Assessment of geographic scope of electricity markets: the case of flow-based market coupling

Dmitri Perekhodtsev[1]

[1] LECG Consulting France SAS
72 rue du Faubourg Saint Honoré
75008 Paris, France
Phone: +33 1 40 07 85 40
E-mail: dperekhodtsev@lecg.com

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***Abstract* - European electricity markets are moving in the direction of market coupling and allocating the cross-border transmission capacity using implicit auctions. The tri-lateral power exchange combining the power exchanges of France, Belgium, and Netherlands is currently operational. German and Danish exchanges are to be coupled in June 2008. The integration of Netherlands, Belgium, France, Germany and Luxemburg is planned to be done by January 1, 2009.**

Such integrated clearing of European national electricity markets would allow for a more efficient use of available cross-border transmission capacity compared to current methods of congestion management. This could help expanding the relevant geographic markets beyond the national borders, and promote competition in the Internal Electricity Market in Europe.

Although integrated management of the power flows over the looped networks best reflects the physics of electric power flows, it significantly complicates the analysis of competitiveness and concentration in such electricity markets. The topology of geographic markets created by such constraints is often non-trivial.

This paper presents a methodology to assess the geographic scope of electricity wholesale markets in continental Europe implied by the cross-border transmission capacity allocated using the flow-based market coupling. This methodology applies the conventional methods of measuring unilateral market power in electricity markets, such as pivotal suppliers and residual demand elasticity, to perform a hypothetical monopoly test for identification of geographic relevant markets.

The paper analyses the change in the topology of relevant geographic markets expected from introduction of flow-based market coupling using an approximate model of interconnected transmission network of 17 European countries compiled by [1].

The contents of this article reflect author's views but not necessarily those of LECG.

I. INTRODUCTION

CURRENT electricity markets in Europe are mostly national in geographic scope due to limited cross-border transmission capacity. Historically, electricity grids within each country have been well developed and generally, little congestion occurs within the national borders. However, the cross-border interfaces often get constrained.

Partly, this happens due to methods used to identify and to allocate the cross-border transmission capacity. In particular, the transfer capacity between two countries is determined assuming fixed load and generation in other regions. This capacity is then allocated in isolation from the rest of the system. Such bilateral congestion management cannot explicitly take into account the fact that transfer capacity between any two neighboring states can be affected by generation schedules in other states. Instead, to make the current bilateral allocation of cross-border capacity feasible, only a part of actual cross-border capacity is made available for commercial use. The remaining capacity is reserved for cases of possible reductions of transmission capacity due to changes in generation schedules elsewhere.

Europe currently considers a proposal of flow-based market coupling, which suggests managing simultaneously all cross-border flows in Continental Europe. To do so, supply and demand bids from each national power exchange are converted into offer curves for export from or import to the each national power exchange. European Transmission System Operators would further consider and clear these export-import offers simultaneously meeting all cross-border transmission constraints. This will allow using the existing cross-border transmission capacity more efficiently accounting for flows on all cross-border links created by every transaction. Several European power exchanges have already started operating coupled market and more exchanges are expected to follow the suit soon.

The current small size of the national markets compared to the large national electricity generation companies raises serious concerns about the market power. Flow-based market coupling can potentially expand the relevant geographic markets by increasing commercially available capacity of the cross-border transmission links and thus can increase competition in the wholesale electricity markets.

The purpose of the paper is to measure the extent to which market coupling can expand geographic relevant markets and help reducing market power of large generators compared to the current state of the market. For that purpose, a standard method for identification of relevant markets applied in antitrust economics, the hypothetical monopolist test is adopted to the case of the wholesale electricity markets operating in a meshed transmission network.

The paper compares the results of the hypothetical monopolist tests obtained from application of two models of transmission network: one approximating the transmission capacity allocation under the proposed flow-based market coupling, and the other approximating current cross-border transmission management.

The remainder of the paper is structured as follows. Section II provides background information on concepts used in the paper: the European electricity markets and current approach to the allocation of the cross-border capacity, the flow-based market coupling proposal, conventional methods for assessing market power in electricity markets, and their application for the geographical market definition test; Section III describes the model used to perform the hypothetical monopolist tests for the geographical market analysis; Section IV provides the results of the application of this model to the European electricity markets; and Section V summarizes the results.

II. Background

A. Cross-border capacity allocation

The liberalization process has started in Europe in 1996 with the Directive 96/92/EC. The directive required electricity companies to perform a legal separation between the electricity generation, trading and supply businesses and to provide the access to the electricity grid for third parties. The directive however did not provide any specific regulations on the cross-border electricity trades or on the specific architecture of the wholesale markets. Therefore, European wholesale markets mostly developed separately from each other, within the control zones of the various transmission system operators, which often coincided with national borders. Much of wholesale power in the European electricity markets is traded bilaterally in forward and over-the-counter (OTC) markets. Retail suppliers buy power in advance using long-term and forward contracts to cover their consumption portfolio. Deviations of actual consumption from the quantities contracted by suppliers in advance are settled in additional daily and hourly spot markets. In order to facilitate spot market contracting most of the member states have created power exchanges to trade electricity one day before the delivery in hourly blocks.

The national spot markets usually do not account for the intra-zonal transmission congestion. The transmission operators manage intra-market congestions in separate balancing markets or by calling upon the generators with which special contracts for balancing services have been signed. The notable exceptions are markets of Nordpool (an electricity market combining the grids of Norway, Sweden, Finland, and a part of Denmark) and Italy. Internal congestion in these markets is dealt with through zonal market splitting [2].

In contrast to the national grids, interconnections between these grids are relatively weak and the cross-border transmission capacity is often a limiting factor in the cross-border transfers.

The cross-border congestion management is based on Net Transfer Capacity (NTC) between every two neighboring countries, that is then allocated in isolation from the rest of the system.

The methodology to determine cross-border transfer capacity available for commercial transactions, NTC, has been developed in 1999 by the European TSOs and it was used since then with little major modifications. The NTC between any two neighboring countries is calculated by TSOs in the following way.

First, a base case power system scenario of the European grid is established. This scenario includes generation schedules and consumption patterns. The Total Transfer Capacity between two zones is then calculated as a maximum interchange between the areas that does not violate transmission constraints while the base-case schedules in the rest of the grid are kept fixed. The calculation of the Total Transfer Capacity uses the full network model to account for indirect flows resulting from the base case power schedules and the interchange between the two considered regions.

To obtain Net Transfer Capacity the Total Transfer Capacity is reduced by the amount of the Transmission Reliability Margin. This is done to account for possible deviation of actual generating schedules from the base case scenarios [3].

This method determines transfer capacity between two regions in a very conservative way. Uncertainty about actual load and generation is only allowed to reduce capacity, although in reality the effect can be positive.

To allocate the scarce cross-border capacity, Transmission System Operators (TSO) mostly use market methods, such as explicit or implicit auctions. In explicit auctions, the TSOs act as sellers of the available transfer capacity and accept bids from potential buyers until the capacity is filled. In implicit auctions, the TSOs use supply and demand bid curves from the neighboring spot markets to value the transfer capacity [4]. The explicit auctions proved to be highly inefficient resulting in utilization of transfer capacity unrelated to price differences between markets. Flows going against the price differentials are common under explicit auctions. In implicit auctions the valuation of the transfer capacity is consistent with energy prices in neighboring areas by the design of these auctions.

B. *Market coupling*

The European Transmission System Operators (ETSO) in cooperation with the Association of European Power Exchanges (EuroPEX) have presented a proposal that could potentially improve the utilization of the cross-border transmission capacity by introduction of coordinated management of the European cross-border transmission.

Market coupling proposal suggests using supply and demand schedules from day-ahead power exchanges administered in neighboring states as inputs for the allocation of the cross-border capacity by an implicit auction. The process will simultaneously maximize the benefit from the trade between all regions as represented by the export-import bid curves while respecting the transmission constraints of the simplified transmission model [5].

The proposal suggests approximating the European electric system by a number of nodes, represented by single-price national markets, connected by notional transmission circuits comprising a simplified transmission grid. The flow properties of the simplified model will be described by the power transfer distribution factors, and thus the parallel flows will be explicitly modeled.

Some elements of market coupling have already been introduced in the Continental Europe. Currently, the tri-lateral power exchange combining the power exchanges of France, Belgium, and Netherlands is operational. The capacity between these countries is allocated simultaneously using implicit auctions. However, this capacity is still determined based on the NTC method.

Integration of power exchanges of the Netherlands, Belgium, France, Germany and Luxemburg is planned to be done by January 1, 2009. Using flow-based methods for this market coupling will be particularly important since this power exchange will clear markets over a looped system.

The market coupling using a stylized model of the European transmission grid is still an approximation of complexities of the actual system. Nevertheless, it is expected that this degree of simplification will provide a material improvement in the management of available cross-border transmission capacity. However, because of the simplified nature of the transmission model, some transfer capacity may still need to be reserved against the uncertainty of the unaccounted flows using a sort of NTC methodology. Such flows may occur, for example, because the single-price regions are not in reality represented by single transmission nodes and power transactions between different points within the same region may cause parallel flows across cross-border transmission circuits (“neighboring flows”).

The flow-based market coupling proposal resembles the principles of the LMP (Locational Marginal Price) markets used in many regions of the United States such as New York, New England, PJM, Midwest, and California.

In LMP markets a centralized agency (Independent System Operator) minimizes the total as-bid cost of the electricity generation needed to meet the system demand while respecting transmission constraints limiting the physical flows. This optimization uses a full network model; as a result, prices in each generator node are calculated according to the of this node effect on the constrained transmission lines. Nodal prices represent the cost of serving an additional MWh to the location to which they refer, while respecting all constraints.

In LMP markets generators are paid and the loads pay the price at their respective locations. Therefore, in the case of transmission congestion the payments from the loads exceed the obligations to the generators and this difference is collected by the transmission operator administering the market. To keep the system operator financially neutral a system of financial transmission rights (FTR, a.k.a. TCC, a.k.a. CRR) is often introduced to supplement the LMP market. Such contracts pay its owner the price difference between a pair of nodes for which a contract is specified. Another purpose of FTRs is to provide a hedge to their holders against the transmission congestion [6]. A similar system of financial transmission rights may be needed under the market coupling [7].

C. *Identification of geographic relevant market*

Conventionally, geographic relevant markets are identified in the antitrust practice using the SSNIP test, also known as the hypothetical monopolist test. This test is an iterative procedure that starts from the smallest candidate market and verifies whether, if this market was dominated by a hypothetical monopolist, a small price increase on the order of 5%-10% from the competitive price would be profitable for such a monopolist. Following the price increase, the demand faced by the hypothetical monopolist falls, either due to the demand substitution away from the monopolist’s product (demand-side substitution) or due to the increased supply of the product by competitors (supply-side substitution). If the reduction of the demand faced by the hypothetical monopolist is high enough to make the price increase not profitable, then the relevant market has to be expanded to include the neighboring market. The test is then repeated being applied to the increased candidate markets until the price increase implemented by the hypothetical monopolist over the candidate market is found to be profitable, at which point the candidate market is considered the relevant market.

In electricity markets, the profitability of a price increase by a generator is closely related to its “pivotality”, that is, the extent to which the capacity of this generator is essential in meeting the demand. Residual Supplier Index (RSI) can be used to measure pivotality of a particular generator. RSI is a share of demand that can be met without relying on the capacity of a particular generator. By CAISO definition, RSI is:

$$\text{RSI}i = \left(\text{Total Capacity} - \text{Supplier } i\text{'s Capacity}\right) / \text{Total Demand} \quad (1)$$

In other words, the RSI assesses the competitive constraints that the available generating capacity not controlled by supplier i exerts on this supplier in serving the total demand [8-9].

The Residual Supplier Index can be applied to the hypothetical monopolist test to provide a stylized measure of profitability of a price increase by the hypothetical monopolist. RSI value less than 1 means that the generator is pivotal, more than 1 – not. However, smaller values of RSI may still mean that the hypothetical monopolist cannot profitably perform a small price increase.

This paper does not precisely perform the hypothetical monopolist test, calculating the profitability of the price increase by the hypothetical monopolist in each candidate market. Instead, the effect on relevant geographic markets of more efficient use of transmission capacity due to market coupling is assessed using different values of the RSI as threshold levels of profitability of the hypothetical monopolist.

III. Model

The model presented below is used to identify the extent of "pivotality" of a supplier given the topology of the network, as well as the location of the generating capacity of the supplier under examination, competitive suppliers, and loads in the network nodes. The model chooses output of all available generators to minimize the output of the considered firm while meeting load in all locations and respecting constraints represented by available generating and transmission capacity. The minimum output that, according to the model, has to be provided by the examined supplier in order to meet the load allows calculating the RSI of the supplier in a given geographic market.

The model is presented in two modifications, each representing one of the two scenarios of cross-border transmission management mechanism: Flow-based market coupling and the current NTC-based cross-border congestion management. The difference between the flow-based and NTC scenarios is in formulation of the transmission constraints.

Model (2) below is applied to the flow-based market coupling scenario:

$$\begin{aligned}
&\min_{q_i, q_i^f, \forall i} \sum_{i=1}^{N} q_i \\
&s.t. \\
&1.\quad 0 \le q_i \le c_i \\
&2.\quad 0 \le q_i^f \le c_i^f \\
&3.\quad \sum_{i=1}^{N} q_i + q_i^f = \sum_{i=1}^{N} d_i \\
&4.\quad \mathbf{PTDF}^{(r)} \cdot \left(\mathbf{q} + \mathbf{q}^f - \mathbf{d}\right) \le \mathbf{L}_{mc}
\end{aligned} \tag{2}$$

The optimization program chooses the production of the examined supplier, q_i and the production of the competitive fringe in every node, q_i^f in every node *i*, to minimize the total output of the supplier. Constraints 1 and 2 limit the output of the supplier and the competitive fringe in each node *i* by their respective available generation capacity in these nodes, c_i and c_i^f. Constraint 3 represents the market clearing constraint suggesting that the sum of the inelastic demand in each node is equal to the total output of the examined supplier and the competitive fringe. Finally, constraint 4 represents the set of transmission constraints $\mathbf{L_{mc}}$ limiting the flows resulting from the net nodal injections and withdrawals. The power flow over each transmission facility resulting from the injections and withdrawals in the grid nodes is determined by the Kirchhoff's laws and is given by a linear relationship through the matrix of the power transfer distribution factors $\mathbf{PTDF}^{(r)}$. Each element of this matrix $\mathbf{PTDF}_{i,j}$ represents the flow over the constraint *j* resulting from 1MW power schedule between the network node *i* and a designated reference node *r*.

The optimization program (2) is a simplified dispatch problem solved by an ISO in an LMP market. The main difference is that instead of minimizing the total as-bid cost of the power generation, the problem (2) minimizes the dependence of the system on the capacity of a given supplier.

The model formulation representing the current European electricity market is:

$$\begin{aligned}
&\min_{q_i, q_i^f, f_j, \forall ij} \sum_{i=1}^{N} q_i \\
&s.t. \\
&1.\quad 0 \le q_i \le c_i \\
&2.\quad 0 \le q_i^f \le c_i^f \\
&3.\quad \mathbf{f} \le \mathbf{L}_{cb} \\
&4.\quad \mathbf{A} \cdot \mathbf{f} = (\mathbf{q} + \mathbf{q}^f - \mathbf{d})
\end{aligned} \tag{3}$$

Here, in addition to the choice of the output of the supplier and the competitive fringe in every node of the network, the flows f_j over each cross-border interface are explicitly chosen. Constraint 3 limits the cross-border flows within the cross-border NTC limits $\mathbf{L_{cb}}$. Constraint 4 ensures the balance of the net injections in each area with the total net inflows into that area including the cross-border flows. In particular, each element a_{ij} of the matrix **A** is either 0 if the line *j* is not attached to the node *i*; 1 if the line *j* leaves node *i*; and -1 if the line *j* enters the node *i*. Constraint 4 also ensures the overall balance of supply and demand in the system.

Models (2) and (3) are used to assess the "pivotality" of the hypothetical monopolist for the identification of the relevant geographic market implied by the cross-border transmission network allocated under the market coupling and under the current cross-border capacity allocation procedures. Following (1), the RSI can be calculated for each candidate market as a ratio of the total "competitive" import to the candidate market implied by models (2) and (3) to the demand in the candidate market.

IV. Results

A. Data

Data elements necessary for the analysis of the effect of the introduction of the flow-based market coupling on the competitive structure of the European wholesale electricity markets using the methodology described above include the data on the European electricity grid, generation capacity by country, and load scenarios.

An important element of the analysis is the information on the simplified European transmission grid connecting national markets such as the one mentioned in the market coupling proposal. This consists of the matrix of Power Transfer Distribution Factors and the capacity values of the cross-border transmission interfaces. The PTDF matrix was obtained from the model of the 1st synchronous UCTE region represented by 17 countries of continental Europe presented in [1]. The matrix calculated with France as a reference node is presented in Table 6 and the simplified network is shown in Fig. 1.

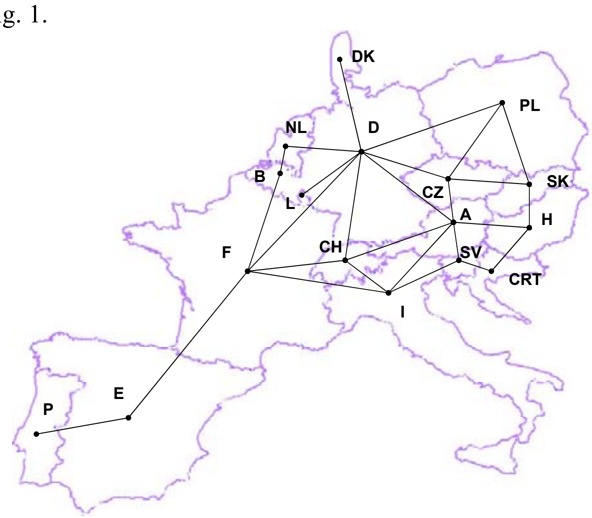

Fig. 1. Simplified network of the cross-border interfaces in continental Europe

The physical limits of the cross-border interfaces available under the market coupling proposal are also obtained from the model of [1].

The cross-border limits actually available for commercial trades in 2002, the period to which the model of [1] applies, were obtained from the publication of the cross-border Net Transfer Capacity (NTC) by the European Transmission System Operators (ETSO). The NTCs are defined separately in two directions, whereas the limits of [1] are directly related to the physical properties of lines and their limits are considered identical in both directions (see Table 1).

TABLE 1
LIMITS ON THE CROSS-BORDER TRANSMISSION INTERFACES IN 2002

Interface	Limit under Market Coupling, MW	Cross-Border NTC, MW	Current Cross-Border NTC Reverse, MW
E-P	2,275	750	650
F-E	2,954	1,400	1,000
F-I	3,413	2,600	0
F-B	2,828	2,850	2,650
Lx-B	0	0	0
B-NL	5,429	2,950	2,500
F-CH	7,126	5,350	0
CH-I	2,572	3,250	0
D-CH	1,580	2,750	2,750
SV-I	2,042	380	0
F-D	3,436	5,000	3,500
D-Lx	2,676	2,676	2,676
D-NL	12,892	3,000	5,600
DK-D	3,620	1,200	800
PL-D	6,324	1,300	1,300
A-CH	6,362	3,000	0
A-I	350	220	0
A-D	11,215	1,500	1,200
CZ-A	2,462	1,170	400
H-A	4,448	700	100
A-SV	2,151	800	800
CZ-D	6,576	2,320	700
PL-CZ	2,760	1,645	800
CZ-SK	4,190	1,740	1,200
PL-SK	5,736	500	500
SK-H	1,660	950	600
H-CRT	1,246	600	300
CRT-SV	7,191	1,000	1,000

According to Table 1, the physical cross-border capacity often exceeds the capacity available under the ETSO NTCs values. In particular, the data from Zhou and Bialek suggest the capacity connecting Germany and Netherlands, Germany and Austria, and Germany and Poland to be several time the NTC value. This may be due to the conservative way to determine NTC discussed above.

The generating capacity available in each country in 2002 is obtained from [10]. Finally, load scenarios for 2002 suggested in the model of [1] were used: Winter Peak, Winter Off-Peak, and Summer. These country data are presented in Table 2.

TABLE 2
TOTAL CAPACITY AND LOAD SCENARIOS BY COUNTRY

Area Name	Load Scenario			Total Capacity
	Winter Peak	Winter off-peak	Summer	
P	6,117	3,563	4,752	11,239
E	31,637	22,959	25,961	60,195
F	69,471	56,628	48,950	115,917
B	11,873	9,759	10,901	15,546
NL	13,138	7,237	12,538	20,800
Lx	800	1,013	741	1,596
D	69,497	49,899	62,103	124,980
DK	718	718	718	13,293
CH	9,407	9,170	7,994	17,313
I	49,641	28,768	34,193	79,744
A	8,335	6,281	6,793	18,021
PL	20,561	17,524	15,398	30,841
CZ	9,086	8,155	6,653	16,304
SK	4,025	3,539	2,980	7,964
H	5,697	4,402	4,573	8,513
SV	1,690	1,137	1,527	3,000
CRT	2,576	1,579	1,852	3,792

B. *Results*

Data presented in Table 1, Table 2, and Table 6 are used as inputs to models (2) and (3) to perform the iterative hypothetical monopolist test. The physical transmission capacity data presented in Table 1 suggest that the Market Coupling may significantly increase the import capacity into Germany. Therefore, the first series of geographic market tests is performed to verify whether the geographic market can be extended beyond the German national boundaries. For that purpose, the pivotality of the hypothetical monopolist over the German generating capacity is first tested. Then, the market definition test is extended to neighboring countries.

To contrast the situation with the German market, a similar series or tests are performed to test the effect of market coupling on the French market. These series of hypothetical monopolist tests under the lowest-load scenario, Winter Off-peak, are presented in Table 3 below. The table shows for each candidate market the market demand as well as the maximum amount of competitive import into the market resulting from the optimization models. The RSI is then calculated from these figures for each of the two congestion management methods.

TABLE 3
SSNIP TESTS FOR GERMANY AND FRANCE, WINTER OFF-PEAK

Candidate Market	Demand at candidate market	Cross-border allocation: Competitive import	Cross-border allocation: RSI	Market Coupling: Competitive import	Market Coupling: RSI
D	49,899	20,253	41%	34,938	70%
D-A	56,180	21,423	38%	36,886	66%
D-CH	59,069	25,853	44%	41,209	70%
D-CZ	58,054	21,178	36%	36,509	63%
D-NL	57,136	17,603	31%	27,001	47%
D-F	106,527	18,903	18%	42,213	40%
D-PL	67,423	20,253	30%	32,293	48%
D-A-CH	65,349	24,023	37%	42,233	65%
D-A-CZ	64,335	20,778	32%	35,440	55%
D-A-H	60,582	21,973	36%	34,768	57%
D-CH-I	87,837	29,053	33%	43,314	49%
D-A-CH-CZ	73,505	23,378	32%	40,139	55%
D-A-CH-CZ-SV-CRT	76,221	23,178	30%	38,251	50%
F	56,628	7,150	13%	19,757	35%
F-E	79,587	6,800	9%	19,078	24%
F-D	106,527	18,903	18%	42,213	40%
F-B	66,388	7,000	11%	22,358	34%
F-B-NL	73,624	7,500	10%	25,799	35%
F-B-NL-D	123,523	10,653	9%	32,118	26%
F-I	85,397	11,000	13%	19,780	23%
F-CH	65,798	12,900	20%	19,811	30%
F-CH-I	94,567	13,500	14%	16,445	17%

First, the national market itself is considered as a candidate market for the hypothetical monopolist test. If it is assumed that the value of RSI below 1 implies that a price increase by a hypothetical monopolist is profitable, then, according to the table, the geographic markets remain within the national borders of Germany and France even under the flow-based market coupling.

However, the situation is more interesting if a threshold value of 50% of RSI is adopted. This level of RSI implies that a half of the demand or more needs to be met by the capacity of the hypothetical monopolist for the price increase to be profitable for him.

Table 1 suggests that under market coupling the relevant geographic market may extend beyond German borders. In particular, Austria, Switzerland and Czech Republic do not decrease the RSI below 50% when the German market is expanded to include them, suggesting possible direction of the market extension. However, Netherlands, France, and Poland do decrease RSI below 50%, suggesting that these countries may not be considered in the same relevant market with Germany. After testing various combinations of countries, it is found that if it is assumed that a hypothetical monopolist having RSI>50% does not have incentive for a 5%-10% price increase, then introduction of a flow-based market coupling may expand German geographic market to include simultaneously Switzerland, Austria, Czech Republic, Slovenia and Croatia. That represents an increase of about 60% compared to German market alone.

The situation is less optimistic for France. Under the current transmission system only 13% of French demand under Winter Off-Peak can be met with the external competitive supply. Under market coupling, the RSI value for France increases to 35%, which is still much less than the values for Germany. This suggests that although market coupling will increase the competitive pressure on the French market, it sill likely remain a market in itself.

Table 4 and Table 5 show the results of the hypothetical monopolist tests for Germany for the scenarios with a medium and high demand: Summer and Winter Peak respectively. Under the threshold of 50%, flow-based market coupling may expand the geographic relevant market from Germany to include Austria and Switzerland under Summer scenario. The geographic relevant market may remain within the German boundaries under the Winter Peak scenario.

TABLE 4
SSNIP TESTS FOR GERMANY, SUMMER

Candidate Market	Demand at candidate market	Cross-border allocation: Competitive import	Cross-border allocation: RSI	Market Coupling: Competitive import	Market Coupling: RSI
D	62,103	20,525	33%	33,198	53%
D-A	68,896	21,695	31%	34,554	50%
D-CH	70,097	26,125	37%	39,027	56%
D-CZ	68,755	21,450	31%	34,460	50%
D-NL	74,641	17,875	24%	27,370	37%
D-F	111,053	19,175	17%	39,781	36%
D-PL	77,501	20,525	26%	30,414	39%
D-A-CH	76,890	24,295	32%	39,415	51%
D-A-CZ	75,549	21,050	28%	33,264	44%
D-A-H	73,469	22,245	30%	32,316	44%
D-CH-I	104,290	23,975	23%	40,423	39%
D-A-CH-CZ	83,542	23,650	28%	37,358	45%
D-A-CH-CZ-SV-CRT	86,921	23,450	27%	35,276	41%

TABLE 5
SSNIP TESTS, FOR GERMANY WINTER PEAK

Candidate Market	Demand at candidate market	Cross-border allocation: Competitive import	Cross-border allocation: RSI	Market Coupling: Competitive import	Market Coupling: RSI
D	69,497	20,466	29%	32,102	46%
D-A	77,832	21,636	28%	32,970	42%
D-CH	78,904	26,066	33%	38,291	49%
D-CZ	78,583	21,391	27%	33,237	42%
D-NL	82,635	17,816	22%	26,965	33%
D-F	138,968	19,116	14%	39,189	28%
D-PL	90,058	20,466	23%	29,417	33%
D-A-CH	87,239	24,236	28%	38,616	44%
D-A-CZ	86,918	20,991	24%	30,136	35%
D-A-H	83,529	22,186	27%	30,856	37%
D-CH-I	128,545	29,266	23%	39,898	31%
D-A-CH-CZ	96,325	23,591	24%	35,622	37%
D-A-CH-CZ-SV-CRT	100,591	23,391	23%	33,605	33%

V. CONCLUSION

This paper presents a model for measuring the potential market power of wholesale electric suppliers operating in constrained meshed transmission networks. The model minimizes the output of the investigated supplier while meeting the demand in all locations of the system and not overflowing the transmission constraints. The output of the model allows calculating the pivotality indices of the supplier, such as the Residual Supplier Index.

The model is used to perform a hypothetical monopolist test to explore the effect of the market coupling on the geographic scope of the wholesale electricity markets in continental Europe. Flow-based market coupling may help increasing the commercially available transmission capacity. The overall competitive effect of flow-based market coupling should be expected to be positive since it provides more flexibility for the external suppliers to provide competitive pressure on national suppliers.

The market coupling allows expanding the geographic dimension of the wholesale markets which are currently limited by the national boundaries. The analysis presented in this paper shows that depending on the profitability threshold of the RSI index, the geographic markets affected by the national champions may, under market coupling, be extended to the neighboring countries. In particular, in Germany, wholesale markets may be extended to include Switzerland, Austria, Czech Republic, Slovenia and Croatia during the off-peak hours and to Austria and Switzerland during shoulder hours. The market, however, may still be limited to German national borders during the peak hours. For France, market coupling does not have such a clear effect and the geographic scope of the wholesale electricity market may remain national for this country.

VI. REFERENCES

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