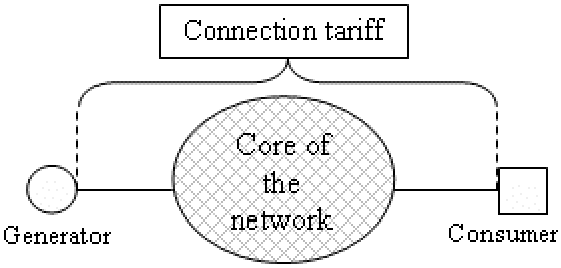

Figure 4 Deep cost allocation method

To the contrary, under the shallow cost allocation method, the beneficiaries pay only the "shallow" part of the network, that is to say the "direct connection assets" through a connection tariff.

The "network reinforcements" (in the core f the network) are socialised among all the network users through a Use of the System (UoS) tariff[2].

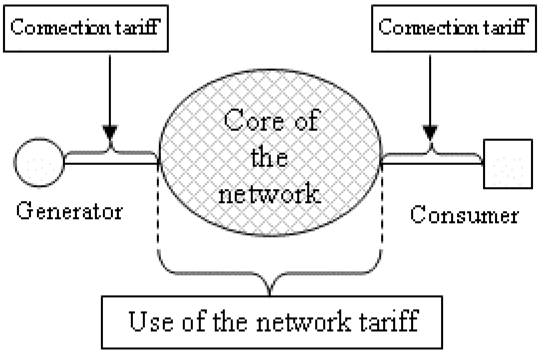

Figure 5 Shallow cost allocation method

Under the "zonal" allocation method, the connection tariff is the same one as in a shallow allocation method but the UoS tariffs are spatially differentiated. Lots of variants are possible. It is an interesting method as positive externality can be internalised at least partly.

The publication of "accommodation capacities" is an additional locational signal that may help the efficient location of the network users. The publication of accommodation capacities should make the allocation method more auditable to the network users. The "accommodation capacity" of a node is the nodal quantity of new generation or consumption that can be connected to this node without creating new congestion. Then, depending on the allocation method, the accommodation capacity allows a network user to anticipate that he will have to pay reinforcement costs or not.

To conclude, the different solutions to allocate network charges can be classified as follow.

Chart 2 Allocation methods of costs of network infrastructures classified by its repartition between the connection and the use of system tariffs

Allocation method	**Connection tariff = x% of the network revenue**	**Use of the system tariff = (1-x)% of the network revenue**	**Internalised externality**
Deep cost	100	0	Negative externality only
Shallow cost	~0	~100	Distance from the core of the network
Hybrid or zonal	0<x<100	0<(1-x)<100	Negative, positive also

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[2] The definition of the use of the system tariff may vary a lot depending on the network and market rules. Mainly, it covers the costs of providing and maintaining transmission assets and balancing the system (system operation, ancillary services, losses and congestions when they are socialised).

II. C. THE COORDINATION OF TSOs

The third mission of TSOs as network managers is to coordinate with each other to internalise external loop flows and border effects[3]. TSOs can then optimally use all existing power resources, ease the arbitrages and help the integration of markets. The coordination between TSOs includes the coordination of both their externality management schemes and their long-term development of networks.

There exists two main ways of coordinating adjacent systems in the context of a power market: "standardising" them or "combining" them (Glachant *et al.* [2005]). The coordination by "standardisation" implies that each TSO must choose the same solution for the externality management scheme, for the long-term development of network and for the allocation of the interconnection capacity, and communicate each other a minimal set of information on the state of its network and market (see Cadwalader *et al.* [1999] for the coordination of externality management schemes). The coordination by "combination" needs the implementation of standard inter-TSO footbridges to allow the coexistence of different individual schemes.

Without considering the cost of implementing coordination, standardisation achieves full efficiency while combination is only a second-best. Nevertheless, depending on the cost of implementing coordination compared to the benefit of the reached coordination, the coordination by combination or no coordination may be more efficient (Costello [2001]).

The need for coordination between neighbouring control areas and the efficient type of coordination greatly depend on the network configuration and topology between these areas. The more highly meshed the links between control areas and internal networks are, the more efficient the coordination may be to deal with border effects (Costello [2001]).

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[3] Also called spillover effects (Costello [2001]).

To conclude, the different solutions of coordination to manage border effects on neighbouring TSOs can be summed up as follow.

Chart 3 Coordination solutions between neighbouring TSOs classified by level of internalisation of border effects

Coordination between neighbouring TSOs	Level of internalisation of border effects
No coordination	Low
By combination	Medium
By standardisation	High

II. D. AN IDEAL FIRST-BEST TSO

The efficient implementation of all the three modules constitutes a first-best TSO. Such a TSO sends economic signals to the network users ensuring an efficient use of the network. This TSO efficiently develops the network. And this TSO coordinates with its neighbours ensuring the management of the border effects between systems.

The short-run externality is managed thanks to a nodal pricing to ensure an efficient dispatch and an efficient allocation of scarce transmission capacities (Schweppe *et al.* [1988]).

The long-term objective of a well-designed TSO is to develop the network in order to maximise the social surplus. Other things equal, this is equivalent to minimise the sum of the cost of externality, the operation and maintenance (O&M) cost and the investment cost (Pérez-Arriaga - Smeers [2003]). In order to invest efficiently, the TSO must then determine the social cost of externality and arbitrate between this social cost and the network investments costs.

Network tariffs are preferentially zonal ones and completed by accommodation capacities to ensure an efficient location of network users despite network externality and indivisibilities.

Since the locational methods such as the nodal pricing and the zonal tariff are the more appropriated to internalise network externality, they are also the more appropriated to internalise the border effects over several control areas (Glachant *et al.* [2005]) if the neighbouring control areas communicate the required set of information and data (see Cadwalader *et al.* [1999] for the coordination of externality management schemes).

To conclude, an ideal first best TSO must fulfil its mission thanks to the following implementation:

Chart 4 Constitution of an ideal first best TSO

Missions of the TSO as an externality market designer	Implementation to reach an ideal first best TSO
Externality management scheme	Nodal pricing
Network development	
Investments	Minisation of externality social cost, centralised by TSO
Tariffs	Zonal tariff + accommodation capacities
Coordination with neighbouring TSOs	By Standardisation

III. COMPATIBILITY OF MODULES OF THE NETWORK MANAGEMENT

No private agenda neither compatibility requirement between modules is assumed in our common modular analysis framework because the TSO and the regulator are assumed to be benevolent, efficient and well coordinated.

In reality, there is no guaranty that a TSO is benevolent. It may face contradictions between its objectives related to its governance structure and its ideal TSO's missions. The regulator may face an ambiguous energy policy. The transmission governance structure generates “weak institutional complementarity” (Pagano [1993], Aoki [2001]) between the operational modules of TSO. The transmission governance structure accounts for the possible gap between real TSOs and the ideal TSO in such matters.

First, we show that transmission governance mainly relies on Transmission Ownership unbundling and impacts regulation and market design. Lastly, we study three kinds of compatibility constraints between the modules of real TSOs that transmission governance imposes.

III. A. THE GOVERNANCE STRUCTURE OF TRANSMISSION NETWORK

Transmission unbundling from incumbent utilities provides more than a non-discriminatory open access to the network. The way transmission unbundling is realised is the ground of the “transmission governance (structure)” and thus frames the institutional complementarity of operational modules that constitute a TSO.

First, we point out the rationale of unbundling transmission ownership. Second, we see the impact of transmission governance on the regulation of TSO. Third, we see the impact of governmental energy policy, regulation and transmission governance on how power flows externality is considered in market design.

III. A. 1. Unbundling transmission ownership

Ownership unbundling is frequently assumed. In reality, network unbundling always implies unbundling System Operation while unbundling Transmission Ownership[4] is constrained by the possibility of imposing the divestiture of this network to incumbents and the wideness of border effects.

The divestiture of system operation is widely recognised as a necessary prerequisite in a deregulation process and rather easy to impose. It stands for few immediate financial stakes while the bundling of this function is strategic for incumbents to the long-term to raise entry barriers by limiting third party access.

To the contrary, the divestiture of the transmission ownership may be hard to impose since the network is a moneymaking asset base. The certainty of regulated revenue provided thanks to network assets is attractive in the context of uncertainty of power market. Besides, transmission ownership for an incumbent can still raise entry barriers by preferentially developing the network to its own advantages.

Network unbundling can be influenced by other constraints, mainly technical ones. If the ownership and operation of the power network is highly balkanised, loop flows create numerous border effects. And the volatility of power exchanges in a market and consecutive parallel flows makes the border effects more and more critical for the network security. The unbundling of both the operation and the ownership of the network from the rest of the power supply chain may not be sufficient to solve them. Another solution is then to divest only the System Operator functions and to merge them over wide areas in a third party, an Independent SO or a Regional Transmission Organisation (ISO/RTO). It implies little change in the industrial structure. Indeed, this solution manages border effects through horizontal integration (Costello [2001], PJM [2004b]). For the rest of this paper, TOSO will refer to TSO that owns part or the whole network it operates while "asset-poor

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[4] If Transmission Ownership is not integrated with System Operation, Transmission Ownership can be bundled or not with another part of the power supply chain.

SO" will refer to TSO that owns no network asset and "TSO" will be used as a generic term referring without distinction to both cases.

Eventually, the wideness of order effects and the possibilities of modification of the industrial structure of the power supply chain frame transmission ownership unbundling.

III. A. 2. Transmission governance and incentive regulation

Transmission ownership unbundling has consequences on the governance and regulation of the transmission monopoly.

The governance of an asset-poor SO is a compromise between its regulation and the industrial structure of the power industry. Regulatory incentives are delicate to impose on an asset-poor SO, due to its small financial size. A self-regulated not-for-profit organisation can be an alternative to a for-profit one that is incentivised only on a part of the social cost of network externality (Barker *et al.* [1997]) and is still to be implemented. Indeed, the fair participation of network users in such organisation should ensure its neutrality and its *de facto* regulation if there is no risk of collusion or capture of the organisation by a group of interests. It is the typical stakeholder participation to the ISO governance in the USA.

On the contrary, the regulator can incentivise a TOSO on its controllable costs to set its monopoly price. The possible financial penalties from the incentive regulation have no severe consequences for the TSO's survival thanks to the tariffs revenues linked to its infrastructures.

To conclude, an asset-poor SO will be preferably not-for-profit self-regulated because it would be too dangerous to impose it a cost control through an incentive regulation. On the contrary, a TOSO may be incited thanks to the threat of financial penalties and rewards.

III. A. 3. Transmission governance and externality market design

As System Operator, a TSO is also the main architect of the market design as for power flows externality. Then, over transmission governance the consistency of governmental energy policy and political economy may interfere with power flows externality market design.

The market participants are not stakeholders of the System Operator in the case of a TOSO. Thus, they may be considered "only" as customers. Therefore, the TOSO also defending its own financial position influences the building of the network externality market design. Moreover, in the construction of a regional market, asset-poor SOs are less subject to incompatibilities of market designs since they are themselves regional coordinators and face little financial stake.

Beside its role of control vis-à-vis the TSO's costs, the regulator may have to take into account tradeoffs due to governmental energy policy ambiguity. For instance, efficient locational signals can penalise wind energy since windfarms are generally far from consumption and so require huge network investments. The regulator may also have to reach an agreement on redistribution of costs and benefits induced by any modification of market rules related to power flows externality (Pérez [2002 and 2004]).

To conclude, externality market design may be suboptimal depending not only on the transmission ownership unbundling but also on inconsistent governmental energy policy and political economy.

III. A. 4. Conclusion about the governance structure of transmission network

The governance of TSOs results in a compromise between its costs control, the market and coordination design. The capital assets of a TOSO allow for an incentive regulation but may interfere in market design and the coordination over various control areas and vice-versa an asset-poor SO may be easier to coordinate but harder to regulate.

III. B. INSTITUTIONAL COMPLEMENTARITY OF OPERATIONAL MODULES

Transmission governance sets compatibility constraints between the implementations of the TSO's missions. Aoki [2001] (and to some extents Pagano [1993]) calls these compatibility constraints "weak institutional complementarity". There is an institutional complementarity on the operational modules because some modules can be constrained in advance by transmission governance and may then constrain other modules. It is a weak institutional complementarity because there is several feasible sequences of modules.

We study three kinds of compatibility constraints that are significant in the context of a deregulated power system. But, other types of compatibility constraints may be found. First, a TSO must be easily incentivised to ensure an efficient operation and development of the network. Second, efficient locational signals have an increasing importance to allow coordination between the network users and the accommodation capacity in spite of network unbundling. Finally, an inter-TSO scheme must allow for an efficient use of the meshed nature of the transmission network.

III. B. 1. Compatibility between the externality management scheme and the network development in term of regulation and costs control

The externality management scheme must be carefully combined with transmission governance. The TSO indeed faces different incentives in managing and investing depending on its combination of externality management scheme and transmission governance since the externality management schemes can generate rent or cost. Besides, the evaluation of these combinations must also deem the robustness of the externality management schemes to the local market power since the local market power can mislead the network investment decision.

As regards the evaluation of the need for network investments, each scheme can be subject to a more or less wide use of local market power by reliability-must-run generators. Such behaviour can lead to an overestimation of the need for investments (Joskow-Tirole [2005]). The redispatch scheme is said to be more sensitive to these issues because the congestion cost is socialised (Harvey-Hogan [2000]). When and where the users of the network don’t bear the cost of externality, they may game it and significantly increase congestion cost (Green [2004]).

Although the nodal pricing scheme is efficient in inciting the dispatch of the network users and partly their locations, it gives counter-incentive signals for the TSO to invest. Indeed, a profit-maximising TSO basically compares the modification of the congestion rent following the investments with the investment costs and the O&M costs. Then, this scheme could entice a profit maximising TSO to make congestion last in order to maintain the congestion rent (Pérez-Arriaga *et al.* [1995]). Similarly, under a zonal pricing, the TSO faces an opportunism issue related to the collection of interzonal congestion rent while minimising the intrazonal congestion cost (Glachant-Pignon [2005]). Therefore, a TSO that manages network externality thanks to nodal pricing will require a more demanding regulatory scheme for the regulator to be sure the TSO’s objective of maximising profit is compatible with the objective of maximising the social surplus.

On the contrary, a congestion management scheme based on redispatch may be inefficient in dealing with short-run externality. But, the corresponding TSO directly faces the congestion cost from the short-run operation of the network and anticipates it from the connection requests. A profit-maximising TSO compares these congestion costs with the investment costs and the O&M costs. As mentioned above (in 0), this process approximates a social welfare maximisation since the congestion cost approximates the social cost of externality (Pérez-Arriaga – Smeers [2003]). The regulator can then easily check for the planning of investment for economic reasons to be compatible with the congestion costs. Nevertheless, the rules of the balancing market must ensure a tight management of the congestion cost to avoid congestion gaming (like Inc and Dec game) and other issues raised by local market power.

Whatever the market design chosen, a solution could be to incentivise the TSO on the deadweight loss. As a result, the regulator is sure to have an open access to this information. It is relevant since the TSO can access more related information than anybody else regarding this topic (Newbery *et al.* [2004]). Besides, it may solve a part of the local market power. However, one must keep in mind that only a TOSO can be incentivised on the socialised costs. Therefore, if the TSO is a self-regulated not-for-profit asset-poor SO, a nodal pricing is a better option, which does not prevent it from calculating the congestion cost from the market bids and offers in order to invest efficiently.

III. B. 2. A very limited compatibility of the externality management scheme and of the network development in term of locational signals

The allocation of network charges can incentivise the location of network users. But, the efficient location of network users may be contradictory with other goals of the governmental energy policy that require huge network investments. For instance, the allocation method of the network charges can be a shallow one to promote network demanding generation technologies such as wind farms, to ease the connection of new entrants in a new market area or to maintain a standardisation of tariffs in the TSO control area. As for the externality management scheme, not only it faces institutional complementarity from costs control, but also it is nevertheless insufficient in emitting long-term locational signals.

As regards the participation of the network externality management scheme in the incentive of the location of the network users, the nodal pricing is indeed more predisposed to the incentives since the nodal prices are *de facto* public data, whereas the redispatch scheme only provides price information to the redispatched units and so requires the publication of a kind of a public nodal dispatch. However, nodal prices only provide a local value of the network constraints, do not measure the impact of a new investment on the other nodes and may not be efficient as long-term locational signals. Even property rights such as Financial Transmission Rights (FTRs) (Hogan [1992]) are subject to such limitations unless the investor receives the algebraic set of created FTRs (Bushnell-Stoft [1997]).

Besides, nodal pricing does not provide enough revenues for the network cost recovery because of economies of scale all the more exacerbated by indivisibilities in network investments (Pérez-Arriaga *et al.* [1995]). Moreover, some externalities are not internalised in nodal prices, for instance network reliability or resource adequacy. Indeed, all these solutions cannot deal with either the network externality of the investments of generation and transmission or the indivisibilities of the network investments (Joskow-Tirole [2005], Smeers [2005]).

Therefore, a locational network tariff is necessary to deal with the locational indivisibilities of the network and the externality of the investments. The deep cost allocation method does not internalise positive externality of connections. The shallow cost allocation method only incentivises the network users to be near the core of the network. The zonal allocation method is a pragmatic solution and consists in keeping the non-discriminatory approach of socialisation and in incentivising the connection area of new users.

As regards the availability of the locational incentive signal, the network users can have to pay to know if they can connect and how much it costs since network studies are costly. In the case of shallow or hybrid allocation method, this information is generally cheap. On the contrary, the deep cost information is costly and only provided to connection requests. The availability of accommodation capacities can make this cost allocation method more auditable to the network users. However, such information can be hard to compute since the accommodation capacities of nodes are interdependent and may vary from connection request to connection request. If nodal accommodation capacities are available, they cannot be simultaneously feasible.

To conclude, the choice for the locational signals is rather limited. Whatever the choice of the externality management scheme, a tariff is needed to send a locational signal that internalise the indivisibilities and the externality of the investments. The provision of accommodation capacities ensures the allocation method to be more auditable to the network users. However these price and volume signals may have a limited impact on the location of the network users since the network users that can choose their location (producers and large consumers) are also constrained by their primary resources such as water, wind, coal, gas, etc…

III. B. 3. Compatibility between TSOs for coordination

We saw that transmission governance frames the individual schemes of each TSO for externality management and for long-term locational signals. As a result, the respective transmission governances frame the coordination either by standardisation if all the individual schemes are identical or by combination when the individual schemes are different.

However, some choice of standardisation may be better than others and ease the coordination because they provide more information. For instance, Cadwalader *et al.* [1999] envisioned coordination between nodal systems since quite a long time while coordination between redispatched systems is more demanding (Marinescu *et al.* [2005]). The coordination may then require an inter-TSO footbridge if the individual schemes completed by data exchanges are not enough. Such mechanisms already exists as for externality management schemes as for the standardisation of network tariffs: the acceptance of grand-fathering rights, the implementation of explicit auctions, or of inter-TSO compensation schemes (ETSO [2005]). Nevertheless, the methods that efficiently internalise not only internal loop flows but also border effects must be preferred for coordination.

Therefore, the coordination between TSOs in itself has also an organisational dimension. Indeed, each TSO's transmission governance structure must support coordination to modify the previous organisations. Otherwise, the TSOs may have difficulties in communicating necessary data and the modules may be unfitted as they may internalise only part of border effects.

With a competent supra-organisation (regulator or government) surrounding the parties to be coordinated, an evolution from a coordination by combination to a coordination by standardisation through the fitted modules is possible (Glachant-Lévêque [2005]). Otherwise, such a concerted mobilisation is highly improbable and hard to gather (Glachant *et al.* [2005]).

IV. EMPIRICAL ANALYSIS AND PRACTICAL RESULTS OF PJM AND NGC

The two TSOs PJM and NGC are compared to “an ideal first-best TSO” thanks to our common modular analysis and the study of institutional complementarity between operational modules. PJM and NGC are two references of TSOs in the context of a competitive wholesale power market but with quite opposite governance structures. Hence, this comparison would give us elements to understand the heterogeneity between the results expected from the TSOs’ management schemes and their observed results.

IV. A. STUDY OF PJM

IV. A. 1. Modular analysis of PJM

PJM is often quoted as an example to be followed for the creation and implementation of a system operator ruling wide areas. As for the module of externality management scheme, PJM uses a nodal pricing but only for congestion management. As far as the module of long-term development of the network is concerned, PJM must improve its economic criteria to justify network investments to take into account the whole set of relevant externality and to evaluate the risk of these investments. As for the module of coordination between TSOs, such a wide operator solves an important part of border effects. Besides, PJM easily coordinates with its neighbours.

IV. A. 1. a) The short-run management of network externality

PJM is the reference of the former FERC’s Standard Market Design, particularly in the Northeast USA, especially as for its congestion management scheme and associated hedging tools. Nonetheless, losses must be added in its pricing scheme to reach best practices of other RTO/ISOs.

Indeed, the nodal pricing system of PJM internalises only congestion. It is completed by an allocation of forward contracts to hedge locational volatility. There exist two complementary kinds of such forward contracts in the PJM system, Financial Transmission Rights (FTR) and Auction Revenue Rights (ARR). FTRs are auctioned to network users taking into account network constraints and give rights to receive a part of the congestion rent based on the price differential between a sink node and a source node. ARRs are allocated to Load Serving Entities (distributors) on the basis of their peak loads while taking into account network constraints. ARR can either be transform into FTRs or give rights to revenues from FTRs auctions (PJM [2005]).

Losses are not included in the nodal pricing scheme but managed thanks to fixed temporally differentiated rates. The socialisation of losses does not provide locational information about the impact of the network users' behaviour and does not incite to reduce losses. PJM as a system operator is not incentivised to reduce the amount of losses.

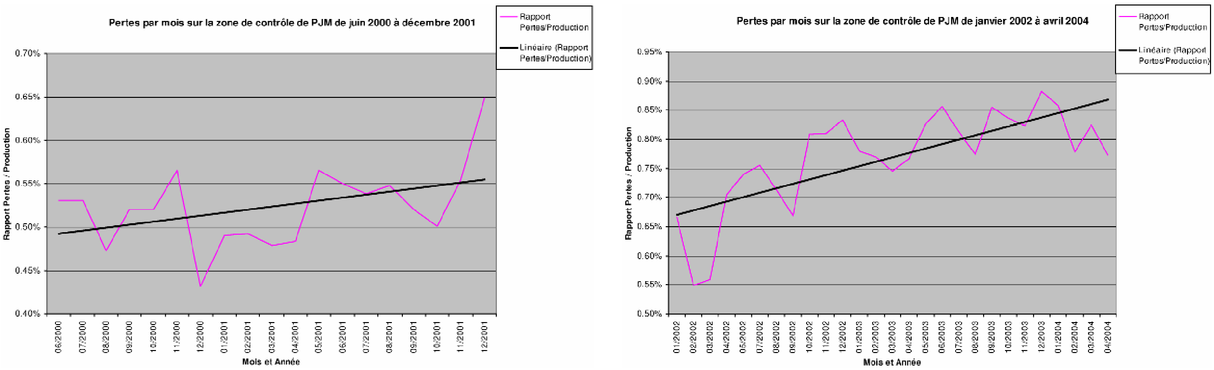

Figure 6 Evolution trends of EHV network losses vis-à-vis energy generation on the PJM control area from June 2000 to December 2001 and from January 2002 to April 2004 (own calculus from PJM data)

Nevertheless, power losses may become of great concern when the efficient use of energy is appearing in the political debate. The expansion of the PJM zone makes it difficult to analyse easily the evolution of networks losses. However, an analysis is possible when focusing on period when the PJM control area is geographically stable (see Figure 6). Thus, the increasing trend of losses on the PJM control area is quite noticeable at least on the EHV network[5].

To conclude, as for the externality management scheme, PJM is an example of an ideal first-best TSO for congestion pricing. But, at least, losses must be included in externality pricing to reach best schemes that are practiced by other RTO/ISOs. And the priority of "grand-fathering" transactions in its allocation of FTR/ARRs raises discriminatory concerns (PJM [2005] and see 0).

IV. A. 1. b) The long-term development of transmission network

As for the long-term development of transmission network, even if PJM is an asset-poor SO, it exists procedures to compel the Transmission Owners to develop their networks. Besides, PJM also guides network users' location as System Operator thanks to long-term signals.

As far as the network investments are concerned, the FERC manifested great care about the absence of comprehensive economic rationale in the decision process for network investments (FERC

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[5] It comprises transmission facilities from 350kV.

[1999], PJM [2004a]). PJM and other control areas of the Northeast of the USA such as NYISO[6] face an increase in congestion that seems related to a lack of network investments.

The gross congestion rent is indeed increasing on the PJM area. The geographical expansion of the PJM control area may explain it (see Chart 5) but it is more difficult to explain its augmentation vis-à-vis its energy consumption only by its geographical growth (see the black bars and the left scale on Figure 7). Before mid 2004, the network investments in the PJM areas were only made on security criteria without considering economic opportunity of new network investments.

Year	Congestion charges ($ million)
1999	53
2000	132
2001	271
2002	430
2003	499
2004	808

Chart 5 Evolution of the congestion rent ($ million) on the PJM control area from 1999 to 2004 (Source PJM [2005])

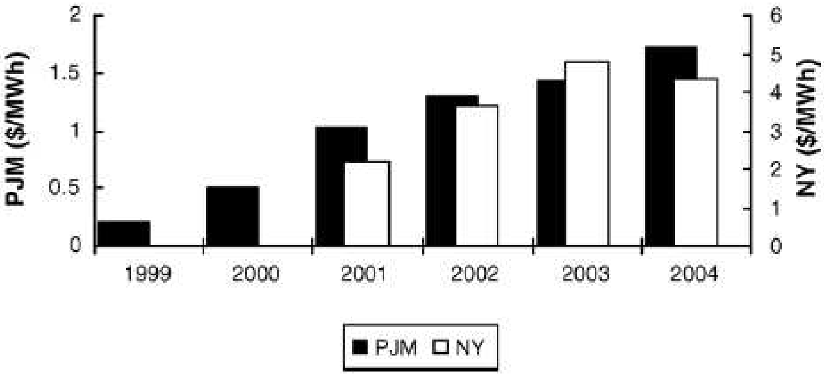

Figure 7 Evolution of the congestion rent on the PJM control area vis-à-vis the energy consumption from 1999 to 2004 (Rossignoli *et al.* [2005])

Since then, PJM has defined the concept of “Economic Planned Transmission Facilities” to develop the network of its control area on new criteria based not only on reliability but also on economic efficiency (PJM [2004a]). Before the definition of this new concept, the economic valuation of the network expansion was assumed to be done by market agents thanks to merchant transmission investments that receive the set of FTRs that the network project creates (PJM [2004a]). This idea is similar to the Hogan’s one [1992 and 2003] of a decentralised transmission market. Very few merchant transmission investments exist within the PJM area and within other RTO areas because they are very risky investments (Rious [2006]).

Regarding the 34 projects hence triggered after April 2004, a very high number of network investments even in a zone as wide as PJM, the need for such network investments is quite obvious. Furthermore, most of these investments have payback periods less than one year and some within few months (Joskow [2005a]).

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[6] New York ISO is the System Operator of the state of New York.

Nonetheless, this economic criterion seems quite odd. The arbitrage between short-run operation costs and investment costs is made without directly calculating congestion cost but estimating it thanks to FTR (Joskow [2005a], PJM [2004a]). Moreover, neither losses nor unsupplied energy are taken into account during the decision process. Investment decisions are eventually made thanks to a snapshot, ignoring dynamic effects and uncertainty about future flows (Hogan [2005]).

The long-term signals to guide the location of the network users are needed to limit the wideness of congestion on the network in this context. On the PJM system, the long term signals are both deep connection cost ones for the new generators and merchant lines connections and zonal use of the system tariffs for other investments. New generators or merchant lines bear not only the shallow direct connection assets but also network reinforcements when there are required by their connection. The deep cost allocation method lacks accommodation capacities to be auditable to transmission-poor investors such as IPP. Nonetheless, the mix of the deep cost allocation method and the bundling of incumbents with transmission assets can be an entry barrier to the transmission-poor investors. All other network reinforcements are socialised over the corresponding utility areas and so generate a *de facto* zonal use of system tariffs through the integration of utility areas into PJM. The use of the system tariff is partly based on non coordinated bundled tariffs fixed by the state regulators and on utilities' requirement for the use of their networks by the wholesale market (Joskow [2005b]). Even if it is not of great concern since the Use of the System tariff is only from 4% (ComEd zone) to 7.1%[7] (Rockland zone) of the energy price for the year 2004 and only paid by consumers, there may be no coherence between the network accommodation capacity and the use of the system tariff of the utility area.

To conclude, the long-term development of the PJM transmission network is evolving but is still to be improved to approach the first-best solution. The economic criteria for network investments must be refined to deal with losses, the economic value of unsupplied energy and uncertainty. Zonal tariffs defined by PJM on its area and not by the state regulators would allow a best internalisation of

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[7] Here, the CESI [2003] example of a representative consumer with an installed capacity of 2.5MW consuming 10GWh a year is used. The mean price in the ComEd zone in 2004 was 30.61$/MWh and the mean price of the Rockland zone was 45.20$/MWh.

externality in the network users' location decisions. The deep cost allocation method combined with the incumbents generators owning transmission networks can stand for an entry barrier to the independent producers.

IV. A. 1. c) The coordination between TSOs

As for the coordination with its neighbours, the PJM control area is crossed by a lot of loop flows from the Midwest export area to the east import areas such as NYISO and TVA[8] (DoE [2002]) and so the internalisation of border effects is of interest.

The loop flows raise some problems of security and inefficiency because of a lack of internalisation of externality and border effects. The integration of the large utility area of Allegheny Power (PJM [2004b]) shows that the management of these effects may greatly modify the pattern of flows and that PJM is used to managing such situations. Similarly, the creation of Midwest ISO from the PJM model without a historical tight pool shows that the ISO/RTOs are coordinators upon utilities' network to provide a non-discriminatory open access to network on a wider wholesale market area.

Besides, PJM has recently signed joint agreements with two other control areas, Midwest ISO[9] and TVA (MISO-PJM-TVA [2005], and MISO-PJM [2005]) in order to couple their system operation and their regional transmission expansion plans. The project of coordination of real-time markets of ISO-NE[10] and NYISO [2003] confirms that the ISO/RTOs can coordinate quite easily.

To conclude as for the coordination between TSOs, RTO/ISOs are foreseeing or implementing first-best solutions at least for System Operation to manage border effects. As for coordinated interconnector investments, the shallow cost allocation method, implemented in some areas and more broadly promoted by the FERC, may raise issues about the implementation of compensation schemes between zones. PJM does not face such issues thanks to deep connection costs.

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[8] TVA is a public power authority that generates and transmits power in the Tennessee Valley.

[9] MISO is the System Operator that manages transmission system of 15 states of Middle West and 1Canadian province.

[10] ISO-NE is the System Operator that manages transmission system of the states of New England.

IV. A. 1. d) Comparison of PJM to the ideal first-best TSO

We compare PJM to the ideal first-best TSO in the following chart.

Chart 6 Evaluation of the implementations of the missions of PJM as a TSO

Missions of TSO	Implementations	First-best choice?	Comments
Externality management scheme Congestion	Nodal pricing, FTR/ARR	Yes	Discriminatory allocation of ARR and FTR
Loss	Fixed rate	No	Nodal pricing discussed
Network long-term development Investment	Threshold criteria	No	recent, no loss cost, no risk assessment
Tariffs	Deep cost for new investments Artificially zonal UoS tariffs	Partially	No accommodation capacity
Coordination	Standardisation	Yes	

IV. A. 2. Compatibility of the modules of the network management of PJM

RTO/ISOs were created because the FERC cannot modify the ownership structure of the power industry. Such organisations are spread over wide areas because of the wideness of border effects. They are not-for-profit self-regulated because asset-poor SOs are difficult to incentivise. Therefore, transmission governance frames the weak institutional complementarity between operational modules.

IV. A. 2. a) Clarity of regulation

The reform of power industry in the USA faces up against the dual structure of its regulation. The FERC is the federal regulator and there are fifty state regulators called the Public Utilities Commissions. The FERC and the PUCs do not have hierarchical links and does not either rule the same fields of power industry or have the same view about deregulation. It makes the deregulation process more difficult for the FERC to implement.

The deregulation process is mainly monitored by the FERC whose jurisdiction is limited to interconnected wholesale markets and corresponding transmission issues. However, entry into deregulation differs from state to state where the jurisdiction of PUCs still covers retail market and vertically bundled transmission assets.

The dynamic of the deregulation process is then quite inhomogeneous and largely incompatible with the numerous border effects (Joskow [2005b]). Therefore, achieving a unified wholesale market may not be ensured without the thorough participation of the transmission network.

The FERC [1999] tried to overpass these obstacles thanks to Order 2000. It requires the transmission owning utilities to join and transfer the operation of the network to Regional Transmission Organisations (RTOs). Such entities were to be responsible, among other things, of system operation and of the coordination of a regional planning process. In particular, PJM became an RTO in 2002.

Although, the FERC were unable to impose full transmission unbundling to the power industry, it achieved success in providing a non-discriminatory open access to transmission network through the unbundling of system operation only.

IV. A. 2. b) The structure of governance of transmission network

RTO/ISOs control wide areas to internalise wide border effects between the utility areas. Their asset-poor not-for-profit structure permits a kind of self-regulation by stakeholders. However, an overrepresentation of generators or bundled generators-distributors-suppliers in the governance structure can undermine the control of the SO cost and so the control of network investments.

In the USA, System Operators that control wide power areas are necessary at the time of deregulation because volatility of power exchanges highlight the border effects between the numerous utility areas. The USA power network is indeed balkanised with around 400 utilities and 100 control areas (Pérez-Arriaga - Olmos [2005]). In this context, loop flows are numerous. And the market volatility is making the border effects more and more critical for the network security. Transmission Load Relief, a procedure to relieve congestion on interconnector between adjacent control areas thanks to the interruption of bilateral contracts crossing it is indeed more and more often activated (Joskow [2005b]). Therefore, the FERC was more concerned about creating operators over wide areas to deal with border effects than about divesting transmission that would not have resolved this critical issue.

So RTO/ISOs are asset-poor SOs. Costs control is then hard to impose because their revenues are not ensured thanks to a regulated asset base. Therefore, an incentive regulation on system operation would be far too more dangerous for their survival. Moreover they are generally not-for-profit organisation. However, they are monopoly and so must be regulated. RTO/ISOs are self-regulated thanks to sophisticated structures of governance to represent fairly each group of stakeholders.

The fair representation of the network users is questioned in the ISO/RTOs. An overrepresentation of the generators is common among ISO/RTOs (Boyce-Hallis [2005]). ISO/RTOs may then act under an unclear political pressure from different lobbying groups. In particular, generators prefer congested networks to use local market power.

To conclude, network operators must deal with wide border effects and so can be only implemented as asset-poor SOs because of the dual regulatory structure. Incentive regulation cannot then be used to control the costs of system operation but self-regulation may not ensure costs control because of an overrepresentation of producers.

IV. A. 2. c) Weak institutional complementarity of operational modules

The governance and regulation of PJM dictate institutional compatibility between the implementation of operational modules that are eventually designed and the achievement of three key goals that are costs control, locational signals and coordination between TSOs.

As for compatibility requirement imposed by costs control of transmission, asset-poor self-regulated SOs faced gaming issues and cost control of congestion in the late 1990's while trying to manage congestion thanks to zonal pricing and redispatch. In particular, PJM engaged itself in 1998 into implementing nodal pricing in its control area. The nodal pricing is the short-run network externality management scheme the more appropriated to asset-poor SO such as PJM. Its not-for-profit structure makes it indifferent to the counter-incentive effect of the congestion rent.

Nevertheless, congestion raised regulatory concerns until the implementation of the concept of Economic Planned Transmission Facilities in 2004 because economic opportunity of network investments was not considered by PJM planning. Even if this concept has some flaws, it is a first step for an asset-poor SO to manage the network development in the long term.

Besides, nodal pricing induces huge distributional changes (Kirsch [2000]). FTRs were first allocated to limit these effects and ARRs were created because of some complaints of FTR rights pre-emption by incumbents (Shanker [2003]). This issue of political economy is evolving with the redesign of the FTRs market but there are still regulatory concerns about the priority given to historical transactions (PJM [2005]) that can limit the efficiency of nodal pricing.

As for compatibility requirement imposed by the provision of locational signals, the nodal pricing and the deep cost allocation method for the producers are the only relevant locational signals. As for the short-run locational signals, losses are not yet integrated in the nodal pricing because PJM surely thought that it was a secondary issue while PJM was focused on its zone extension and the integration of neighbouring utilities. As for the long term locational signals, the deep cost allocation method cannot internalise the positive externality of some connections. Besides, the deep cost allocation method can be an entry barrier to the connection of new entrants since the incumbent generators still own most of the network. Accommodation capacities on the PJM system could make the cost allocation method more transparent and so reduce the entry barrier for the independent producers.

As for compatibility requirements imposed by coordination between TSOs, the FERC's Standard Market Design displays a framework that allows for a coordination by standardisation between RTOs and similar organisations at least for System Operation. FERC preferring shallow costs allocation method raises compensation issues between coordinating parties as for interconnectors. PJM does not face such dilemma thanks to deep connection costs.

IV. A. 2. d) Conclusion about PJM

The institutional complementarities that account for the implementations of the PJM modules can be summed up as follow:

Chart 7 Institutional complementarities of the PJM system

Key goals	Concerned modules	Implementations	Institutional complementarity imposed by
Costs control	Externality management 1. Congestion	Nodal pricing	Transmission governance of asset-poor SO
		FTR/ARR	Political economy for FTR/ARR allocation
	2. Loss	Fixed rates	Political economy, unfitted to transmission governance with an increase of losses
	Network Development a) Investments	Systematic criteria	Transmission governance of asset-poor SO
Locational signals	Externality management	Nodal pricing	1 and 2
	Network development b) Tariffs	Deep cost and Zonal UoS tariffs	Locational signals to be provided despite legacy of past industrial structure
Coordination	Externality management	1 and 2	1 and 2
	Network development	a) and b)	a) and b)
	Coordination	Standardisation	Adapted nodal methods, Standard Market Design (FERC) over the coordinated parties

IV. B. STUDY OF NGC

IV. B. 1. Modular analysis of NGC

Despite its flawed externality management scheme, the operation cost of NGC is under control. The network investments are satisfactory, that is to say consistent with the regulation and the need of the wholesale market. Besides, the zonal use of the system tariff progressively has a contrasted impact on the location of the network users. The coordination with its neighbouring TSOs seems to be a secondary problem because of its network topology that is little meshed.

IV. B. 1. a) The short-run management of network externality

The externality management scheme of NGC has been criticised for its theoretical inefficiency. But, it is admired for its results as much for congestion as for losses. The externality cost is a shared financial responsibility of generators and consumers on the basis of 45/55 without locational signals to internalise externality while NGC is incited to reduce this cost thanks to incentive regulation that is now called System Operator regulatory scheme. This incentive system prompts NGC to manage congestion and loss jointly with the schedule of maintenance operation

Congestion is managed thanks to redispatch since the beginning of power market in England and Wales from the UK Pool to the NETA (and even to the BETTA) despite its well-known flaws especially noticed in the UK Pool. Nonetheless, the introduction of an incentive system in 1994 and the possibility to arbitrate between different marketplaces (NGC [2004a]) has allowed to reduce significantly the redispatch cost (see Figure 8).

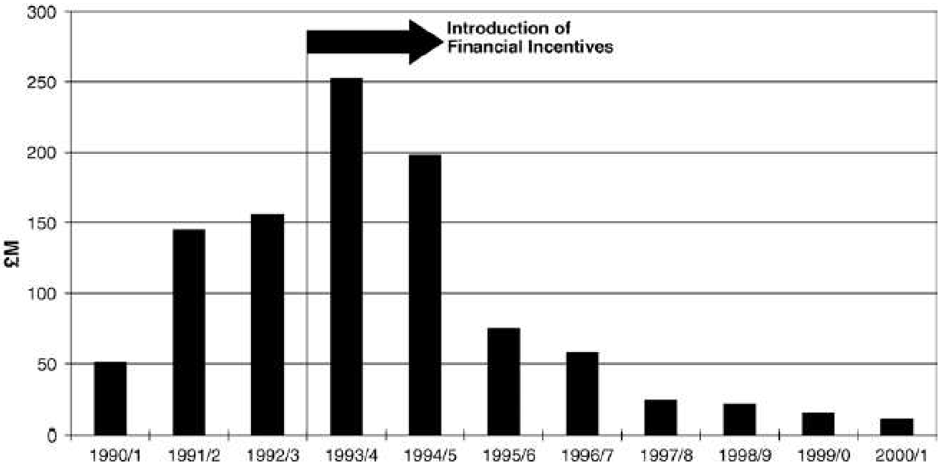
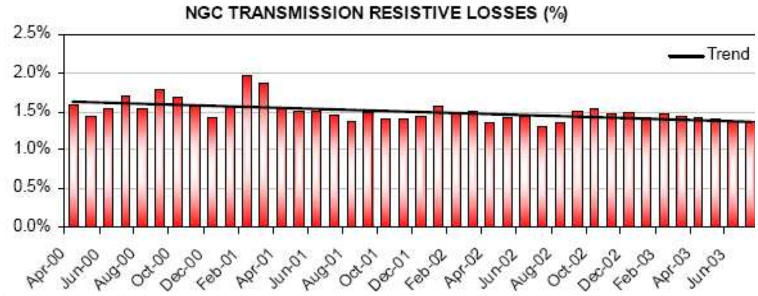


Figure 8 Evolution of redispatch cost on the NGC network (Rossignoli *et al.* [2005])

NGC manages congestion on a medium-run basis over various months. The regulatory scheme consists as much in incentivising the TSO to improve the schedule of its operation as to reduce the market power in itself. Indeed, NGC anticipates the flow patterns thanks to the availability of generators. NGC can modify its schedule of maintenance operation to arbitrate between the cost of maintenance and the cost of congestion (Brunekreeft *et al.* [2005]). NGC can also contract an option with potential reliability-must-run generators (NGT [2005a]) to reduce its exposition to a local market power.

Losses are uniformly allocated to all network users without deeming their location thanks to Estimated Transmission Losses Adjustments rates. Meanwhile, NGC is incited to manage the amount of losses optimising the topology and the voltage plan. As a result, although the network users do not know their locational influence on losses and thus are not incentivised to reduce power losses, we notice a decreasing or at least stable trend of losses.



Source: NGC

Figure 9 Losses on the NGC's network and trend (Joskow [2005a])

To conclude, as for the externality management schemes, the theoretical flaws of the methods used by NGC are compensated by incentives schemes to reach efficient System Operation.

IV. B. 1. b) The long-term development of the transmission network

As for the long-term development of transmission network, NGC must not only invest since it owns network but also guides network users' location as System Operator.

Two complementary regulatory budget constraints, a short-run one and a long-term one frame network investments. The short-run regulatory budget constraint is the incentive system related to System Operation mentioned in IV. B. 1. a). It prompts NGC not only to manage externality jointly with the schedule of maintenance operation but also to arbitrate between the short-run and medium-run operation costs and some small-scale network investments that have short paybacks. The long-term regulatory budget constraint imposed on the network investments called the Transmission Owner regulatory scheme is a RPI-X regulation. As we will show it afterwards, these budget constraints coupled with the governance of the TSO are normally enough to ensure satisfactory network investments.

This set of policies seems to prove to be efficient whereas the OFGEM [2004a] guidelines concerning the economic justification of network developments are quite fuzzy and NGC [2004b] (see also OFGEM [2004a]) justifies the network development more by engineering criteria. The operation costs decrease (Figure 8 and Figure 9) and the investments are made while respecting the regulatory contracts (OFGEM [2004b]). The level of the RPI-X regulation seems quite well set since efficiency gains allow to reduce controllable costs by more than half in a decade (see Figure 10), while there was a 40% reduction of transmission cost (NGT [2005b]).

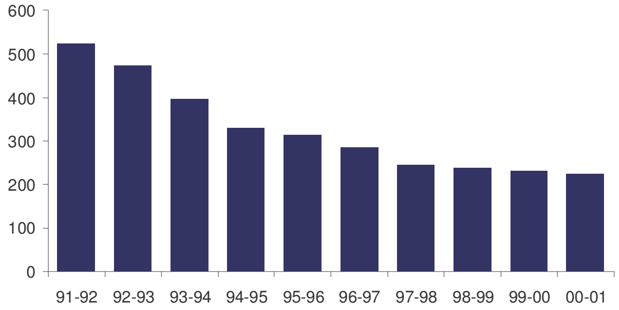


Figure 10 Controllable operating costs (£m) on the NGC's network (NGT [2005b])

As for long-term signal, the incitement to an efficient location of the network users may need to be improved. A zonal tariff introduced in 1994 at the time of the dash for gas completes this scheme in order to compel the generators to arbitrate between the cost of transporting their primary energy and the cost of connecting to the power transmission network, Some importing zones have negative tariffs to attract new connections of generators.

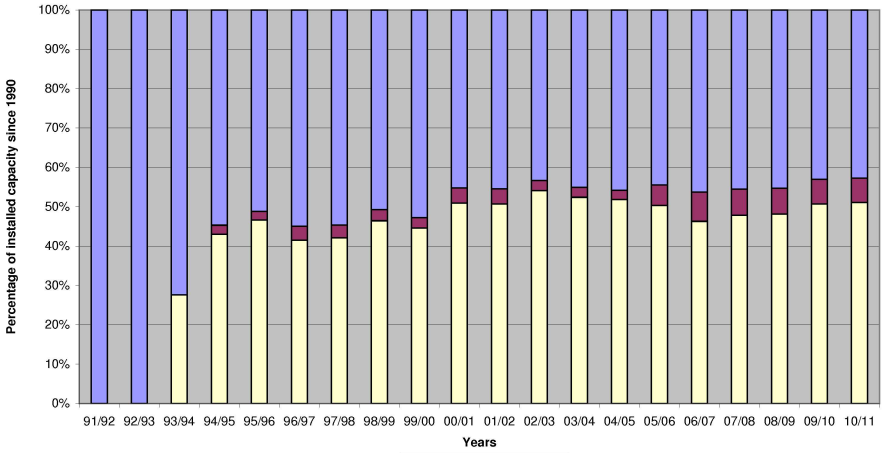


Figure 11 Cumulative dispositions of new capacities since 1990 (own calculus – data from NGC [2004b])

The results of the zonal tariff are quite mixed as shown on the Figure 11. A majority of the connections is in the South part of the NGC network but there are still a lot of connections in the North part of the NGC network despite the tariff differential. With a mean energy price of 25£/MWh, the maximum tariff differential stands for 11%[11] of the energy price. With the same hypothetical consumer as before, the maximum tariff differential reaches 13%.

To conclude, even if economic criteria must be more clear and explicit for NGC to be nearer of the ideal first-best TSO, network investments are satisfactory as regards decreasing system operation costs and respects of the Transmission Owner regulatory scheme. As for long term signal, the impact of zonal tariffs is not very conclusive.

IV. B. 1. c) Coordination of TSOs

As for coordination with its neighbours, the NGC control area is crossed by few loop flows and so border effects are secondary issues.

The flow through the interconnector between France and England could be independently adjusted because it is a DC one. And even the Scottish interconnector is quite easy to tackle because of its radial nature. Therefore, NGC faces few border effects from its neighbouring TSOs. Then the coordination schemes are quite basic. The interconnector between France and England is only managed thanks to pay-as-bid explicit auction. The Scottish interconnector is managed thanks to a predefined share of the interconnector between the users mainly Scottish Power and Scottish and Southern Energy without the provision of any scarcity signal. The NGC's ability of coordination as the British System Operator might be challenged as the BETTA goes alive and extends the NGC control area to the Transmission Owners Scottish Hydro-Electric Transmission Limited and SP Transmission Limited.

To conclude, even if the border effects that NGC encounters do not require much coordination, coordination could be improve by using more oriented and integrated market solutions such as marginal pricing and market coupling solutions. Nevertheless, the cost of implementation may be greater than the benefits of coordination since NGC faces few border effects.

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[11] Here, we consider the CESI [2003] example of a representative producer with an installed capacity of 400MW consuming 2.5TWh a year.

IV. B. 1. d) Comparison of NGC to the ideal first-best TSO

The implementations of the missions of NGC as a TSO can be summed up in the following chart and compared to the ideal first-best TSO.

Chart 8 Evaluation of the implementations of the missions of NGC as a TSO

Missions of TSO	Implementations	First-best?	Comments
Externality management scheme Congestion	Redispatch	No	But decreasing trends thanks to incentive regulation
Loss	Fixed rate	No	
Network long-term development Investment	Mainly engineering criteria Fuzzy economic criteria	Near	But good results thanks to incentive regulation
Tariffs	Zonal use of the system tariffs Zonal accommodation capacities	Near	
Coordination	Combination	No	But little need of coordination

IV. B. 2. Compatibility of the modules of the network management of NGC

A quite clear regulation allows for an in-depth modification of the industrial structure of power industry with a full transmission unbundling. Transmission Owner and System Operator being the same entity allows to frame the monopoly activity thanks to a performance-based regulation without jeopardising its financial survival. Therefore, incentive regulation allows to attenuate the suboptimal choice of operational modules imposed by political economy.

IV. B. 2. a) Clarity of regulation

The hierarchical arrangement between regulatory agencies has made the full transmission unbundling easier to reach. It not only allows for a non-discriminatory open access of transmission network but also is the ground of transmission governance.

The link between the different regulatory organisations that frame the activity of NGC, that is to say mainly the energy regulator OFGEM and the European Commission and to a lesser extent the DTI, is hierarchical. The DTI must transpose the European Commission Directives in the national laws that must then be enforced by the OFGEM. The principle of subsidiarity can lead to divergence between the European and the national level and the principle of independence of regulation vis-à-vis government can lead to divergence between the transposed laws and its enforcement. Both cases of divergence are seldom or not public in the United Kingdom since it is often referred as a reference of power deregulation in Europe.

Clear regulatory relations allow for discretionary decisions about the industrial structure and particularly transmission network in order to ensure competition and non-discriminatory open access of transmission network.

IV. B. 2. b) The governance structure of transmission network

The deregulation of the English and Welsh power industry resulted in the transmission unbundling. Therefore, NGC is a private independent TOSO that controls the power network of England and Wales. The transmission ownership of NGC then allows the regulator OFGEM to use incentive schemes.

The ownership of the network by the System Operator allows for an efficient development of the network for two reasons. First, the revenue from the network ownership ensures that financial penalties on either the SO or TO regulatory scheme would not jeopardise the survival of the TSO. Second, the association of the SO and TO regulatory schemes guarantees the arbitrage between short-run and medium-run operation costs and larger-scale network investments (Joskow [2005a]). The SO regulatory scheme entices NGC to arbitrate between short-run operation costs and small-scale investments with short payback. The TO regulatory scheme entices NGC to arbitrate between small-scale and large-scale investments all the more that there are economies of scale in developing the transmission network and that the budget constraints can be renegotiated with the OFGEM in the next regulatory period.

To conclude, a profit maximising TOSO can minimise operation costs and reach a satisfactory network costs under the pressure of well-designed financial regulatory incentives.

IV. B. 2. c) Weak institutional complementarity of operational modules

The governance and regulation of NGC dictate institutional compatibility between the design of operational modules and the achievement of three key goals that are costs control, locational signals and coordination between TSOs.

As for compatibility requirement imposed by costs control of transmission, the governance structure of TOSO of NGC allows for an incentive regulation to reduce operation costs and control investments costs and even to compensate the theoretical flaws of suboptimal schemes such as redispatch.

As for compatibility requirement imposed by the provision of locational signals, a nodal pricing could have been more advantageous (Green [2004]) in sending appropriated economic signals to the market actors to limit the extent of externality. However, at the time of (re)designing the English and Welsh power market, the consumers that are mainly in the South feared that their bill increased and the generators that are mainly in the North feared that their revenues decreased while the network would have the rent (Green [1997], OXERA [2003]). A zonal tariff is used to reduce the entry barrier on network demanding generators (Hiroux [2005]) while taking into account a degree of cost causality. First, such a tariff prevents the allocation method from being far too discriminatory (Green [1997]) as regards a deep cost approach. Second, it is part of a policy to promote the Renewable Energy (OFGEM [2003]) and it may have been justified at the beginning of the deregulation to limit the entry barriers to new entrants.

As for compatibility requirements imposed by coordination between TSOs, it is of little concerns in the case of NGC not only because of the topology of the NGC network but also because of the organisational barriers. The pay-as-bid structure of the auctions of the France-England interconnector may be hard to change to reach ideally a coupling between France and Great Britain. Indeed, this interconnector is a separate merchant business out of the scope of the OFGEM (Joskow [2005a]) and changing the related allocation method may reduce the profit that NGC earns from it. The flow on the Scottish interconnector was quite predictable, on top from Scotland to England because of the overcapacity of the Scottish energy producers. The industrial structure of the Scottish power industry also impacts it since there are only two power companies Scottish and Southern Energy and Scottish Power. Then, the access to the Scottish interconnector would not be very competitive under an auction, which justifies the use of administrated rules. This is consistent with the Scottish interconnector now being part of the British system operation and then being managed thanks to redispatch.

IV. B. 2. d) Conclusion about NGC

The institutional complementarities that account for the design of the NGC modules can be summed up as follow:

Chart 9 Institutional complementarities of the NGC system

Key goals	Concerned modules	Implementations	Institutional complementarity imposed by
Costs control	Externality management 1. Congestion	Redispatch	Political economy (Producers in the North and Consumers in the South)
	2. Loss	Fixed rate	
	Network development a) Investments	Engineering criteria	Transmission governance of TOSO adapted to incentive regulation
Locational signals	Externality management	Redispatch	1 and 2
	Network development b) Tariffs	Zonal tariffs	Locational signals but connection of network demanding generator
Coordination	Externality management	1 and 2	1 and 2
	Network development	a) and b)	a) and b)
	Coordination	Combination	No need in general A concentrated industrial structure for Scottish Interconnector

IV. C. CONCLUSIVE COMPARISON OF PJM AND NGC

There is not really a better way to be away from an "ideal first-best" TSO since each context is peculiar and the job to be done is mainly determined by the configuration of the network, its incumbent capacity and regulation. The NGC control area is a peculiar case because of the insularity of Great Britain. Hence, NGC does not face the common European conflicts of interests between coordination of neighbouring control areas and financial stakes of developing the national networks. Therefore, coordination is only a secondary issue to NGC while the network development is its core activity. In the USA, the System Operators (in particular PJM) are regional coordinators and the network development was only a secondary issue let to the market actors without any success. As the coordination is a solved issue in the PJM area, the network development is becoming of importance to avoid a market balkanisation.

V. CONCLUSION

Our modular analysis framework that gathers the operational TSO's missions as for the management of the flows on its network and completed by the organisational structure of transmission demonstrates that the institutional context and the regulatory policies imply compatibility requirements on the design of the network management schemes.

Our empirical analysis concludes in a quite opposite way than other drastic views (Boucher-Smeers [2001], Ehrenmann-Smeers [2005], Hogan [2003]). Some network management schemes may be inefficient compared to an ideal first-best TSO but relatively efficient regarding the institutional context surrounding their design, all the more regulation may limit inefficiency in some cases. There are two reasons to this statement. First, the institutional context can limit the set of feasible network management schemes in such way that only inefficient solutions can be implemented. Indeed, institutional constraints must not be considered as secondary ones but as the ground of the implemented network management schemes. Secondly, regulation can complete these inefficient management schemes in an efficient way to reach unexpected satisfactory results by providing the good incentives to the appropriated actors and/or by imposing the relevant criteria. Therefore, even inefficient implementations of network management schemes must be deemed and studied because they may be the only ones to be possible given the context. Hence inefficiency could be measured rather than noticed from more or less painful experiences. Complementary rules could then be designed to limit its undesired effects.

However, the efficient solutions are still the target to be reached (Boucher-Smeers [2001], Ehrenmann-Smeers [2005]) thanks to the relevant institutional ground or its modification since they may ease the creation of wide market areas. Meanwhile, in the context of a meshed power transmission network and of a subsidiarity, the windows of feasibility of such simultaneous modifications are short and limited (Glachant *et al.* [2005]). As a consequence, this anticipation of continuation of inefficient solutions makes the study of suboptimal management schemes such as Pérez-Arriaga - Olmos [2005], Marinescu et al. [2005], or ETSO-Europex [2004] more necessary.

REFERENCES

Aoki M. (2001), *Towards a comparative institutional analysis*, MIT Press, Cambridge

Baker J. Jr., Tenebaum B., Woolf F. [1997], “Governance and regulation of power pools and system operators. An international comparison”, Worldbank

Bjørndal M., Jørnsten K. [2001], “Zonal Pricing in a Deregulated Energy Market”, The Energy Journal, 22(1), 51-73

Boucher J., Smeers Y. [2001], “Towards a common European Electricity Market-Paths in the right direction… still far from an effective design”, Journal of Network Industries, 3(4), 375-424

Boyce J. R., Hallis A. [2005], “Governance of electricity transmission systems”, Energy Economics, 27(2), 237-255

Brunekreft G., Neuhoff K., Newbery D. [2005], “Electricity Transmission: An overview of the current debate”, Utilities Policy, 13(2), 73-93

Bushnell J., Stoft S. [1997], "Improving private incentives for electric grid investment", Resource and Energy Economics, 19(1-2), 85-108.

Cadwalader M. D., Harvey S. M., Hogan W. W.; Pope S. L. [1999], "Coordinating congestion relief across multiple regions", http://ksghome.harvard.edu/~whogan/

Caramanis M., Bohn R., Schweppe F. [1982], "Optimal Spot Pricing: practice and theory", IEEE Transactions on Power Apparatus and Systems, 101, 3234-3245

CESI, [2003], "Implementations of short and long term locational signals on the Internal Electricity Market", report for Eurelectric, www.eurelectric.org, December

Costello K. W. [2001], "Interregional coordination versus RTO mergers: a cost-benefit perspective", The Electricity Journal, 14(2), 13-24

Department of Energy (DoE) [2002], "National Transmission Grid Study", may

Ehrenmann A., Smeers Y. [2005], "Inefficiencies in European congestion management proposals", Utilities policy, 13(2), 135-152

European Commission (EC) [2004] "Strategy paper: Medium term vision for the internal electricity market". DG Energy and Transport Working Paper, march

ETSO [2005], "The current ETSO ITC model and possible development",

ETSO-EuroPEX [2004], "Flow-based Market Coupling: A joint ETSO-EuroPEX proposal for cross-border congestion management and integration of electricity markets in Europe. Interim Report"

FERC [1999], "Regional Transmission Organizations. ORDER n° 2000, Final Rule, Docket No.RM99-2-000", www.ferc.gov

Glachant J-M., Lévêque F. [2005], "Electricity Internal Market in the European Union: What to do next?", CEEPR Working Paper

Glachant J-M., Pérez Y., Pignon V., Saguan M. [2005], "Un marché européen de l'électricité ou des marchés dans l'Europe ? Regards croisés : économistes et ingénieur", Droit de la régulation et l'économie, Annales de l'UMR, André TUNC, Université Paris I, May (in French)

Glachant J-M., Pignon V. [2005], "Nordic congestion's arrangement as a model for Europe? Physical constraints vs. economic incentives", Utilities Policy, 13(2), 153-162

Green R. [1997], "Transmission pricing in England and Wales", Utilities Policy, 6(3), 185-193

Green R. [2003], "Cost recovery and the efficient development of the grid", in François Lévêque (Ed.) Transport Pricing of Electricity Network, 137-153

Green R. [2004], "Electricity Transmission Pricing: How does it cost to get it wrong", CEEPR Working Paper

Harvey S., Hogan W. W. [2000], "Nodal and zonal congestion management and the exercise of market power", http://ksghome.harvard.edu/~whogan/

Hogan W. W. [1992], "Contract networks for electric power transmission", Journal of Regulatory Economics, 4(3), 211-242

Hogan W. W. [2003], "Transmission market design", Electricity Deregulation: Where to From Here? Conference at Bush Presidential Conference Center, Texas A&M University, 4 April

Hogan W. W. [2005], "Market design failures and electricity restructuring", presentation at The Economics of Electricity Markets Conference, IDEI Toulouse, 2 June 2005, http://idei.fr

Hiroux C. [2005], "The Integration of Wind Power into Competitive Electricity Market: The Case of the Transmission Grid Connection Charges", 28th annual IAEE international conference, Taipei, June 3-6

ISONE, NYISO [2003], "Virtual Regional Dispatch: concept, evaluation and proposal", Joint working paper ISO New England, Inc., New York ISO, Inc.

Joskow P. [2005a], "Patterns of transmission investment (and related issues)", Electricity Infrastructure Investment Workshop, CRE, Paris, France, March

Joskow P. [2005b], "Transmission Policy in the United States", Utilities policy, 13(2), 95-115

Joskow P., Tirole J. [2005], "Merchant Transmission Investment", Journal of Industrial Economics, 53(2), 233-264

Kirsch L. D. [2000], "Pricing the Grid: Comparing Transmission Rates of the U.S. ISOs". Public Utilities Fortnightly, February 15, 30-42

Marinescu B., Coulondre J-M., Tsamasphyrou P., Bourmaud J-Y. [2005], "Improving TSO's coordination for cross-border redispatch: a discussion of possible approaches in the European context", 2nd CIGRE/IEEE PES International Symposium Congestion management in a market environment, San Antonio, October 5-7

MISO-PJM [2004], "Joint Operating Agreement", www.pjm.com

MISO-PJM-TVA [2005], "Joint reliability coordination agreement", www.pjm.com

Newbery D., Green R., Neuhoff K., Twomey P. [2004], "A review of the monitoring of market power: The possible role of TSOs in monitoring for market power issues in congested transmission systems", report prepared for ETSO (www.etso-net.org)

NGC, [2004a], "Balancing Principles Statement", October

NGC, [2004b], "Seven Year Statement"

NGT, Carlton J. [2005a], "Investment in transmission", presentation at the Conference of Economics of Electricity Markets, IDEI Toulouse, 2 June 2005

NGT, Martin T. [2005b], "Benefit of transmission focused development", presentation at the 2005 Energy Roundtable, May 31, www.energyroundtable.org

OFGEM [2003], "Transmission Investment and Renewable Generation. Consultation Paper", October, www.ofgem.gov.uk

OFGEM, [2004a], "Planning and operating standards under BETTA, An Ofgem/DTI conclusion document Volume 2", September

OFGEM [2004b], "Extending the National Grid Company's transmission asset price control for 2006/07. Initial consultation", May

OXERA [2003], "The impact of the average zonal transmission losses applied throughout Great Britain", study for the DTI, June

Pagano U. (1993), "Organisational equilibria and institutional stability", in Bowles S., Gintis H., Gustafson B. (Eds.) *Market and Democracy*, Cambridge University Press, Cambridge

Pérez Y. [2002], "L'économie néo-institutionnelle des réformes électriques européennes, Thèse de l'Université Paris 1 Panthéon-Sorbonne", in French

Pérez Y. [2004], "L'attractivité des réformes électriques, un problème de mesure ?" in Saboly & Cailluet (Eds.) Mesure(s), Presses de l'Université de Toulouse, in French

Pérez-Arriaga I. J., Rubio F. J., Puerta J. F., Arceluz J., Marin J., [1995], "Marginal Pricing of Transmission Services: an analysis of cost recovery", IEEE Trans. on Power Systems, 10(1), 546-553

Pérez-Arriaga I., Smeers Y. [2003], "Guidelines on tariff settings", in François Lévêque (Ed.) Transport Pricing of Electricity Network, 175-203

Pérez-Arriaga I. J., Olmos L. [2005], "The plausible congestion management scheme for the internal electricity market of the European Union", Utilities policy, 13(2), 117-134

PJM [2004a], "PJM FERC Filing in Docket Number RT-01-2-01", www.pjm.com, April

PJM [2004b], "State of the Market 2003", www.pjm.com, March

PJM [2005], "State of the Market 2004", www.pjm.com, March

Rious V. [2006], "What place for competition to develop the power transmission network?", 29th IAEE International Conference, 9 June 2006 in Potsdam

Rossignoli J., Paravalos M. E., Besser J. G. [2005], "Transmission: The Critical Link Delivering the Promise of Industry Restructuring to Customers," The Electricity Journal, 18(9), 18-27

Schweppe F., Caramanis M., Tabors R., Bohn R. [1988], Spot Pricing of Electricity, Kluwer Academic Publisher

Shanker Roy J., [2003], "Affidavit of Roy D. Shanker, Docket No. ER03-406-000, PJM Interconnection L.L.C.",, www.pjm.com, February

Smeers Y. [2005], "Long term locational prices and investment incentives", 4th Conference on Applied Infrastructure Research, 8 October

Wilson R. [2002], "Architecture of the power markets", Econometrica, 70(4), 1299-1344