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CROSS BORDER CONGESTION MANAGEMENT – INTERNATIONAL EXAMPLES AND COMPARISON

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This paper presents methodologies for congestion management on cross-border interconnections that are currently being used in Brazil, USA (PJM), Norway, the Netherlands and Spain. Facilitating the market and cross-border trade is an important activity of System Operators in a liberalised market. All countries use different approaches, despite of sometimes similar market models, and all countries are looking for further improvements.

Keywords: Congestion Management, Transmission Constraints, Interconnectors, Cross-border trade, TSO, ISO, Electricity Market Liberalisation

1 Introduction

Management of congestions or transmission constraints is one of the major issues that needs to be solved properly to enable a fair and transparent functioning power market. Integrated utilities are being unbundled and Independent System Operators (ISOs) or Transmission System Operators (TSOs) are created to safeguard reliability of the transmission system and to allow open access to the network. Technical barriers for electricity exchanges are firstly due to transmission capacity limits. As a minimum, procedures must be in place that can relieve the congestion before physical or security limits are breached.

Several methodologies have been discussed and implemented over the last years. In many cases different methodologies are being used for internal congestions and for cross-border congestions. Cross-border congestion management is more complicated due to the fact that for each interconnector two SOs and possibly Power Exchanges (PX) are involved. Also market prices at both sides of the interconnector can be very different which leads to pressure from market participants on the SOs to acquire cross-border transmission capacity. Finally cross border trade plays an important role in the good functioning of markets as it can stabilise prices and reduce market power. This paper therefore focuses on the management of cross-border congestions. European countries have implemented several methodologies. More simple methodologies like pro rata allocation have been used but market based approaches like market splitting and auctions find increasing application.

The paper describes methodologies that have been practically implemented in Europe (Norway, the Netherlands and Spain) as well as in America (USA and Brazil). The methods and future developments are compared.

Working Group 39.05 (Development and Changes in the Business of System Operators) was established in 2000. In 2002 it published its first report [1]. Since then the Working Group is analysing congestion management, services provided by SOs and quality standards for system operation.

2 USA (PJM)

PJM is the Regional Transmission Organisation and ISO for the Mid-Atlantic region of the USA (this region includes all or parts of seven states and the District of Columbia). PJM is both the region's System Operator and Market Operator and it is independent of the Transmission owners. PJM is directly interconnected to five TSOs in NY, Virginia, Ohio and Pennsylvania. Total peak load is 64 GW and the cross border transfer capacity is 3.5 GW.

2.1 USA (PJM): current methodology

Congestion Management is defined in terms of area effected: (1) internal effects, (2) adjacent interregional (cross-border) effects, and (3) non-adjacent (off-system) regional effects. Using Locational Marginal Pricing (nodal pricing), PJM manages congestion using a centralised dispatch/redispatch co-ordinated with Financial Transmission Rights (to allow members to manage congestion "risk"). PJM's goal is, without jeopardising transmission system integrity, to place congestion management in the hands of its market participants through "market-driven redispatch". PJM handles both Internal and Cross-border congestion in the same way – through Locational Marginal Pricing. Although PJM's nodal pricing methodology is not used by all of its neighbours, and such inconsistency allows for the possibility of arbitraging those inconsistencies, nodal pricing still provides the correct solution for the resources within PJM. Non-adjacent regional congestion is handled by an interconnection-wide Transmission Loading Relief process.

PJM supports bilateral transactions in three ways – through a day ahead financially binding forward market, a real time physical market, and a Financial Transmission Entitlements market. These three markets "provide the mechanisms to manage transmission congestion in system operations, while integrating with and facilitating forward trading of energy and financial entitlements." [3] Unique ownership and operational agreements (such as Phase Angle Regulators, or jointly owned generation) are handled through ad hoc negotiated inter -regional procedures.

2.1.1 Transactions and Redispatch

Market redispatch actually begins in the transaction creation process, where market participants can declare that their respective transaction should be curtailed prior to any redispatch (i.e. they are unwilling to pay congestion charges). Prior to redispatch the PJM System Operator will curtail these transactions. The redispatch process continues when PJM System Operators request generation redispatch. Out of order redispatch signals result in nodal price differences. Under nodal pricing, loads must pay for energy at the load's nodal price, generators get paid at their nodal price, and point-to-point transactions pay the difference between the nodal prices at the identified source and sink multiplied by the size of the transaction.

Those generators on the constrained side of the congested path must decide whether or not to receive a reduced payment for generating and those suppliers on the unconstrained side must decide whether the increased cost is high enough for them to increase generation. On the demand side, those participants whose transactions adversely impact the congestion will face higher costs. Those participants will decide whether or not to continue with the transaction or to curtail the transaction (thus reducing the problem). Market participants are also encouraged to create transactions that will relieve the congestion. In the case of cross-border congestion the 'signals' may differ but the concept is the same – provide the correct market signals to the PJM participants to allow the PJM participants to make the choice in how to relieve the congestion.

This approach does two things: it encourages proper real time behaviour as it relates to congestion management and it also identifies to the public where added resources should be installed (to maximize profits). The major advantage of this approach is there is no delay between the time the constraint is identified and the time that redispatch actions are taken.

LMP provides an effective market solution for internal and for cross-border congestion. Non-adjacent congestion (i.e. congestion caused by one region on another non-adjacent region) is addressed by a non-market, transaction-focused, interconnection-wide Transmission Loading Relief (TLR) process.

2.1.2 TLRs

In North America, the TSO is responsible for solving congestion within its own region. When the TSO has exhausted its congestion options, that TSO may make use of an interconnection-wide power flow analysis program. This program identifies sources of congestion caused by external point-to-point transactions. These sources of congestion can be requested to relieve up to their respective pro-rata impact as calculated by the TLR program. At issue with this procedure is that it is focused on curtailing market activity and does not readily lend itself to non-transaction based solutions.

2.2 USA (PJM): future developments

The current 'regional' redispatch process works better as the area of the Energy Market increases (thus avoiding the issues of off-system impacts). Inter-regional congestion management provides market participants with gaming opportunities i.e. the ability to hedge across regional boundaries. Until there is a single market, there will continue to be a need for ad hoc cross-border congestion management procedures.

Until common Market Designs, such as those being envisioned by the Federal Electric Regulatory Commission, are effected throughout the interconnected region, conflicting market timing rules, operating procedures, and co-ordination will continue to adversely impact the growth of energy markets. In addition transmission availability, capacity liquidity/deliverability and settlement disputes over transaction disputes will continue to be a problem.

Market solutions that economically include demand side solutions are and will continue to emerge. PJM's has implemented an initial Demand-side market and will continue to explore ways of expanding that market. Inclusion of demand side solutions will greatly expand the options, and competition, needed to manage congestion.

Nodal prices do not guarantee transmission or generation facility investments. Open information of nodal prices, system conditions must be followed up by mandatory, regulatory and market-supported backup procedures.

3 Brazil

ONS is the ISO for the Brazilian Interconnected System responsible for system operation as well as transmission services and transmission access. ONS is not responsible for the operation of the wholesale market, this function is performed by MAE. There are 3 major interconnections with Uruguay, Argentina and Paraguay. These interconnections are equipped with HVDC facilities, for different nominal frequencies (60Hz at the Brazilian side and 50Hz at the neighbouring countries). The interconnection with <u>Uruguay</u> is a HVDC back-to-back link with 70MW nominal capacity; located on the border at Rivera city. The interconnection with <u>Argentina</u> is composed of a 50MW nominal capacity HVDC back-to-back link located at Uruguaiana and two HVDC back-to-back links (2x500MW) each one with associated AC transmission systems in Brazil and Argentina. The interconnection with <u>Paraguay</u> is different. The Itaipu hydro plant is located at the Paraná river on

the border of Brazil and Paraguay, and belongs to both countries half by half. Itaipu hydro plant has 18 units (700MW each), 9 at 60Hz and 9 at 50Hz. There is a 750kV trunk (3 circuits) connected to the 60Hz side that supplies directly the South and Southeast Brazilian regions. The energy of the 50Hz units supplies the Paraguayan system by means of 500/230kV transformers and the Brazilian system by a double bipole HVDC link (± 600kV), from Foz Iguacu (Itaipu) to Ibiuna (São Paulo state).
The peak load of the Brazilian system is 56196 MW and the cross border transfer capacity is 2000 MW for the Brazil-Argentine interconnector and 12300 MW for the Brazil-Paraguay interconnector..

3.1 Brazil: current methodology

The two main interconnections (Garabi and Itaipu) are considered.

3.1.1 Garabi (Brazil-Argentina)

There is an agreement between ONS (Brazil) and CAMMESA (Argentina). Although having different attributions, ONS and CAMMESA are the ISOs for the Brazilian and Argentinean grids. The access to the interconnector is done through them. In the short term planning (1 month ahead) a first evaluation is made with no commercial concern. This first interchange estimate is detailed by load period (heavy, medium and light load) on a weekly basis, with no commercial concern.
The commercial agreement is made for the day after, on an hourly basis. Nowadays this interconnector operates with power flow from Argentina to Brazil. At the time of concluding the contract, only imports from Argentina were considered. Recently, due to the new energetic and economical scenarios, exports from Brazil are being considered. The price of energy is defined by contract and updated by economical indexes. There is a fixed payment for the availability of the convertor substation. ONS imports energy surplus when the agreed price is lower than the Brazilian energy price.

3.1.2 **Itaipu (Brazil-Paraguay)**

Practically all payment due to Itaipu is related to the installed capacity. Brazil buys all the energy produced at the 60Hz side and the remaining energy produced at the 50Hz side not consumed by Paraguay. Dispatch of Itaipu is defined by ONS. Furnas and Eletrosul, two federal state utilities that own the transmission system connected to the Itaipu plant, buy the energy on behalf of the Brazilian system and deliver this energy to all the distribution utilities. The amount of energy to each distribution utility is defined based on its share of the Brazilian energy market, verified in 1992. The operational and maintenance costs and the investments associated with the 750kV trunk and HVDC bipoles are paid by the distribution utilities.

3.2 Brazil: future developments

Considering the natural gas availability in other countries, mainly Argentina and Bolivia, there are some projects in evaluation considering the following alternatives: Construction of gas thermal plants in Argentina and/or Bolivia and AC-60Hz system to transmit energy to Brazil. New HVDC interconnections on the borders.
There is a necessity for detailed analysis of regulatory questions in order to permit the progressive implementation of competitive markets. This is essential in order to attenuate the internal resistances of some generation and load agents to the economic benefits of the international energy trade.
There is a necessity for a more integrated planning involving all the South-American countries in order to take advantage of energetic “complementarities” of the neighbouring countries (gas and electricity surplus in Brazil).

System information development, including real time, to permit the demand supply with economic dispatch and to take advantage of the different peak hours.

4 Norway

In the Nordic countries there is a common electricity market for Denmark, Finland, Norway and Sweden. In these countries there are five TSOs, one in each country and two in Denmark. In the Nordic market there are common basic rules for congestion management, but with some national differences in the implementation of the rules. The fundamental principle is to use market splitting for structural bottlenecks, while more temporary transfer limitations are solved by counter-trade. This description will mainly address the basic Nordic principles and especially the solutions in Norway.

Statnett SF is the TSO for Norway. Norway has interconnections to Sweden (3350 MW), Denmark (1040 MW), Finland (100 MW) and Russia (50 MW). There are three HVDC links (1040 MW) to Denmark. There are seven interconnections to Sweden (3x420 kV, 1x300 kV, 1x220 kV and 2x132 kV). There is one 220 kV interconnection to Finland and a 154 kV interconnection to Russia. The recorded peak load of Norway is 23054 MW. The cross border transfer capacity is some 20 % of the peak load, well above the EU-Commission goal of 10 %.

4.1 Norway: current methodology

The basic principle of handling congestions in the Nordic market is a combination of market splitting and counter-trade. Congestion management is performed in close cooperation between the TSOs and the Nordic electricity exchange, NordPool. Every morning before 10 am the TSOs inform NordPool about the capacity on all interconnectors between the countries and on important internal cross-sections for each hour the next day. This information is made available to market participants before they bid into the physical electricity spot market at 12 am. Normally the Nordic market is divided in 6 bid areas, one in Finland and Sweden and two in Denmark and Norway.

After the bids are received the market price is decided using the basic principle for market price calculation:

- Find the balance price in the whole system assuming no congestion. This price is called the system price.
- In case any congestion is present, recalculate the balance price in each area affected by the congestion. The transfer capacity between the areas is used to the maximum taking into account technical limitations. Reserve margins are also accounted for.

By this method, trade of energy and capacity is taking place at the same time. There is no need for separate capacity trading. The existing capacity is made available to the market participants in a non-discriminatory fashion. Prerequisites for using the method, is one or more electricity exchanges and cooperation between the exchanges and the TSOs.

If a temporary bottleneck should occur after the electricity spot trade, due to disturbances or other reasons, this congestion will be solved by the TSOs using counter-trade. With counter-trade generators are paid to decrease their generation on the surplus side of the bottleneck and similarly paid to increase their generation with the same amount on the deficit side. This amount of power will then flow in the opposite direction to the power the market participants wish to transmit, and this extra capacity can be made available to the market.

There is no priority on the use of connections for import/export to Norway. Bilateral contacts are processed similarly as the power in the spot market. This implies that in the spot price calculations, all actors must bid into the predefined price areas. Each actor must be balanced within each area. A producer supplying customers in another price area will get paid according to the price in the injection area and have to buy the required resources in the supply area. A price risk will be present with the market split. Special contracts, contracts for differences (CfD), can be signed to reduce the price risk.

The market splitting principle will generate income from the power flow between the congested areas. This is a capacity fee and amounts to the price difference times the physical flow. The income is shared between the involved TSOs and is used for reinforcements and tariff reductions.

The costs incurred by the TSOs in counter-trading are the costs of purchasing power (upward regulation) less the revenue from the corresponding sale of power (downward regulation). The market participants do not see explicitly the costs for counter-trade, it adds to the network tariff.

The amount and duration of congestions between Norway and the neighbouring countries depend on the hydrological conditions in Norway. Year 2000 was an extreme wet year, and there was congested flow from Norway to Sweden in south for slightly less than 65 % of the time. The additional need for transfer capacity to produce a completely uncongested case would have been 3400 MW. In 2001 which was a normal year, the duration of congestion was only 3 % of the time.In north, the duration of the transfer limitation was shorter, in year 2000 25 % of the time and in 2001 11 %.

4.2 Norway: future developments

Work is going on to harmonize the congestion management principles applied in the different Nordic countries. Especially the appropriateness of using the borders between each country to define the congestion areas is discussed. It is argued that the utilization of the network would have been enhanced if more physical conditions were accounted for in the definition.

Furthermore when the TSOs are responsible for reduction of capacity due to outages, there will be an increased use of counter-trade to eliminate this capacity reduction for the market.

Work is also going on analysing the benefits and costs for the market players at different levels of counter-trade.

5 The Netherlands

TenneT is the TSO for the Netherlands. There are three interconnectors with Germany, and two with Belgium. Peak load of the Netherlands is 14200 MW and the cross border transfer capacity is 3600 MW.

5.1 Netherlands: current methodology

Before 2001 “first-come-first-serve” and “proportional allocation” methodologies were used to allocate cross-border capacity. Due to high market price differences between the countries, there was an enormous interest of traders to acquire import capacity to the Netherlands. Therefore it was considered necessary to implement market-based solutions for capacity allocation. For that reason, the four TSOs are operating a joint entity “TSO Auction” since January 2001 to allocate the capacity at the Dutch-German and Dutch-Belgian borders by means of auctions [2]. Separate auctions are held for import and export, for three different time periods (yearly, monthly and daily) and for the borders between the control areas (TenneT-EON Netz, TenneT-RWE Net and TenneT-Elia). This means that in total 18 different types of auctions can be distinguished. The auctions are also called “explicit auctions”, which means that only capacity is auctioned and energy is allocated by other market mechanisms. Participants can submit bids (price and volume) with a maximum volume of 400 MW per participant. The selling price is determined by the marginal bid (lowest bid price to which capacity is allocated). The revenues obtained are split between the four TSOs. The TSOs are allocating firm capacity, which means that congestions during real-time operation must be managed by the TSOs. However, in extreme situations (force majeure), TSOs have the right to cancel allocated transfer capacity to a maximum number of occurrences per time period per type of gained capacity (year, month, day). More information on the auction rules can be found at www.tso-auction.org.

5.2 Netherlands: future developments

The current auction procedures have been very successful in allocating cross-border capacity in a fair (market-based approach) and transparent way (based on published rules). An additional advantage is that the rules are harmonised for the different borders. Still, some difficulties or disadvantages can be mentioned:

- The TSOs might have little incentives to invest in additional capacity, as this will reduce the revenues obtained through the auctions.
- As the different interconnectors are located in different positions in the meshed network, the available transfer capacity for each of the interconnectors is dependent on the flows through the network, that namely vary due to changed generation dispatch, topology of the network and load in the area (e.g. special holidays). As the TSOs want to allocate firm capacity, they have to make somewhat conservative estimations on these possible dispatch scenarios. (This disadvantage also applies to many other approaches).

The TSOs are currently developing procedures to improve data exchange in order to further optimise the capacity determination process. This exchange will be done on a daily basis and includes hourly information on generation, load and network status data. Another development is the introduction of coordinated real-time congestion measures, including cross-border redispatch to assure the firmness of the capacity sold to the market.

Other possible developments are to let more TSOs participate in the capacity allocation procedures and to coordinate network investments.

6 Spain

In the case of Spain, REE is the TSO and there are four interconnections with Portugal , four with France and one with Morocco. Peak load of Spain is 35 GW and the cross border transfer capacity is about 2.2 GW.

6.1 Current methodology

In the Spanish electricity market, it is possible to submit bids to the daily market (Power Exchange operated by OMEL) or to execute bilateral contracts, and both transactions will be considered to solve the cross-border congestions. This approach applies to all interconnectors.

There are two steps in the matching process. In the first step the international exchange is unconstrained, and a marginal price is obtained. If the matched energy plus the bilateral contract volume are exceeding maximum cross-border capacity this must be split between both transactions proportional to the matched energy and the energy executed in the bilateral contract. The second step is a matching process in which the exceeded matched energy for the daily market is rejected using price precedence order. The exceeded executed bilateral contracted energy is rejected through an auction that is run after the matching process only in case of congestion.

Main disagreements to this method are:

- In case of congestion, utilities that execute bilateral contract must pay to use the interconnector, while utilities that match energy in the daily market don't have to pay to use it.
- Splitting capacity between the daily market and bilateral contracts can be regarded as arbitrary and not "market based".

6.2 Future developments

Different methods to change the current methodology have been proposed to the Spanish ministry. One of them was based on an explicit auction and the other was based on an implicit auction (market splitting). Neither of these two proposals has been considered until now. Another possible new method based on simultaneous auction of energy and cross-border capacity, both managed by the Power Exchange (OMEL), is described below. In this new method, both bilateral contracts and participants in the daily market must compete for the available capacity in case of congestion.

The participants in the Spanish Electricity Market can submit bids (price and volume) to the daily market or execute bilateral contracts. Moreover, those agents who are in areas with limited exchange capacities (External Agents, EA) can submit bids to obtain cross-border capacity or sell capacity previously bought. EA can send three types of bids: a) Energy bids (price and volume, import or export bids); b) Capacity bids (price and volume, import or export capacity bids); c) Both capacity and energy bids.

Energy and capacity auctions are always simultaneous but matching conditions in both markets are different depending on time horizon:

- **Annually, Quarterly and Monthly markets**

In the long time horizon, transmission capacity allocated to a certain EA participant does not necessarily have to be equal to energy volume allocated in the daily market or bilateral contracted energy that can be below or over the capacity allocated.

- **Daily and Intra-day markets**

In the short time horizon, energy bids will be accepted in the daily market or bilateral contracts will be executed only if the corresponding cross-border transmission capacity is allocated in the capacity markets and vice versa. In case of congestion, all EA energy bids in each area without transmission capacity or not matched in the energy market must be matched amongst themselves. As a result, a different price will be obtained in every geographical area in case of congestion.

In real time, EA scheduled energy without the corresponding capacity allocated previously in the capacity markets will be removed by the System Operator.

7 Comparison

7.1 Comparison of current methodologies

All countries use different methodologies, in case of Brazil different interconnectors are dealt with in different ways.

In Brazil capacity of interconnectors is used directly by the ISO depending on market prices (e.g. interconnector with Argentina) or it is used by existing utilities.

In the USA PJM uses a security constrained dispatch/redispatch to deal with congestions also for interconnectors. This centralised dispatch results in nodal prices and these prices include both energy as well as congestion costs.

Spain also applies central dispatch, but has no nodal prices. Capacity on interconnectors is allocated over transactions on the central market and over bilateral transactions. Both types of transactions are dealt with in separate ways.

Norway and the Netherlands have a very similar market design, with self dispatch and a voluntary Power Exchange. Still cross-border congestions are dealt with differently. Norway allocates all capacity through the spot market through a market splitting mechanism. In the Netherlands all capacity is allocated through a number of auctions. Norway uses counter trade by the TSOs to deal with constraints in operation, whereas this is not yet the case for the Netherlands.

7.2 Comparison of future developments

All countries are looking for further improvements. Most drastic changes can be expected in Brazil, where third party access to interconnectors is not possible yet. The other countries are looking for further improvements based on the existing methodologies, with the main goal to better facilitate the market. In the case of PJM improvement is sought in extension of the market area. A special problem arises in the case of interconnectors being part of heavily meshed networks. Increased cooperation between SOs is necessary.

8 Concluding remarks

The System Operators discussed in this paper are facing the process of liberalisation, which is an evolutionary process. The driving forces are the same: facilitate the market and maintain security of the power system. The solutions for cross-border congestion management are different and are being improved. Countries that are still preparing liberalisation are in the position to learn from these experiences and may be able to define congestion managemenet methodologies based on longer term objectives. Harmonisation with neighbouring countries remains the main challenge.

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