THE INTEGRATION OF INDIVIDUAL ELECTRICITY MARKETS REQUIRES STRONGER COORDINATION AMONG TSOs

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Abstract – TSOs are responsible for maintaining system security. For international trade, this requires coordination among TSOs. One of the existing tools is the NTC calculation for estimating available cross-border transmission capacity, while different methods are used for allocation of this capacity. Day-ahead data exchange between neighbouring TSOs allows estimating the probability of congestions. These methods have to be further developed. Examples illustrate the occurrence of high-risk network situations in the Northwestern European network. Growing market pressure, shorter time-scale trading, increased wind production, the wish to fully exploit any new grid elements and most of all the need for a true integration into a single European market for electricity will further increase the need for a better and deeper coordination between TSOs.

Keywords: electricity market, system security, congestion management, coordinated auctioning, grid investments

1 INTRODUCTION

In the liberalised electricity markets, the transmission system operators (TSOs) play an essential role in maintaining system security, while at the same time facilitating the free market to all players with a minimum of restrictions. Within each country or control area, at least one TSO is responsible for this.

For the real integration of the various national electricity markets into one European electricity market, cross-border trade and congestion management mechanisms are needed, which should allow a maximum use of the existing transmission assets without endangering European wide system security. Some mechanisms are already in place for coordination between TSOs, but further development is needed to allow a growing trade.

In this paper, an overview will be given of the existing mechanisms, some critical network situations that occurred in the Benelux area in 2004 will be discussed, and ideas for further development of market mechanisms will be proposed.

Grid investment will not be discussed in detail, given the different time scale required for investments. The aim of market mechanisms is to allow the maximum use of existing assets in a secure and economically correct way, with potentially an indication of the areas where investments would be most useful.

2 EXISTING SITUATION

2.1 *Regulatory context*

The principles of system operation within each control area are governed by national regulation, describing the conditions imposed on market players for access to the system, as well as the ancillary services delivered by the system operators to guarantee the safety of the system.

For cross-border electricity exchanges, there is no single regulator. Principles are developed and proposed between the TSOs, the Council of European Energy Regulators (CEER) and the European Commission (EC). From the side of the EC, there is a clear push to use market mechanisms.

2.2 *Organisations of TSOs*

ETSO, the organisation of European TSOs, mainly works on market mechanisms. They are the central interface to market players, the CEER and the EC. ETSO comprises members of the various synchronous areas in Europe.

For the European continent, UCTE (Union for the Coordination of Transmission of Electricity) is responsible for developing the rules for system operation between the TSOs on a more technical level.

2.3 *System operation*

The TSOs are responsible for the daily operation of the system in their control area, and for the interconnection with the neighbouring systems. For this, they can conclude operational agreements with the other TSOs and with market operators like power exchanges that are active in several control areas.

Individual market players such as producers, traders, suppliers and consumers have access to the interconnected network through contracts with their local TSO and nominations on the borders for trade with counter parties in other control areas.

2.4 Contract path – Physical flow

The use of a highly meshed network like the European power system requires a proper coordination between all the nominations from market players and power exchanges. These nominations per border only give a contractual path, and give no accurate prediction of actual physical flows over the borders [1].

The difference between the overall physical flows (including loop flows) and the contract path flows is called the unidentified flow.

The physical flows result from the combination of all the entries and exits of power in each node of the transmission network. At the very least, a net balance of all nominated cross-border transactions is needed to estimate the physical flows across the borders between neighbouring control areas.

This flow may lead to congestions at the borders or within individual control areas that jeopardise the usual high level of system security.

2.5 Preventive – corrective management

The aim of market mechanisms for congestion management is to prevent congestion based on announced transactions; this will be the subject of the remainder of this paper. In real-time, there will always be deviations from the expected flows, for which a more limited set of corrective actions is available. Topological changes in the power system may provide some help, but redispatching will most likely remain the main tool.

If these do not suffice, load shedding and transaction curtailment would be needed as a last resort.

2.6 Capacity determination

At present, the capacity for cross-border transmission is calculated with the NTC concept as defined by ETSO [2], [3].

In short, the maximum allowable power shift across a specific border relative to a reference situation is calculated, assuming the flows across other borders do not change and taking into account a transmission reliability margin.

The NTC values are calculated at least twice a year, for summer and winter conditions. These values are always indicative.

For those borders where TSOs expect congestion, the indicative values are updated more regularly into operational values, in step with the anticipated changes in circumstances – grid maintenance, power plant operation, inter-TSO agreements, ... – and with the time frame used for the allocation of the capacity.

If no physical congestion is expected on a border, no operational update will take place in order not to create an artificial commercial congestion on the nominations for these borders.

By its very definition, NTC values for different borders cannot be combined. Furthermore, the choice of reference situation may have a significant impact on the resulting NTC values.

A more accurate way of taking into account the mutual influences of the transmission capacity available to the market, would be through the Power Transfer Distribution Factors, or PTDF.

In this method, the impact on every border between all control areas is calculated for a power transfer from any area A to another area B. The capacity calculations involved are much more complex, but the results more closely represent the reality of power flows in a meshed network.

2.7 Sequential approach

Limiting the cross-border exchanges to the published NTC values reduces the risk of congestion, but does not eliminate it.

It is important to note that determining the available capacity and allocating it to the market are today separate and sequential processes. This ignores the fact that unidentified flows and the interaction between different cross-border trades may increase or decrease the transmission capacity on any specific border that is actually available to the market.

As a result, the overall available physical cross-border transmission capacity is not used in an optimal way.

2.8 Existing mechanisms for capacity allocation

The existing mechanisms for allocation of available capacity will not be discussed in detail, but some elements can be mentioned [12].

TSOs will avoid having a double allocation mechanism on both sides of the border, to limit the commercial risk to the market players. However, there still are a lot of different techniques in use for the various European borders, even for the borders of one country. One exception is the Netherlands, where all the allocations for the different borders and the different timescales are organised through an auctioning mechanism.

A market coupling project is underway for the French, Dutch and (future) Belgian power exchanges.

An existing example of an implicit allocation mechanism is Nordpool, in the Scandinavian synchronous system Nordel.

Some other mechanisms that are still used are not market based, like access limitation, priority lists, or pro rata rationing.

European regulation from June 2003 prescribes that market based mechanisms have to be introduced.

2.9 Timescales of allocation

A final characteristic of capacity determination and allocation mechanisms is the timescale of the power transfers and capacity rights.

At present, most actual power transfers are arranged under longer time scales – year and month – and day-ahead contracts.

An evolution towards intra-day trade can be seen, with contracts concluded a few hours down to less than an hour in advance of the actual trades during the day itself.

This requires a close coordination with the development of balancing markets and the sharing of reserves between TSOs, as the implementation time of these products is very similar.

2.10 Other TSO duties

There are a number of other TSO duties with impact on cross-border exchanges that will not be discussed at present in the context of cross-border trade, in order not to unduly complicate matters.

These include frequency control, control of the contractual level of exchanged energy, guaranteeing the required levels of reserve power, and voltage control [15].

The UCTE is the body responsible for developing the technical guidelines that have to be observed at all times, to insure the system security, but it is one of the operational duties of the TSOs to foresee mechanisms for preventing congestion.

3 DAY-AHEAD CONGESTION FORECAST

3.1 Description

One of the most important tools existing at present for ensuring system security in a system highly stressed by insufficiently coordinated international trade, is the Day-Ahead Congestion Forecast, or DACF [14].

This system was developed by the TSOs of Belgium, France and the Netherlands, and is now extended to other TSOs. It consists of a daily exchange between the TSOs of the expected situation within each control area for the day-ahead, taking into account their cross-border nominations. This allows all TSOs to check the situation within their control area and at the borders, via full load flow and contingency calculations using a more detailed and accurate model of the neighbouring systems.

Although the system itself does not solve any congestion problems created by lack of coordination of cross-border trades, it can be a very useful trigger to coordinate countermeasures when needed.

3.2 Limitations

One limitation of the system is that, at present, only a few time-stamps for the next day are used. Intraday trading is not foreseen.

Load and production forecast errors – especially wind energy production – and unplanned outages of generators or transmission elements may have a major impact on the actual load flow and congestion situation.

3.3 Developments

Calculating a DACF for each hour of the next day would be a first step forward.

To reduce the impact of forecast errors and outages, one or more hourly time-stamps could be calculated not the day before, but every couple of hours for the next couple of hours, in a sliding window approach. This would also be required for intraday trading.

A more fundamental step forward would be not only to exchange raw data, but also to share the results of the security analysis performed separately by each TSO.

4 COORDINATED COUNTERMEASURES

With a high availability of data, congestion can fairly easily be predicted. Agreeing on appropriate preventive or real-time countermeasures can be more difficult. Negotiations between TSOs on general principles should lead to contractual agreements, which can be implemented when needed.

4.1 Efficiency

Topological changes are cheap in direct cost, but effective ones are not always available. Furthermore, the impact on neighbouring systems may be difficult to assess. Very unusual configurations may even lead to unforeseen problems in other parts of the TSO’s own control area.

Redispatching is by its very nature always available but expensive; essentially redispatch means that TSOs embark on a transaction against the direction of the market. Redispatch between the TSOs immediately next to the congested border will be most effective, but also most expensive as it constitutes a trade against a strong market push that caused the congestion. Redispatch with TSOs further away from the congested border will require larger volumes, but may turn out to be less expensive.

4.2 Cost allocation

An unsolved problem is the allocation of both the causes and the (cost of) countermeasures to specific transactions.

There is no easy geographical link between the "origin" of a congestion, the place of the congestion and the possible locations for counter-measures.

Also, there is no objective reference situation on which to superimpose congestion causing or alleviating transactions, even if a reference situation had to be determined to calculate NTC values.

4.3 Real time data and information exchange

Progress has been made in better data exchange between TSOs, using the Electronic Highway and the TASE2 protocol. Even if the amount of real-time data should still be increased, this only represents raw data used by each TSO in their own state estimator and security analysis.

Real progress, as mentioned earlier, would be made by a better exchange of richer information, such as available countermeasures or clearer information on margins known to one TSO but not obvious to the other TSOs.

5 GROWING NEED FOR COORDINATION

Several elements will lead to a growing need for coordination.

The first and most obvious one is the market pressure for more available interconnection capacity. Grid investments take a long time, and may be hampered by public opposition against new overhead lines. Also, even after grid investments, there will remain a constant pressure towards a more optimal use of the existing infrastructure.

The full use of new infrastructure in one country or across one border may increase existing problems or cause new problems in other areas of the interconnected network. Without a more coordinated approach, new investments may not deliver the intended increase in cross-border capacity.

The growing amount of installed wind power and the difficulty to accurately predict wind production increase the strain on the operational, real-time control of the system.

Finally, as the markets develop towards higher levels of trade at shorter time intervals, higher demands are imposed on the TSOs.

6 CRITICAL NETWORK SITUATIONS

Two examples of critical situations in the Benelux network may illustrate some of the points mentioned above.

6.1 February 24, 2004

Traditionally, flows through Belgium are dominated by a large south to north flow, from France though Belgium to the Netherlands. On the 24^{th} of February last year the DACF predicted very high exports from Germany – mainly from the north – and low exports from France, causing a very high flow from Germany through the Netherlands and Belgium to France. The forecast showed a severe situation on the German-Dutch border. Opening one line from Maasbracht (N) to Siersdorf (G) and separation of the connection Rommerskirchen (G) – Maasbracht (N) – Meerhout (B) from the rest of the Dutch network allowed operating the system with a safe base case. However, potential risk remained in the German network near the Dutch border in N-1 situations.

6.2 June 12, 2004

On the 12^{th} of June 2004, high exports from France and high imports to Germany were expected. Comparison between the DACF and the actual flows showed that actual flows through Belgium and the Netherlands were 20% higher still than expected.

Several causes were identified, including a shift of 1500 MW of production from one part of Germany to another, the operation of the phase shifting transformers on the Dutch-German border, lower production in the Netherlands and higher import into Belgium.

The high flows across the French-Belgian border could have had a cascading effect, which would have moved the problem to the neighbouring TSOs of France, the Netherlands and Germany.

Opening the Belgian-Dutch border would have solved the immediate problem for Belgium and the Netherlands, but would again have moved the problem to, mainly, Germany. Furthermore, the angle difference across the Belgian-Dutch border after opening of the border would have been too high to allow an automatic reclosure of the interconnection lines.

Separation of busbars in one of the main 380 kV substations in Belgium was required.

6.3 December 30, 2004

The market situation in the Netherlands and Belgium was as usual in the given circumstances. Due to the lack of an allocation algorithm in the direction from Germany to France, an amount of contractual exchanges exceeding the default NTC value by 2000 MW had been nominated by market players. TSOs had to curtail the nominations down to the NTC value in order to avoid or limit congestion of German networks. In spite of this corrective action very high loop flows from North to South were measured in the systems of the Netherlands and Belgium.

6.4 Lessons learned

Both situations presented a UCTE network situation with high risk. Some observations can be made from these events.

For the security point of view, the Belgian and Dutch networks can be considered as a sole system. Problems occurring in one part of the system can quickly move to the other part.

Each TSO is responsible for the security of his system and is able to manage the situation in his own network, but it is difficult for him to evaluate the risk of moving the problem to his neighbours.

Opening the south or the north border of Belgium e.g. could solve congestion problems for Belgium, but could move the problem to France or Germany, and reclosure could be difficult due to the angle difference. Clearly, opening a border is only the last emergency measure.

An increased and improved communication between the TSOs of France, Belgium, the Netherlands, Germany and sometimes Switzerland, is needed to prevent these high-risk situations from occurring, or at least to allow a safe resolution. The results of DACF analysis should be exchanged and discussed, pointing out potential problems. Changes in the internal network that could influence the real or forecasted flows should be announced as quickly as possible. Exchanging real time information should allow each TSO to have an accurate and reliable view on the whole system.

Clearly, the DACF as used today is a very important first step and a good starting point, but its limitations do mean a further development is required, as discussed in paragraph 3.

7 ETSO VISION

7.1 Principle

The ETSO vision can be expressed as follows [5], [6]:

"Our goal is to create the network access arrangements that the market needs to enable effective competition across Europe, and to optimise the use of the network in a pan-European perspective. This goal will be achieved by providing practical market based mechanisms to manage congestion between regions, while allowing the co-existence and evolution of different market-based structures within regions."

A practical mechanism to apply this vision is proposed, consisting of an integrated iterative optimisation method, in which the available capacity and the allocation are determined together through flow-based modelling, not as sequential steps.

7.2 Different kinds of bids

The first step in the allocation method is to gather all the bids for allocation. Different kinds of bids for different products can be used.

Explicit bids are bids for transmission right products only; they can be for entry into a system, exit out of a system, or transfer between two systems. Auctioning of transmission capacity, used e.g. by the Netherlands, is an example of this last kind of bid. Players who have obtained transmission rights can use this right to transfer energy.

Implicit bids are bids for energy injection and/or withdrawal, with the transmission rights being implicitly included. Market splitting is an example.

The congestion management method proposed by ETSO allows both kinds of products and all kinds of bids at the same time. This means no standardisation is required between markets using either method, and a gradual implementation is possible. Bilateral bids as well as bids from power exchanges are possible.

7.3 Allocation method

The allocation consists of an iterative optimisation. The target function to be maximised is the overall value of the accepted bids. The constraints are the generation-demand balance and the volume limits of all bids, but also and most importantly the inter-regional transmission constraints.

In this way, all interactions between the different power flows resulting from the accepted bids are taken into account, allowing an optimal use of the available transmission capacity, taking into account the security of the system. At the same time, the economic value of transmission has been maximised.

A priori calculated available transmission capacity, using NTC or PTDF values, are only used as indicative values to the market.

7.4 Flow-based market coupling

Together with the Decentralised Market Coupling proposed by the Association of European Power Exchanges, EuroPEX, the ETSO flow-based modelling is being developed into a flow-based market coupling mechanism [11].

8 FLOW CONTROL

8.1 Control area representation

One reason for sub-optimal use of the available transmission capacity between control areas, common to most if not all existing mechanisms, has not yet been mentioned.

All methods of capacity auctioning, market splitting, ETSO flow-based modelling or ETSO-EuroPEX flow-based market coupling use a highly simplified representation of the power system of the various countries. Often, an entire control area is represented by a single node, representing some electrical point of gravity. These nodes are connected by equivalent transmission circuits, with equivalent limits. Bids within one control area are assumed to be located at this fictitious single node.

The impact of the location within the control area of any single bid in the bidding process is ignored. However, if e.g. the westernmost connection between France and Belgium is congested, and their still is capacity left on the eastern connection, extra transit from France to Belgium may still be possible for a production unit located in the north-east of France, but not for a production unit in the north-west.

Since the mathematical models used at present, or envisaged for new methods like flow-based market coupling are not yet designed for making this distinction, safety margins have to be used to cope with the uncertainty on the exact location of the bids.

8.2 Phase-shifting transformers

Apart from HVDC links, phase-shifting transformers are the only means of controlling the path a power transit will follow - albeit an expensive method. They are being installed in increasing numbers at various European borders; one of their main objectives is to more evenly charge the different connections between two control areas, allowing a higher overall use of the connections. In the example of the Benelux, phase-shifting transformers are being planned at the Belgian-Dutch border, i.a. to control the flow distribution between the two main connections from France to Belgium. On four out of six line circuits connecting the Netherlands and Germany phase shifters are already installed.

8.3 Coordinated use

Without a coordinated use of these transformers, or even a coordinated decision on where to install them, phase-shifting transformers controlled by separate TSOs could be used against each other. Only a coordinated use will truly allow developing their full potential.

This will also allow reducing the safety margins necessary because of the uncertainty on the exact location within one control area of bids for power transfer. In this way, grid investments and market mechanism development could go hand in hand.

9 GENERAL CONCLUSION

The growing pressure of the market for more available transmission capacity, at shorter time intervals and in a less predictable production environment, can only be met through increased coordination between TSOs.

Investments take a long time, are expensive and may encounter public opposition. Once in place, the market demands full use of these new installations. Without proper coordination on the choice of grid improvements and their use, this may not be possible due to problems in neighbouring grids.

Particular mention should be made of the importance of phase shifting transformers.

The existing methods like NTC calculations and DACF are important milestones, but are to be further developed to allow a more optimal use of the transmission assets, without endangering system security. Not only raw data can be exchanged, but also richer information on system security.

Separate allocation mechanisms used by TSOs individually should be more coordinated.

Finally, different market mechanisms like auctioning and market splitting should be combined, allowing a gradual evolution towards a true single European market for energy.

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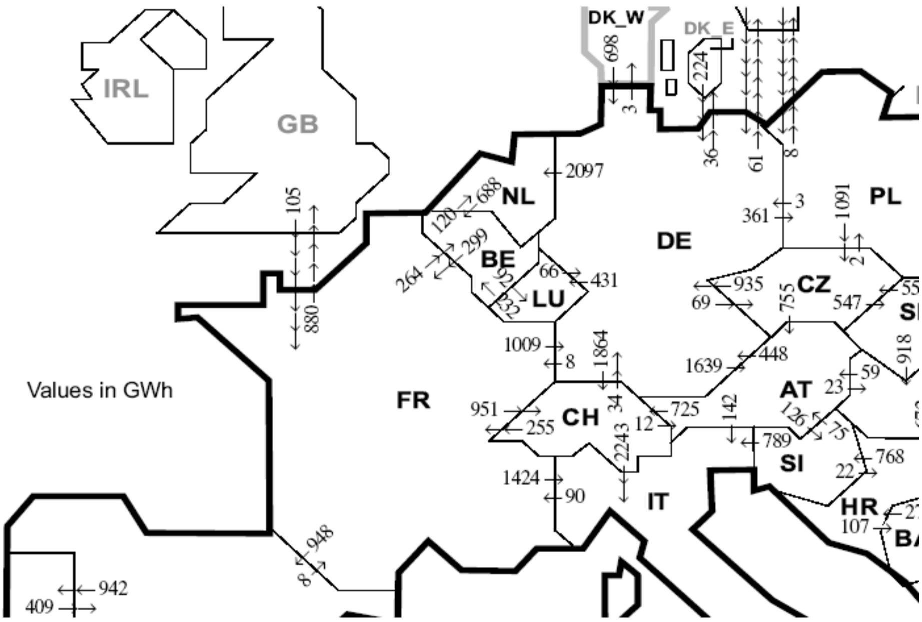

Figure 1 – Map of (part of) European power system