Evolution of Transmission Rights in the European Electricity Market

Christof Duthaler, Matthias Finger

Abstract — In the European electricity market, transmission rights currently evolve from a physical to a financial nature. This requires a fundamental change in the underlying market design and the institutional setup. This paper applies the framework of congestion revenue rights (CRRs) to physical and financial transmission rights, which allows a comprehensive view on the issue, including financial regulation. Based on this framework, two options for transmission price hedging in an integrated European electricity market are discussed.

Keywords: Financial Transmission Rights, Congestion Revenue Rights, Contracts for Differences, Markets in Financial Instruments Directive (MiFID).

I. INTRODUCTION

In a congested electricity network, three distinct types of costs associated with congestion can be defined. These are:

Congestion rent or congestion revenue (see figure 1) is defined as the price difference times the flow over a network constraint. Congestion rent is collected by those who transfer the energy over the constraint (see below).
Congestion cost (see figure 1) is defined as the system cost that results from the inability to dispatch least-cost generation due to the constraint. Congestion cost is a deadweight loss, i.e. it is social welfare not collected by anybody.
Cost of congestion to consumers is defined as the extra-cost consumers face due to higher prices caused by the constraint, i.e. the product of total consumption times the difference between the clearing prices with and without constraint.

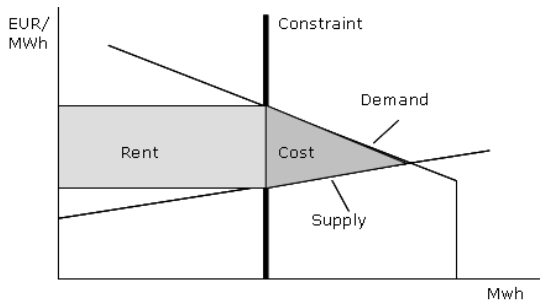

Figure 1: Congestion rent and congestion cost.

Manuscript of May 22, 2009.
Christof Duthaler is with the Swiss Federal Institute of Technology in Lausanne (EPFL), CH-1015 Lausanne, and works for the Swiss Transmission System Operator swissgrid ag. (christof.duthaler@epfl.ch; phone: +41 76 311 24 33).
Matthias Finger is with the Chair of Management in Network Industries at the Swiss Federal Institute of Technology in Lausanne (EPFL), matthias.finger@epfl.ch .

In the following, we will focus on the congestion revenue, since this is the money collected from the market by transferring electricity over constraints. Depending on the underlying electricity market design, there are two different ways of collecting congestion revenue:

1. In a decentralized or self-commitment market, i.e. a market based on (physical) bilateral contracts, congestion revenue is collected by the market actors (producers, consumers, traders) that transfer electricity over a constraint by themselves.
2. In a centralized or central-commitment market, congestion revenue is collected by the central market operator, i.e. a power exchange (PX) or an independent system operator (ISO). The central market operator plays the role of a "shipping agent", in the sense that he transfers the energy over constraints.

In addition to these two market designs, a hybrid market design is conceivable as well. In that case, part of the network capacity is reserved for self-commitment (physical bilateral trades), while the remainder is used for central-commitment.

II. CONGESTION REVENUE RIGHTS

A. Definition

Based on the two ways of collecting congestion revenue, three different types of congestion revenue rights (CRRs) can be defined:

1. Self-commitment CRR: The congestion revenue is received by holding a right to physically deliver power over a constraint from hub A to hub B. A self-commitment CRR therefore contains a transmission right.
2. Central-commitment CRR: The congestion revenue is received by holding a right on the revenue between hub A and hub B that is collected by the central market operator. A central-commitment CRR therefore does not contain a transmission right. Instead, the transmission right remains with the central market operator, which plays the role of the "shipping agent".
3. Hybrid CRR: In a hybrid market model (see above), congestion revenue is received by holding either a self-commitment CRR or a central-commitment CRR, or by holding a hybrid CRR. A hybrid CRR can be one of two things: It is either a self-commitment CRR that can be sold back to the central market operator in exchange for a

central-commitment CRR, or, if there is no central-commitment market, a hybrid CRR can be defined as a self-commitment CRR that can be sold back to the auctioneer of self-commitment CRRs in exchange for an auction revenue right (ARR, see below).

In the continental European context, a self-commitment CRR is typically called a "Physical Transmission Right (PTR)", while the central-commitment CRR is often called "Financial Transmission Right (FTR)". The hybrid CRR is equivalent to a PTR that can be sold back to the central market operator or PTR auctioneer. Such a CRR is often called a "PTR Use-it-or-Sell-it".

B. Assignment of CRRs

Regardless of the underlying market design, CRRs can be assigned to market actors in three different ways:

1. Allocation (free of charge)
2. Auction
3. Combination of allocation and auction

The choice of the assignment method depends on the purpose to be fulfilled by the CRR (see below).

Importantly, if CRRs are auctioned, this will result in an auction revenue (AR) for the central market operator or CRR auctioneer. In the same way as congestion revenue is distributed to the holders of CRRs, the distribution of auction revenue requires the definition and allocation of auction revenue rights (ARRs). How does auction revenue relate to congestion revenue? In an ideal market, auction revenue would be equal to congestion revenue. In practice, however, auction revenue can be bigger, equal, or smaller than congestion revenue. The outcome depends on how market actors bid for CRRs.

Furthermore, CRRs can be assigned either between any two hubs of an electricity network (centralized CRR) or only between adjacent hubs of a network (decentralized CRR, sometimes called "Flowgate right"). While the former option requires a single market operator accessing the congestion revenue of the whole relevant network, the latter option allows for decentralized market operators issuing CRRs (as is the case today in Europe).

By distinguishing between self- and central-commitment CRRs, and between allocating and auctioning CRRs, four different ways of assigning CRRs to the market have to be considered. In the following, the four procedures are described from the perspective of the CRR issuing entity (e.g., the grid operator or the central market operator):

1. Self-commitment CRR, Allocation
    a. Allocation of CRRs
2. Self-commitment CRR, Auction
    a. Allocation of ARRs
    b. Auctioning of CRRs
    c. Distribution of AR to holders of ARRs
3. Central-commitment CRR, Allocation
    a. Allocation of CRRs
    b. Collection of CR
    c. Distribution of CR to holders of CRRs
4. Central-commitment CRR, Auction
    a. Allocation of ARRs
    b. Auctioning of CRRs
    c. Collection of CR
    d. Distribution of CR to holders of CRRs
    e. Distribution of AR to holders of ARRs

There are real-world experiences with all of these assignment methods:

1. Self-commitment CRR, Allocation: This is typical for existing transmission contracts (ETCs), in Europe often called long term contracts (LTCs).
2. Self-commitment CRR, Auction: This is a typical European PTR auction.
3. Central-commitment CRR, Allocation: Several restructured US electricity markets allocate part of their CRRs to certain market actors.
4. Central-commitment CRR, Auction: PJM and other restructured US electricity markets auction all or part of their CRRs to market actors.

Besides these four ways of assigning CRRs, there are also markets that (currently) do not feature CRRs are at all. Examples are New Zealand or the market of the Nordic countries. We will come back to these cases later in this article.

C. Volume of CRRs

How many CRRs can be given to market actors by the CRR issuing entity? Importantly, the feasible volume of CRRs, whether self- or central-commitment, is always limited by the physical network capacity. With self-commitment CRRs, an over-allocation would create too many physical flows and endanger the network security. With central-commitment CRRs, physical flows are not an issue, since the units are centrally committed. However, an over-allocation of CRRs would endanger the revenue adequacy of the central market operator, since congestion revenues collected by the market operator would no longer cover total payments to CRR holders. To prevent an over-allocation of CRRs, the market operator has to perform a simultaneous feasibility test (SFT). This is necessary for both a centralized and a decentralized assignment of CRR, though it is more demanding for a centralized assignment. The SFT is the reason why a CRR issuance disconnected from the underlying physical network and its constraints is not possible. Even so, the SFT remains vulnerable to a changing grid topology in the time span between the issuance and the settlement of CRRs.

CRRs can be defined as options or as obligations. An option *can be* used (its value will be positive or zero), while an obligation *has to be* used (its value can be positive or negative). A CRR obligation therefore can turn into a payment obligation for its holder, namely when the CRR is defined from a high price to a low price hub. In this case, the holder of a self-commitment CRR obligation has to "buy high and sell low" the electricity, while the holder of a central-commitment CRR has to pay the price difference between the two hubs to the central market operator. In the SFT described above, the physical (self-commitment) or financial (central-commitment) flows associated with CRR obligations can be taken for granted. Thus, CRRs defined in opposite directions cancel out each other. This is why for a certain network capacity, the volume of CRR obligations that can be allocated is higher than the volume of CRR options.

D. Purpose of CRRs

Next, let's turn to the purpose of CRRs. Indeed, self- and central-commitment CRRs have several and in part differing purposes:

1) Self-commitment CRR

1. Scheduling of energy: In a self-commitment market, a CRR is indeed required by market actors to deliver electricity over a constraint. This is the transmission right component of the CRR.
2. Transmission investment: If a merchant investor builds a new line, he could be allocated a physical CRR for it, which is equivalent to using the line exclusively.
3. Transmission price hedging: The transmission price, and thus the congestion price risk, is fixed in advance through the CRR auction.

2) Central-commitment CRR

1. Offset redistribution of economic rents from tariff reforms: As an example, the introduction of nodal pricing in a former uniform price market implies that some market actors will face higher or lower prices. By allocating CRRs, such a redistribution of economic rents can be offset without impeding the signals given by nodal pricing, and without precluding the dispatch efficiency gained by switching from a self-commitment to a central-commitment market.
2. Replacement of Existing Transmission Contracts (ETCs): This is essentially a special case of purpose number 1. An allocated self-commitment CRR is replaced by an allocated central-commitment CRR. The former ETC holder is financially hedged, while the ETC capacity is freed up for the central market operator [1].
3. Transmission investment: Instead of a self-commitment CRR, a merchant investor can be allocated a financial CRR to reap the financial benefits of a new line, while the line is used by the central market operator.
4. Transmission price hedging: As with self-commitment CRRs, the auction price pre-determines the price for using transmission.

As mentioned earlier, the intended purpose of CRRs determines the choice of how to assign them. On one hand, to offset the redistribution of economic rents (including the replacement of ETCs) and to finance merchant transmission investments, CRRs will be allocated free of charge to the relevant market actors. On the other hand, auctioning CRRs is sufficient to hedge transmission prices. Of course, instead of allocating CRRs, a market operator can also allocate ARRs and auction off corresponding CRRs. It can be argued that compared to allocating CRRs, auctioning CRRs is more flexible and efficient, reaches a broader range of market actors, and allows determining a market price for transmission. In practice, some market operators allocate one part of their CRRs to certain market actors (e.g. to ETC holders) and auction the remaining CRRs to general market actors.

As described above, the choice between self- and central-commitment CRRs depends on the underlying market design. Theoretically, it can be shown that central-commitment attains a higher overall dispatch efficiency [2]. Nevertheless, market actors used to self-commitment are often reluctant to cede dispatching authority to a central market operator.
Regarding the choice between centralized and decentralized assignment of CRRs (see above), a centralized assignment is likely to be more efficient, requiring of course a single market operator for the whole relevant network.

E. CRRs and the usage of congestion revenue

Whether or not CRRs are implemented, congestion revenue can be used for several purposes:

1. Funding of past network investments
2. Funding of future network investments (as proposed by the 3rd EU energy package)
3. Funding of operational expenditures (e.g., redispatch cost)
4. Funding of CRRs (see above on the purpose of CRRs)

As long as CRRs are auctioned (not allocated) to market actors, the congestion revenue stream is not ended, but *transformed* into an auction revenue stream. Therefore, you *can* auction CRRs as a transmission price hedging *and* use the congestion revenue or rather the auction revenue for one of the first three purposes. Keep in mind, though, that auction

revenues can be bigger, equal or smaller than congestion revenues. However, if you have to allocate CRRs after the introduction of zonal or nodal pricing in order to offset the redistribution of economic rents, congestion revenues can no longer be used for funding past or future network investments or operational expenditures. In that respect, the 3rd EU energy package, even though aiming at a European market integration, is based on the assumption that congestion remains (only) on national boundaries, where there are no historical claims to congestion revenues (see part III below).

III. CRRs IN THE CONTINENTAL EUROPEAN ELECTRICITY MARKET

A. *Regulation of CRRs in the EU*

With regard to the regulation of CRRs in Europe, the question is whether CRRs, and especially central-commitment CRRs (which do not include a transmission right), are to be seen as financial instruments and have to be regulated accordingly. If so, the EU directive 2004/39 on markets in financial instruments (MiFID) and the MiFID Implementation Regulation (MIR) 1287/2006 (including organizational requirements and rules on customer relations, transparency, reporting, record-keeping, etc.) as well as associated capital requirements (EU directives 2006/48 and 2006/49) may apply to CRR market participants.
The financial instruments covered by MiFID are listed in its Annex 1, Section C. If anything, CRRs could qualify as commodity derivatives. Indeed, if electricity transmission capacity is defined as a commodity, then CRRs could be seen as derivatives (options or futures) on the price of transmission capacity. MIR article 2.1 defines commodities as "any goods of a fungible nature that are capable of being delivered, including metals and their ores and alloys, agricultural products, and energy such as electricity." According to this definition, electricity transmission capacity is not a commodity, and hence CRRs are not commodity derivatives in the sense of MiFID Annex 1 Section C. This is also how (central-commitment) CRRs are regulated in the U.S.: They are not covered by the Commodities Futures Trading Commission (CFTC) [1], although this is currently reviewed (see below).

However, MiFID Annex 1 Section C(10) adds another group of underlyings covered by MiFID:

"Options, futures, swaps, forward rate agreements and any other derivative contracts relating to climatic variables, freight rates, emission allowances or inflation rates or other official economic statistics that *must be settled in cash or may be settled in cash* at the option of one of the parties (otherwise than by reason of a default or other termination event), as well as *any other derivative contracts relating to assets, rights, obligations, indices and measures not otherwise mentioned in this Section*, which have the characteristics of other derivative financial instruments, having regard to whether, inter alia, they are *traded on a regulated market or an MTF, are cleared and settled through recognised clearing houses or are subject to regular margin calls."*

MIR article 39 then further specifies which underlyings qualify as "C10 underlyings". Letter c) mentions "transmission or transportation capacity relating to commodities, whether cable, pipeline or other means".
Thus, electricity transmission capacity qualifies as a C10 underlying covered by MiFID.

Does this mean that CRRs qualify as C10 derivatives? No. MIR article 38.4 makes the crucial exemption: "A contract shall be considered to be for *commercial purposes* for the purposes of Section C(7) of Annex I to Directive 2004/39/EC, and as *not having the characteristics of other derivative financial instruments* for the purposes of Sections C(7) and (10) of that Annex, *if it is entered into with or by an operator or administrator of an energy transmission grid, energy balancing mechanism or pipeline network, and it is necessary to keep in balance the supplies and uses of energy at a given time.*"

Since CRRs by definition have to be issued by an "operator or administrator" of the electricity transmission grid, and it is indeed necessary to keep in balance the supplies and uses of electricity at any given time, MiFID would consider CRRs to be for commercial (instead of purely financial) purpose and as not having the characteristics of derivatives on C10 underlyings. Consequently, CRRs do not fall under MiFID regulation for the time being. Keep in mind, though, that MIR article 40 foresees regular re-examinations of the criteria mentioned above and the instruments that will qualify as financial instruments.

Is the exception according to MIR article 38.4 justified? It can be argued that contracts issued by a network operator or administrator are by definition part of the spot market. At the example of CRRs, whether self- or central-commitment, both their volume and their value are purely determined by the electricity network capacity and the spot market prices. Manipulation of CRRs is equivalent to manipulating the network, generation or consumption, all of which is covered by traditional energy regulation. Energy regulation therefore should include CRRs as an integral part of the spot market.
Additionally, the balancing requirement of electricity should, at least in theory, prevent market participants from withholding or flooding the market with electricity, two of the most powerful forms of manipulation in other commodity markets. In practice, however, examples such as the Enron case in California showed that market actors, especially if they possess market power, actually *can* withhold electricity and drive prices up, sometimes even endangering the network security.
Moreover, at the example of CRRs, several financial risks are involved. The auctioning of both self- and central-commitment CRRs involves a credit risk for the issuing entity and therefore requires collaterals by market

actors. And both types of CRRs pose a financial risk to their holders (especially in the case of CRR obligations, since they can turn into a payment obligation) as well to the issuing entity (in case of a revenue inadequacy). According to the U.S. regional transmission organization PJM, it is because of these risks that the U.S. CFTC currently reviews the need to regulate CRRs.

How would the financial regulation of CRRs in Europe look like without the exception granted in MIR article 38.4? In this case, MIR article 38.3 specifies three conditions. If a C10 derivative satisfies at least one of them, it will be considered as having the characteristics of other derivative financial instruments, i.e. it will be regulated:

"(a) that contract *is settled in cash or may be settled in cash* at the option of one or more of the parties, otherwise than by reason of a default or other termination event;
(b) that contract is traded *on a regulated market or an MTF*;
(c) the conditions laid down in [article 38.1] are satisfied in relation to that contract."

MIR article 38.1 provides three conditions, namely 1) trading on a regulated market, multilateral trading facility (MTF) or third country trading facility, 2) clearing by a clearing house or a central counterparty, 3) standardization of the contracts.

The cash settlement condition of MIR article 38.3 may indeed distinguish between self- and central-commitment CRRs, despite their common, often commercial purpose: Self-commitment CRRs can be settled only physically by the issuing entity (through provision of transmission capacity), while central-commitment CRRs can be settled only in cash (through congestion revenue). A central-commitment CRR would therefore be considered as a regulated financial instruments. A self-commitment CRR would not qualify as long as it cannot be settled in cash (note: a hybrid CRR can be settled in cash), it is not traded on a regulated market or an MTF (note: secondary markets could qualify as MTFs), and the conditions of MIR article 38.1 are not met.

Apart from exemptions to certain financial instruments, MiFID also exempts certain companies from its regulation. Article 22 in the introduction to the MIR states that:

"The exemptions in Directive 2004/39/EC that relate to *dealing on own account* or to dealing or providing other investment services in relation to commodity derivatives covered by Sections C(5), C(6) and C(7) of Annex I to that Directive or derivatives covered by Section C(10) of that Annex I could be *expected to exclude significant numbers of commercial producers and consumers of energy and other commodities,* including energy suppliers, commodity merchants and their subsidiaries from the scope of that Directive, and therefore such participants will not be required to apply the tests in this Regulation to determine if the contracts they deal in are financial instruments."

B. Potential usage of CRRs in the continental European electricity market

Cross-border electricity trading in continental Europe is predominantly based on self-commitment (i.e. physical bilateral contracts) between adjacent countries [3]. Consequently, network operators mostly assign decentralized self-commitment CRRs, or, in some cases, hybrid CRRs, to market actors by way of auctions (called "explicit auctioning of PTRs").
Meanwhile, the introduction of central-commitment CRRs is discussed in Europe. Apart from the fundamental change in the market design and the institutional setup that is required (i.e. a central market operator operating the constraints between countries, see above), how would the different purposes of central-commitment CRRs (see section II.D) apply to the European context?

1. Offset redistribution of economic rents from tariff reforms: This is currently not an issue in Europe, since there are no historical claims to congestion rents between national markets. A uniform European electricity market that would justify such cross-border claims did not exist historically. This is the difference between the introduction of *intra*-market CRRs (typical for U.S. ISOs) and *inter*-market CRRs (the European case). However, the situation would change as soon as Europe opts for the introduction of nodal pricing or price zones other than the political ones today. In that case, at least part of the CRRs may have to be allocated to offset the redistribution of economic rents.
2. Replacement of Existing Transmission Contracts (ETCs): As an exception to number 1, this could be an issue in Europe, since there exist some ETCs between countries. It is a special case, however.
3. Transmission investment: This is problematic in Europe, since commercial constraints are defined only between countries, and therefore congestion revenue only arises between countries. However, actual physical constraints often lie within countries. A merchant investment policy based on CRRs would therefore lead to investments at the wrong or at least sub-optimal places. Essentially, a coherent merchant investment policy would require full nodal pricing throughout Europe.
4. Transmission price hedging: Apart from the special case of ETCs, transmission price hedging remains as the only valid purpose of central-commitment CRRs in Europe. To achieve a truly integrated European electricity market, *centralized* central-commitment CRRs would be required, i.e. CRRs between any two European hubs, even though decentralized central-commitment CRRs between existing hubs (i.e. countries) may be a first step.

This analysis leads to the following question: If commercial transmission price hedging remains as the sole purpose of central-commitment CRRs in Europe, does this justify the use of congestion revenues and the implementation of a centralized CRR auctioning system?

On one hand, a hedge against locational price risk may be necessary to encourage competitors from outside of a market to enter that market even without possessing own generation there. Without a transmission price hedge, such competitors would be left unprotected against locational price risk. This is the experience made in New Zealand, which operates a nodal market without CRRs since 1996 [4].

On the other hand, the centralized auctioning of CRRs requires a single operator with access to the regional congestion revenue and the regional network model. Moreover, the connection to congestion revenues creates a financial risk to the market operator and eventually to the rate-payers, since an over-allocation of CRRs would cause a revenue inadequate situation. Mitigating this risk means scaling-down pay-outs to CRR holders in case of a revenue inadequacy.

IV. Alternatives to CRRs

If European policy makers perceive a need for an instrument to hedge transmission prices in order to foster a true European electricity market, but at the same time refrain from a centralized CRR auctioning system, then which alternatives are on the table? To answer this question, one has to look at who can hedge the transmission price risk (also called the locational price risk) between two arbitrary hubs A and B. In fact, there are two entities capable of doing that:

1. The central market operator that collects the congestion rent between A and B. He could issue CRRs as described above.
2. A market actor that trades in the opposite direction, i.e. from B to A, or a combination of an actor exporting from B to a reference hub and another actor importing from the reference hub to A. At the reference hub, the single system price for an unconstrained network would be determined, i.e. the pure energy price without any locational (congestion) cost. The locational price risk of someone exporting from A or B cancels out with the risk of someone importing to A or B, and vice versa. Those actors would sign a "Contract for Difference (CFD)", i.e. a forward contract on the difference between the system price and an area or hub price. Importantly, a load in area A is actually exporting from the area price A to the system price (hedging against rising area price), while a producer in area A is actually importing from the system price to the area price A (hedging against falling area price).

The CFD model is the one implemented by Nordpool in the Nordic market [5, 6].

How do CFDs compare with CRRs? The key difference is that CFDs have no connection to the congestion revenue. This in turn has several implications:

1. There is no need for a simultaneous feasibility test (SFT) that depends on the network capacity and has to be run by a central operator.
2. Commercial risks are shared between market actors, not between market actors and the rate payers (via a revenue inadequacy of the market operator).
3. CFDs may face a liquidity problem, since there is no "natural" counter-party with access to the congestion rents.

There are some measures that help improving the liquidity of a CFD market, for instance:

1. Electricity price futures should be available only on *one* price reference, namely the unconstrained system price, but not on the several area prices. That way, not only traders *between* areas will participate in the CFD market, but also producers and consumers *within* areas, since they would like to hedge the locational price risk between the system price and their respective area price.
2. Area price zones have to include a sufficiently large number of producers and consumers as potential CFD market participants. This is why CFDs are not feasible in a nodal electricity market. However, to increase liquidity, even CRRs are usually not defined between any two network nodes, but from trading hubs (aggregated network nodes) to load zones and generation nodes, while electricity price futures are based on trading hub prices. The NYMEX futures on the PJM Western Hub are a prominent example of this scheme [7].

The introduction of CFDs in the European electricity market would therefore require the computation of a European system price for the unconstrained network (basis for forward/future contracts), and the computation of area or country prices (basis for CFDs).

With regard to EU regulation, energy market CFDs (not to be mistaken with financial contracts for differences on stock price variations etc.) are likely to be covered by MiFID, since MIR article 38.4 does not apply to CFDs.

V. Conclusion

This paper applied the framework of congestion revenue rights (CRRs) to physical and financial transmission rights. The CRRs associated with the two fundamental electricity market designs, i.e. self- and central-commitment markets, were described. The institutional requirements of centralized, central-commitment CRRs ("FTRs" between any two hubs) were highlighted, namely a single market operator with access

to the regional congestion revenue and the regional network model (for determining a simultaneously feasible set of CRRs).

With regard to financial regulation, both self- and central-commitment CRRs would not be considered as financial instruments by current European legislation (MiFID). The different purposes of CRRs were described. It was shown that in the European context, the purpose of central-commitment CRRs would be limited primarily to the commercial hedging of locational price risk. In principle, this could be achieved as well by user-based forward products such as contracts for difference (CFDs). Since CFDs have no connection to congestion revenues, rate-payers would not face a financial risk as in the case of a CRR revenue inadequacy. The liquidity requirements of a European CFD market should therefore be examined carefully, especially with regard to the required size of price zones.

REFERENCES

[1] C. Duthaler and M. Finger, Financial Transmission Rights in Europe's Electricity Market, *CRNI conference*, Brussels, 2008

[2] R. Sioshansi et al., The Cost of Anarchy in Self-Commitment-Based Electricity Markets, *Competitive Electricity Markets*, 2008

[3] ETSO, An Overview of Current Cross-border Congestion Management Methods in Europe, www.etso-net.org, 2006

[4] New Zealand Electricity Commission, Issues for Managing Locational Price Risk, www.electricitycommission.govt.nz , 2008

[5] T. Kristiansen, Congestion management, transmission pricing and area price hedging in the Nordic region, *Electrical Power and Energy Systems*, 2004

[6] J. Marckhoff and J. Wimschulte, Locational price spreads and the pricing of contracts for difference: Evidence from the Nordic market, Energy Economics 31 (2009) 257–268

[7] See www.nymex.com and www.pjm.com