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An operational and institutional modular analysis framework of Transmission and System Operator

Why Transmission and System Operators are not ideal ones

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Abstract

Transmission and System Operator (TSO) is the power flows externality market designer. And so, not only is TSO a module of power markets but its missions that are related to the management of power flows can also be studied thanks to a modular analysis. An ideal first-best TSO can then emerge as a benchmark for comparison with real TSOs. The governance structure of TSO accounts for the gap between such an ideal first-best and real TSOs. Then, although the economic theory specifies a unique arrangement to reach efficiency, the diversity of transmission governance accounts for the diversity of arrangements to manage power flows. Moreover the comparison between an ideal first-best TSO and two reference TSOs, PJM and NGC, with quite opposite features accounts for heterogeneous results among TSOs.

1. INTRODUCTION

One knows that Transmission and System Operator (TSO) is a module of power markets (see [15]). In this paper we only focus on the management of power flows and do not deal with balancing issues. As for the management of power flows, a TSO must achieve three main interdependent missions: the short-run power flows externality management, the development of the network (see [3]) and the coordination with neighbouring TSOs to deal with border effects (see [7]). So the management of power flows by TSO can also be studied thanks to a modular analysis. And an ideal first-best TSO can then be designed by implementing the most efficient solutions for these three missions. Nonetheless, reference TSOs such as PJM and NGC are not ideal TSOs. The governance structure of transmission (or transmission governance) imposes compatibility constraints between the implementations of TSO’s missions and accounts for the gap between an ideal first-best TSO and real TSOs.

We show that a TSO can be studied thanks to a modular analysis framework as for the management of power flows. The modules are its three missions and transmission governance. We also show that transmission governance accounts for the wide diversity of arrangements of TSOs and their inhomogeneous results.

In section 2, we present the three missions of TSO that are operational modules of the analysis framework and their possible implementations. An ideal first-best TSO is designed thanks to the most efficient implementations.

In section 3, we define a last module, transmission governance, and show that it introduces compatibility constraints between the implementations of TSO's missions.

In section 4, the two reference TSOs, PJM and NGC, with quite opposite features are studied thanks to our modular and institutional analysis framework.

2. A MODULAR ANALYSIS FRAMEWORK

The implementations of the three TSO's missions for the management of power flows are differentiated thanks to their level of internalisation of the power flows externality in price mechanisms. These implementations are presented assuming that the TSO is benevolent and efficient. An ideal first-best TSO is designed as a benchmark thanks to the most efficient implementations.

2.1. The short-run power flows externality management

There exist two main solutions with opposite levels of integration between the externality management scheme and the energy market to internalise network externality in energy price.

The nodal pricing is in theory the most efficient method since the power flows externality is internalised in the energy market. It 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 limitations while maximising the social surplus (see [14]). The differential of nodal prices linked to externality generates a merchandise surplus for TSO. The network limitations generate also a social cost.

Under the redispatch scheme, the energy market is cleared "out of the network" at a unique system marginal price (SMP). TSO manages externality apart from the energy market by "constraining on" (and pay P_{on}) or "off" (and is paid P_{off} by) some generators or consumers. The subsequent redispatch cost is borne by TSO for the short-run operation, and generally socialised to the long-term in the Use of the System (UoS) tariff. Only the redispatched units know that there are network constraints.

Each scheme can be subject to a more or less wide use of local market power by reliability-must-run generators. The redispatch scheme is said to be more sensitive to these issues because the congestion cost is socialised ([9]). However, this scheme facilitates the use of standardised forward products on energy markets which may increase liquidity of marketplaces and therefore mitigate oligopolies' market power. There is a balance to find between increasing internalisation externality in energy prices, mitigating local market power and increasing liquidity of power marketplaces.

2.2. The development of the network

The development of the network is a two-part TSO's mission. The benevolent TSO invests to make the social cost decrease. And long-term locational network tariffs must complete the short-run signals to guide the location of new network users and to recover the network costs (see [13]). There is no ideal theoretical solution to define this tariff and to allocate the network charges but only pragmatic ones that internalise more or less network externality.

As for the development of the network, the benevolent TSO arbitrates between on the one hand the social cost noticed from the short-run operation and anticipated from the connection requests and on the other hand the cost of network investments. Other things equal, it is equivalent to a social welfare maximisation (see [13]).

As for the allocation of network charges, there are three main methods. Accommodation capacities can complete them.

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. This method is controversial. Costs that are associated to the lumpiness of the transmission line capacity are individually allocated. And it is a one-way internalisation as positive externalities are not rewarded.

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 upgrades” are socialised among all or part of the network users through a UoS tariff. The network users are then only incited to be near the core of the network.

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” 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.

2.3. The coordination of TSOs

The third TSO’s mission is to coordinate with neighbouring TSOs to internalise external loop flows. TSO can then optimally use all interconnected power resources. The coordination between TSOs includes both their externality management schemes and their long-term network developments. The issue of compensation between coordinated parties is not considered here and is still to be tackled by literature.

“Standardisation” and “combination” are the two main ways of coordinating adjacent systems (see [7]). The coordination by “standardisation” implies that each TSO elects the same implementations for the two previous modules and communicate a minimal set of data on the state of its network (see [4] for a coordinated externality management). The coordination by “combination” needs the implementation of standard inter-TSO footbridges to allow the coexistence of different individual schemes.

Standardisation achieves full efficiency while combination is only a second-best. Nevertheless, depending on its cost compared to its benefit, the coordination by combination or no coordination at all may be optimal.

The most efficient type of coordination depends on the topology of both TSOs’ networks. The more meshed the networks are, the more efficient the coordination is to deal with border effects (see [5]).

2.4. An ideal first-best TSO

The efficient implementation of the modules of this analysis framework constitutes an Ideal first-best TSO (ITSO). An ITSO must send economic signals to the network users to ensure an efficient use of the network. An ITSO efficiently develops the network. And an ITSO must coordinate with its neighbours to internalise the border effects.

To conclude, an ITSO is designed as follow:

Table 1 An ideal first-best TSO

Missions of TSO	Ideal first best TSO
Externality management	Nodal pricing
Network development Investments	Social cost minimisation, centralised by TSO
Tariffs	Zonal tariffs + Accommodation capacities
Coordination with TSOs	By Standardisation

3. COMPATIBILITY OF TSO’S MODULES

In reality, there is no guaranty that a TSO is benevolent. It may face contradictions between its private agenda and ITSO missions. Transmission governance accounts for the possible gap between real TSOs and the ITSO in such matters. This may generate some compatibility constraints between the implementations TSO’s missions.

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.

3.1. Transmission governance

Transmission unbundling from incumbent utilities provides more than a non-discriminatory open access to the network. It is the ground of transmission governance and frames the compatibility constraints of the implementations of TSO's missions.

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.

Unbundling transmission ownership

Transmission Ownership unbundling is frequently assumed. However, it is constrained by the possibility of divesting network from incumbents and the wideness of border effects.

The divestiture of system operation is widely recognised as a necessary prerequisite in a deregulated process and rather easy to impose: it stands only for few immediate financial stakes although those stakes may prove to be strategic in terms of entry barriers to third party network access. To the contrary, the divestiture of the transmission ownership may be hard to impose in the legal framework. Network ownership in an industrial activity, often held by private companies, to which it provides a riskless regulated revenue is attractive in the context of uncertainty of a power market.

Border effects also influence network unbundling. If transmission ownership and system operation are balkanised and uncoordinated, loop flows create numerous border effects that even an unbundling of both operation and ownership may not be sufficient to deal with. A merger of the divested System Operators (SO) in a third party, an Independent System Operator (ISO) keeps the industrial structure quite unchanged while the horizontal integration internalise border effects. For the rest of this paper, “TOSO” refers to a TSO that owns part or the whole network it operates while “SO” refers to a TSO that owns no network asset and “TSO” is used as a generic term referring without distinction to both.

Incentive regulation

Ownership unbundling has consequences on the governance and on the incentive regulation of the transmission monopoly.

Regulatory incentives are delicate to be imposed on a SO due to its small financial size. A self-regulated not-for-profit organisation is an alternative to a for-profit one (see [1]). Indeed, the participation of transmission owners and 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 lobbying group. 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 its tariffs revenues.

To conclude, a SO will be preferably not-for-profit self-regulated because it cannot support an incentive regulation. On the contrary, an incentive regulation is less risky for a TOSO thanks to its tariffs revenues.

Power flows externality and 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.

A TOSO may defend its own financial stakes while designing the market of power flows externality. To the contrary, a SO is theoretically neutral while designing the market of power flows externality thanks to a stakeholder process that is assumed to be balanced. Then, SOs are also less subject to incompatibilities in the construction of a regional market design.

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.

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

Conclusion about transmission governance

The governance of TSOs results in a compromise between its regulation, and market and coordination design. A TOSO can be incentivised but its financial stakes may interfere in market and coordination design while a SO may be easier to coordinate but harder to regulate and incentivise.

3.2. Compatibility of modules

Transmission governance imposes compatibility constraints between the implementations of TSO's missions. We study three kinds of compatibility constraints. First, incentivising easily a TSO is important to ensure an efficient network development. Second, locational signals coordinate the network users with the network accommodation capacity despite network unbundling. Finally, an inter-TSO scheme allows an efficient use of the meshed nature of the transmission network.

Compatibility constraints due to incentive regulation

The TSO faces different incentives in managing and investing depending on the combination of transmission governance and the externality management scheme.

Although the nodal pricing scheme is efficient in inciting the dispatch of the network users and partly their locations, it entices a profit-maximising TSO to underinvest and to oversize the congestion rent (see [12]). Therefore, a TSO that manages network externality thanks to nodal pricing will require a more demanding regulatory scheme to compensate the counter-incentive effect of the congestion rent.

On the contrary, although a redispatch scheme seems inefficient to deal with short-run externality, it makes the TSO facing directly short-run operation congestion costs. A profit-maximising TSO compares these operation costs with investment costs and so approximates a social welfare maximisation (see 2.2). The regulator can then rather easily check the compatibility between economically efficient investment planning and externality costs.

Whatever the market design, one could compel TSO to calculate the social cost of externality and so to ensure an open access of the regulator to this information. However, one must keep in mind that only a TOSO can be incentivised on the socialised costs. If the TSO is a SO, a nodal pricing appears to be a better option, all the more that it is not-for-profit and so insensitive to congestion rent.

Compatibility constraints due to 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. As for the externality management scheme, not only does it face compatibility constraints from regulation, but it is also insufficient in emitting long-term locational signals.

Even if nodal prices provide a local value of the network constraints, they do not measure the impact of a new investment on other nodes and are not efficient as long-term locational signals.

Moreover, they do not internalise some externalities, for instance network reliability.

Therefore, a locational network tariff is necessary to deal with the indivisibilities and the externality of the network investments. 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.

Public accommodation capacities can make the 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 a connection request to another. If nodal accommodation capacities are available, they may not be simultaneously feasible.

However zonal tariffs and accomodation capacities may have a limited impact on the location of the network users compared to other constraints, as their primary resources (water, wind, coal, etc…)

Compatibility constraints due to the coordination between TSOs

We saw that transmission governance frames the individual schemes of TSO. As a result, the respective transmission governances frame the coordination between TSOs.

Locational methods are a better choice of standardisation for coordination since they can internalise not only internal but also external loop flows and so border effects. Otherwise, the coordination may require an inter-TSO footbridge if the individual schemes completed by data exchanges are not sufficient.

Therefore, coordination must also be desired by each organisational structure of transmission. Such a concerted mobilisation is hard to gather (see [7]). A competent “supra-organisation” (regulator or government) surrounding the parties to be coordinated is necessary at least to incentivise compensation rules associated to the development of coordination, at most to ease the evolution towards a standardised coordination.

4. STUDY OF PJM AND NGC

NGC and PJM are briefly compared to “an ideal first-best TSO” thanks to our common modular analysis. We focus on the study of compatibility constraints between operational modules.

4.1. Comparison of PJM to the ITSO

PJM is often quoted as an example to be followed for the creation of a system operator ruling wide areas.

As for externality management, PJM uses nodal pricing, for congestion management only. Losses must be integrated in its nodal pricing scheme to reach the best practices of externality internalisation of other SOs.

As for the development of the network, PJM must improve its too simplistic criterion that is based on congestion thresholds to evaluate the economic opportunity of its Economic Planned Transmission Facilities. The arbitrage between short-run operation costs and investment costs is made without directly calculating congestion cost but just estimating it ([10]). Moreover, neither losses nor unsupplied energy are taken into account during the decision process. Investment decisions are eventually based on a snapshot, ignoring uncertainty about future flows.

As for the coordination between TSOs, such a wide operator solves an important part of border effects and coordination with neighbours is theoretically fully achievable.

Implementations of PJM’s modules are summed up in the following chart:

Table 2 Comparison between PJM and an ITSO

Missions of TSO	Implementations	First-best?	Comments
Management of:			
Congestion	Nodal pricing	Yes	
Loss	Fixed rate	No	
Development			
Investment	Congestion threshold criteria	No	recent, no loss cost, no risk assessment
Tariffs	- Deep cost for new generators - Zonal UoS tariffs	Partly	No accommodation capacity
Coordination	Standardisation	Yes	In progress

4.2. Compatibility of the PJM's modules

Clarity of regulation

The reform of the power industry in the USA faces up against the dual structure of its regulation with one federal energy regulator, the FERC, and fifty state regulators, the PUCs. The FERC whose jurisdiction is limited to the interconnected wholesale markets leads the deregulation process. The desirability of deregulation differs from state to state. Their jurisdiction surrounds bundled activities and in particular transmission. It makes the deregulation process more difficult for the FERC to implement.

However, even if the FERC cannot impose full transmission unbundling to the power industry, it achieved success in providing non-discriminatory open access to transmission network thanks to unbundling system operation only.

Transmission governance

ISOs control wide areas to internalise wide border effects between the utility areas. Their asset-poor not-for-profit structure imposes a self-regulation. However, an overrepresentation of generators in the governance structure can undermine the costs control of this monopoly.

Considering the numerous border effects between the numerous utility areas (around 400 utilities), the FERC was more concerned about creating operators over wide areas than about divesting transmission ownership that would not have resolved this critical issue.

So the ISOs are SOs. Therefore, they cannot support an incentive regulation, all the more that they are generally not-for-profit. As monopolies, ISOs are self-regulated thanks to sophisticated structures of governance to represent fairly each group of stakeholders.

An overrepresentation of the generators questions the fair representation of the market actors in the ISOs ([2]). ISOs 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. They can only be implemented as SOs because of the dual regulatory structure. Incentive regulation cannot then be enforced but self-regulation may not ensure enough costs control because of an overrepresentation of the generators.

Compatibility analysis

The governance of PJM dictates the compatibility constraints between the implementations of TSO's missions, as for costs control, the provision of locational signals and the coordination between TSOs.

As for compatibility constraints due to costs control of transmission, self-regulated SOs faced congestion gaming in the late 1990's while using redispatch. In particular, PJM engaged itself in 1998 into implementing nodal pricing. The nodal pricing is the power flows externality management scheme the more appropriated to a SO such as PJM. Its not-for-profit structure makes it indifferent to the counter-incentive effect of the congestion rent. As for the integration of losses in its nodal pricing, it may have been a secondary issue while PJM was focused on extending its area to neighbouring utilities.

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 a SO to manage the network development in the long term.

As for compatibility constraints due to the provision of locational signals, the “deep cost” do not allow an internalisation of the positive externality of network investments. Accommodation capacities on the PJM system are nevertheless missing for the connection costs to be auditable.

As for compatibility constraints due to the coordination between TSOs, the FERC’s Standard Market Design displays a framework that allows a coordination by standardisation between ISOs and similar organisations at least for System Operation.

4.3. Comparison of NGC to the ITSO

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

Implementations of NGC’s modules are summed up in the following chart:

Table 3 Comparison between NGC and an ITSO

Missions of TSO	Implementations	First-best?	Comments
Management of Congestion	Redispatch	No	Decreasing trends and good results thanks to incentive regulation
Loss	Fixed rate	No	
Network development Investment	Mainly engineering criteria Fuzzy economic criteria	Near	
Tariffs	Zonal UoS tariffs Zonal accommodation capacities	Near	
Coordination	Combination	No	Little need

4.4. Compatibility of the NGC’s modules

Clarity of regulation

The role of the energy regulator OFGEM, and to a lesser extent the European Commission and the DTI in the regulation of NGC and their relations are clear-cut. It has made the full unbundling of transmission network easier to reach.

Despite the principles of subsidiarity and of independence of the regulator vis-à-vis the government, there are few public divergences between these organisations. Great Britain is often referred as a reference of power deregulation in Europe.

Clear regulatory relations allow discretionary decisions about the industrial structure and particularly full transmission unbundling in order to ensure competition and a non-discriminatory open access to transmission network. NGC is a private independent TOSO that operates the power network of England and Wales.

Transmission governance

The NGC’s transmission ownership then allows the regulator OFGEM to use incentive schemes.

The ownership of the network by the System Operator allows an efficient development of the network for two reasons. First, the revenue from the network ownership ensures that the financial penalties in the framework of an incentive regulation will not jeopardise the survival of the TSO. Second, an incentivised TOSO arbitrates between on the one hand short-run operation costs and small-scale investments with short payback and on the other hand small- and larger-scale investments all the more that there are economies of scale in network investments ([10]).

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.

Compatibility analysis

The governance of NGC dictates the compatibility constraints as for costs control, the provision of locational signals and the coordination between TSOs, between the implementation of operational modules.

As for compatibility constraints due to costs control of transmission, the governance structure of NGC as a TOSO allows 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 constraints due to the provision of locational signals, a nodal pricing could have been more advantageous ([8]). However, at the time of (re)designing the English and Welsh power market, the consumers (producers) that are mainly in the South (North) feared that their bill might increase (revenue might decrease) while the network would earn the rent ([8]). A zonal tariff provides a degree of cost causality while it reduces the entry barrier in particular for network demanding generators such as windfarms.

As for compatibility constraints due to the coordination between TSOs, it is of little concerns in the case of NGC. Indeed, the NGC's interconnectors create few loop flows. The France-England interconnector is a DC line whose flow is controllable. It is a separate merchant business out of the scope of the OFGEM ([10]). This is an institutional barrier to reach ideally a coupling between France and Great Britain. The overcapacity of the Scottish generators makes the flow on the Scottish interconnector quite predictable. And their high concentration justifies the Scottish interconnector being administrated rather than auctioned.

5. CONCLUSIVE REMARK ABOUT PJM AND NGC

There is not really a better way to deviate from an "ideal first-best" TSO since each context is peculiar and the job of TSO is mainly determined by the incumbent topology and capacity of the network and its regulation. The NGC control area is a peculiar case of insularity. Therefore, coordination is only a secondary issue to NGC while the network development is its core activity. In the USA, the ISOs such as PJM are regional coordinators and the network development was only a secondary issue. As the coordination is a solved issue in the PJM area, the network development is becoming of importance to avoid a market balkanisation.

6. CONCLUSION

Our operational and institutional modular analysis framework shows that the institutional context of TSO induces compatibility constraints between the implementations of its missions.

Our empirical analysis concludes in a quite opposite way than some other drastic views (see for instance [6]). The ideal TSO is still the target to be reached (see [6]) thanks to the relevant institutional ground as they may ease the creation of wide market areas. But suboptimal network management schemes may be relatively efficient regarding the institutional context surrounding their implementation. All the more regulation may limit inefficiency in some cases. Besides, the windows of feasibility of such institutional modifications are short and limited (see [7]). Therefore, even suboptimal solutions must be deemed and studied because they may be the only ones to be institutionally implemented.

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