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COMMISSION FOR ELECTRICITY AND GAS REGULATION

STUDY

(F)111208-CDC-1129

on

‘the relationship between the physical and commercial interconnection capacity at the Belgian electricity borders’

undertaken in application of Article 23, § 2, paragraph two, 2° and 19° of the law of 29 April 1999 on the organisation of the electricity market

8 December 2011

PREAMBLE

1. Since 21 November 2006, with the launch of the Belgian short-term wholesale market for electricity, the Belpex Day Ahead Market (Belpex DAM), has been coupled with the two neighbouring countries with which Belgium has a commercial interconnection: France and the Netherlands. This allows more efficient use of the commercial interconnection capacity, because capacity and energy are auctioned together (implicit auction).

2. Over the years, two major adaptations have been made that have increased efficiency:

- Netting of nominations of annual and monthly capacity: these nominations are done manually before the clearing of the short-term markets and can therefore take place in the wrong direction in economic terms (i.e. from a high price zone to a low price zone). By netting these flows, these wrong nominations in economic terms are added to the daily capacity for the coupling of the short-term markets. If this netting is not carried out, this leads to an inefficient use of the interconnection capacity. The CREG Management Board approved a memo on this subject at its meeting of 30 July 2008 (document number: (Z) 080730-CDC-775). This memo noted that the grid operator did not apply netting to the interconnections with a welfare loss estimated at € 1.55 million for the period January 2007 to May 2008. The memo also noted that by not applying netting, the grid operator failed to comply with Article 177 of the Royal Decree of 28 December 2002 (Technical Regulations). Netting was introduced by the grid operators at the French border on 1 July 2008 and at the Dutch border in September 2008.
- Use-it-or-sell-it: market players can buy annual and monthly capacity at the explicit auctions. They can, however, sell it among other things to the power exchange; this capacity is then used for market coupling. The capacity holder who sold its capacity receives the price difference between the two exchanges (with a minimum of € 0/MWh). Since November 2009, the grid operators have simplified this principle, so that if the annual or monthly capacity is not nominated, this is automatically sold to the short-term power exchanges. This makes the mechanism more flexible for the market players.

3. The developments described above have resulted in greater flexibility. In addition, the commercial capacity that the grid operator makes available is used in the most efficient manner possible within the existing framework of the calculation of interconnection capacity. This framework is the so-called ATC method, whereby one capacity is calculated per direction per national border and possible congestions in other non-adjacent control zones are not explicitly considered.

4. With regard to the safety of the grid, the applicable criterion is that the grid must be managed in such a way that it can still be operated in the event of a major incident. This is the so-called N-1 criterion, which is accepted at European level. At the same time, the grid operator does not have any financial incentive to make as much commercial interconnection capacity as possible available to the market without this jeopardising the safety of the grid. In other words, the grid operator is in a situation in which it is called to account in the event of a black-out or other serious incident. If, however, the grid operator is in situation in which it can offer more interconnection capacity to the market without this jeopardising the safety of the grid, then it actually does not have any financial incentive to offer more capacity.

5. The CREG has taken the initiative to analyse the relationship between the use of the physical capacity on the one hand and the use of the commercial capacity on the other. The CREG believes that the regulator has a very important role to play here, because the grid operator has a monopoly on determining the commercial interconnection capacity. According to Article 176 of the Technical Regulations, when calculating the interconnection capacity the grid operator has to take into account the safety of the grid on the one hand, but also the matter of efficiency on the other.

6. The CREG has twice given Elia the opportunity to react to the findings of the study. The CREG has also met with Elia once to discuss the conclusions of the initial analyses, after which the reactions of Elia were taken into account as much as possible. This study should be considered as an initial observation of a number of phenomena for the year 2009. The CREG is to extend the analysis to other years and take account of more parameters. The CREG has already requested the necessary data for this purpose from Elia.

PART I INTRODUCTION

7. The Belgian control zone has two interconnections with other countries: one with the Netherlands (northern border) and one with France (southern border). Electricity can flow in both directions (import and export); the Belgian control zone therefore has four interconnection directions. The grid operator, Elia, adopts the convention that export flows are positive; the CREG accepts this convention.

8. In physical terms, an interconnection with another country consists of several overhead power lines, each of which has a certain capacity to transport energy. For the market, however, just one available interconnection capacity is calculated: the full interconnection.[1]

9. The total physical capacity of the interconnection is equal for the two directions of one interconnection and is determined by the sum of the physical capacity of the separate overhead power lines[2]. In principle, the physical capacity does not alter, unless there are grid elements (such as an overhead line or a transformer) that are out of order. In practice, however, the physical capacity varies with the weather conditions: temperature, cloud cover, precipitation, wind speed and wind direction affect the maximum permitted physical load. Between winter and summer seasonal limits, this results in a difference of 12% on the total available physical capacity, whereby the higher capacity is available in the winter. The table below gives the overhead power lines that form the two interconnections of the Belgian control zone, as well as their physical capacity[3]. The physical interconnection capacity for the border with France is 5,000 MVA, for the Netherlands it is 6,000 MVA.

10. To protect the safety of the Belgian control zone, the interconnections must be capable of coping with a major unforeseen incident, the so-called N-1 criterion. Such events may be, for instance, the unexpected failure of a major power station or of one of the overhead power lines that form the interconnections, or an overhead line elsewhere in the grid. In practice, this means that there must always be reserve capacity at the interconnection so that the interconnection can continue to transport the physical flow, even in an N-1 situation. The scenario adopted here is that the biggest overhead line of the interconnection may fail. So if the N-1 criterion is taken into

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[1] At the moment all interconnection lines are AC lines. In the future, however, Belgium will also be interconnected via HVDC lines and then this principle will have to be reviewed.

[2] The actual physical usable capacity is usually lower in practice, as the load on the various overhead power lines that form the interconnection is not entirely equal: some overhead cables reach the saturation point more quickly than others, which means that the total capacity of the interconnection is limited.

[3] All data used in this study come from Elia.

account, the available capacity of the interconnection falls. For the Belgian control zone, the capacity with the French border thus falls to 3,500 MVA; for the Dutch border the figure is 4,420 MVA.

For the Dutch border, however, this overestimates the real interconnection capacity, because the actual capacity is determined by the phase-shifter transformer in Zandvliet and Van Eyck with a capacity of 1,400 MVA. The two interconnections Zandvliet-Borssele and Zandvliet-Geertruidenberg (in grey in the table below) therefore have to be taken together and this gives a capacity of 1,400 MVA. The real N-1 capacity at the Dutch border is therefore 2,750 MVA.

Border with	kV	From	To	Pmax (MVA)
France	380	Achêne	Lonny	1,316
	380	Avelgem	Avelin	1,350
	380	Avelgem	Avelin	1,528
	220	Monceau	Chooz	405
	220	Aubange	Moulaine	426
Total FR				5,026
Theoretical Total FR N-1				3.497
The Netherlands	380	Maasbracht	Van Eyck	1,420
	380	Maasbracht	Van Eyck	1,350
	380	Zandvliet	Borssele	1,650
	380	Zandvliet	Geertruidenberg	1,650
Total NL				6,070
Total NL N-1				4,420
Theoretical Total NL N-1				2,750

Table 1: Capacity of interconnection lines at Belgian borders. The figures only apply with a fully available internal Belgian grid (source: Elia + own calculations)

11. At first sight it should, in principle, be possible to make the physical capacity that takes account of the N-1 criterion available to the market players (the ‘theoretical physical capacity’). However, the commercial capacity differs from the physical capacity for the following reasons:

- The maximum physical capacity as determined in §4 is a purely theoretical figure. The distribution of the flows over the various interconnection lines that form a border is never perfect and depends on various factors such as the distribution of the consumption and production units in the vicinity of the border[4]. This distribution also depends largely on the direction of the exchange (import ⇔ export). Consequently, the available commercial capacity may differ sharply, depending on the direction of the flow.

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[4] This can be taken into account via Power Transfer Distribution Factors (PTDFs).

- Elements of the grid that have an impact on the available capacity at the border may be unavailable. If an interconnection line is unavailable, then the impact on the border capacity is clear. However, if internal grid elements are unavailable, this too can have an effect on the interconnection capacity at the borders.
- The grid operator reserves a margin of 250 MW at the interconnections (the TRM or ‘Transmission Reliability Margin’).
- In principle, the adjacent grids also calculate capacity. At the border with France, a capacity calculation is also carried out by RTE, the French transmission grid operator and the minimum value of RTE and Elia is made available to the market. So the limiting situation may equally well lie in the French electricity grid.
- The interconnection capacity with the Netherlands is determined by the Dutch Grid Code, which results in a maximum capacity of 1,401 MW in both directions. It is not clear to the CREG what technical or economic reasons lie behind this restriction.

12. The table below gives the actual available commercial capacity. The table indicates the average available commercial capacity in the four interconnection directions per year for the period 2006-2010; the last row of the table indicates the total average for this period (all values are given in MW). This is then compared with the theoretical physical capacity. The table shows three striking points:

- The available commercial capacity is far smaller than the real physical capacity in accordance with the N-1 criterion (see Table 1): in three of the four interconnection directions, the ratio between the commercial capacity and the physical capacity is less than 50%. Only for the import direction at the southern border is this ratio greater than 70%.
- At the southern border, the commercial capacity available for import is 2.5 times greater than that for export.
- The average available commercial capacity per year varies only slightly, except for the export direction at the southern border: at this border the variation may be as much as 30% (2006 in comparison with 2008).

Average available commercial capacity - per year (MW)				
	French border		Dutch border	
	export	import	export	import
2006	1,286	2,593	1,264	1,323
2007	1,003	2,578	1,317	1,333
2008	899	2,532	1,344	1,350
2009	1,089	2,507	1,373	1,376
2010	1,189	2,702	1,370	1,324
2006-2010	**1,093**	**2,582**	**1,334**	**1,341**
theoretical physical capacity	3,497	3,497	2,750	2,750
%	**31%**	**74%**	**48%**	**49%**

Table 2: Average available commercial capacity (source: Elia + own calculations)

13. The table below also gives the average per seasonal period, whereby the months November-February (winter) and May-August (summer) are compared with one another for the period 2006-2010. The striking point here is that a higher commercial capacity is indeed available in the winter at the border with France. The differences depend on the direction: 34% (import) and 17% (export). These differences are far greater than the differences in seasonal limit of 12% (see above). However, there is hardly any variation to be seen in the capacity with the Dutch border. As has already been said, this can be explained by the fact that the interconnection capacity with the Netherlands is determined by the Dutch Grid Code. This legal limit ensures that even the seasonal variations, which may be as much as 12%, are not reflected in the quantity of commercial interconnection capacity that is made available.

	French border		Dutch border	
	export	import	export	import
average	1,093	2,582	1,334	1,341
winter	1,187	3,065	1,358	1,339
summer	1,004	2,184	1,309	1,345
difference winter-summer	183	880	49	-6
% difference	**17%**	**34%**	**4%**	**0%**

Table 3: Average commercial capacity at the interconnections at Belgian borders 2006-2010 (source: Elia + own calculations)

PART II THE IMPACT OF LOOP FLOWS ON THE COMMERCIAL INTERCONNECTION CAPACITY

14. In the previous part a number of reasons were given for the difference between the theoretical physical capacity and the capacity that is made available to the market (the ‘commercial capacity’). The differences between the physical and the commercial capacity can be very substantial. In this part an additional reason for this difference is examined, namely the fact that so-called *loop flows* are present in the grid.

15. Loop flows are caused because electrical current follows the path of lowest impedance (resistance). Let us illustrate: if a Belgian market player wants to import 100 MW from the Netherlands, then this player nominates 100 MW from the Netherlands to Belgium. This nomination represents the commercial flow. In practice, however, the physical flow will travel from the Netherlands to Belgium along various paths: a (substantial) portion of this physical flow of 100 MW will indeed follow the direct route, i.e. via the interconnection from the Netherlands to Belgium; a (small) portion will, however, unintentionally follow the indirect route, i.e. via Germany and France, and reach Belgium this way (and possibly via Poland, Switzerland, Italy, etc.). This also applies for other market players in other control zones. The commercial flow is a nominated flow at a specific border; the unintentional physical flows are not nominated at the border in question and so they are referred to as non-nominated flows or loop flows.

16. These loop flows may come from various sources and offset or increase one another. For each interconnection, the loop flow per border can be calculated as follows:

loop flow = physical flow – commercial flow[5]

The physical flow is the actual flow that is measured at the interconnection; the commercial flow is the net flow that is nominated by market players at the interconnection. This study adopts the convention that a loop flow is positive if it runs from north to south.

17. Loop flows can explain the discrepancy between the available physical and commercial interconnection capacity as follows. Suppose that the following applies for the interconnection capacity in the direction from Belgium to France for a certain time:

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[5] In practice the calculation of a loop flow has to take into account the PTDFs, which make the calculation a more complicated. As this study only aims to illustrate the principle and impact of loop flows, this complexity is set aside using this approach.

MW	**BE=>FR**	**FR=>BE**
physical capacity	3,500	-3,500
predicted loop flow BE=>FR	2,000	2,000

Table 4: Example of physical capacity with predicted loop flow

The grid operator can not make commercial capacity of 3,500 MW available now to the market at the interconnection from Belgium to France: after all, if the grid operator were to make 3,500 MW available to the market and the market players were actually to nominate these 3,500 MW, then the actual physical flow from Belgium to France would amount to 3,500 + 2,000 = 5,500 MW, which means that the N-1 criterion would be infringed. The grid operator can only make commercial capacity of 3,500 – 2,000 = 1,500 MW available at the BE => FR interconnection. If the market players were actually to use all this available capacity, then the physical flow would only amount to 3,500 MW, i.e. within the N-1 criterion. It is important to note that in the opposite direction the grid operator should in principle be able to make – 3,500 – 2,000 = – 5,500 MW available to the market, because the loop flow is going in the opposite direction.

18. Figure 1 gives the trend at the French interconnection of the monthly average, physical flow, as well as the maximum flow in the export (positive) and import (negative) direction (the blue, red and green line respectively) for the period 2006-2010. Figure 2 gives the same information, but this time for the interconnection with the Netherlands.

19. Figure 1 (French border) shows that the monthly maximum physical import flow (green line – negative) is in excess of -3,500 MW during just one of the 60 months. The maximum flow in the export direction (red line – positive) is never more than 3,500 MW. Figure 2 (Dutch border) shows that the monthly maximum physical import flow (green line – negative) is in excess of -2,750 MW for 11 months (of the 60). The maximum physical export flow (red line – positive) is never more than 2,750 MW.

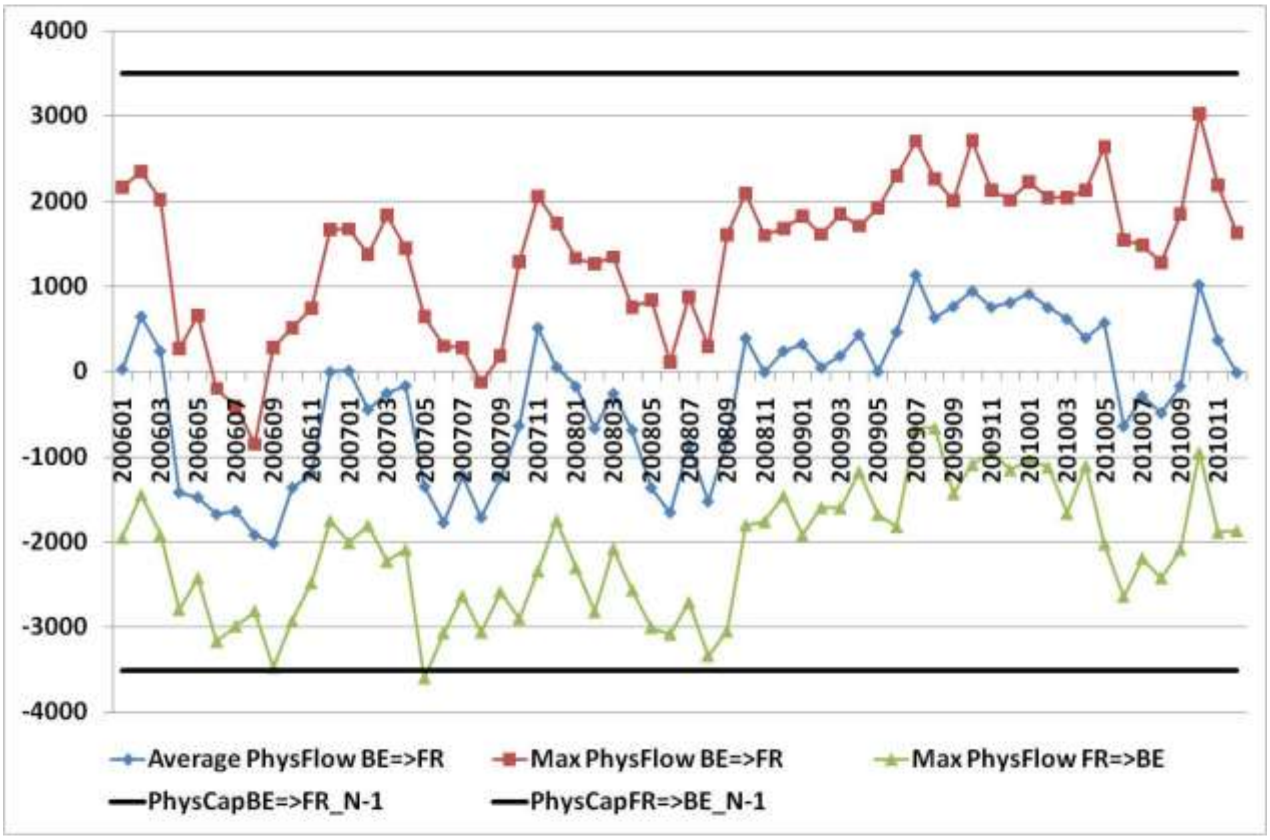

Figure 1: Physical flows at the Belgium-France border in comparison with physical capacity in accordance with the N-1 criterion

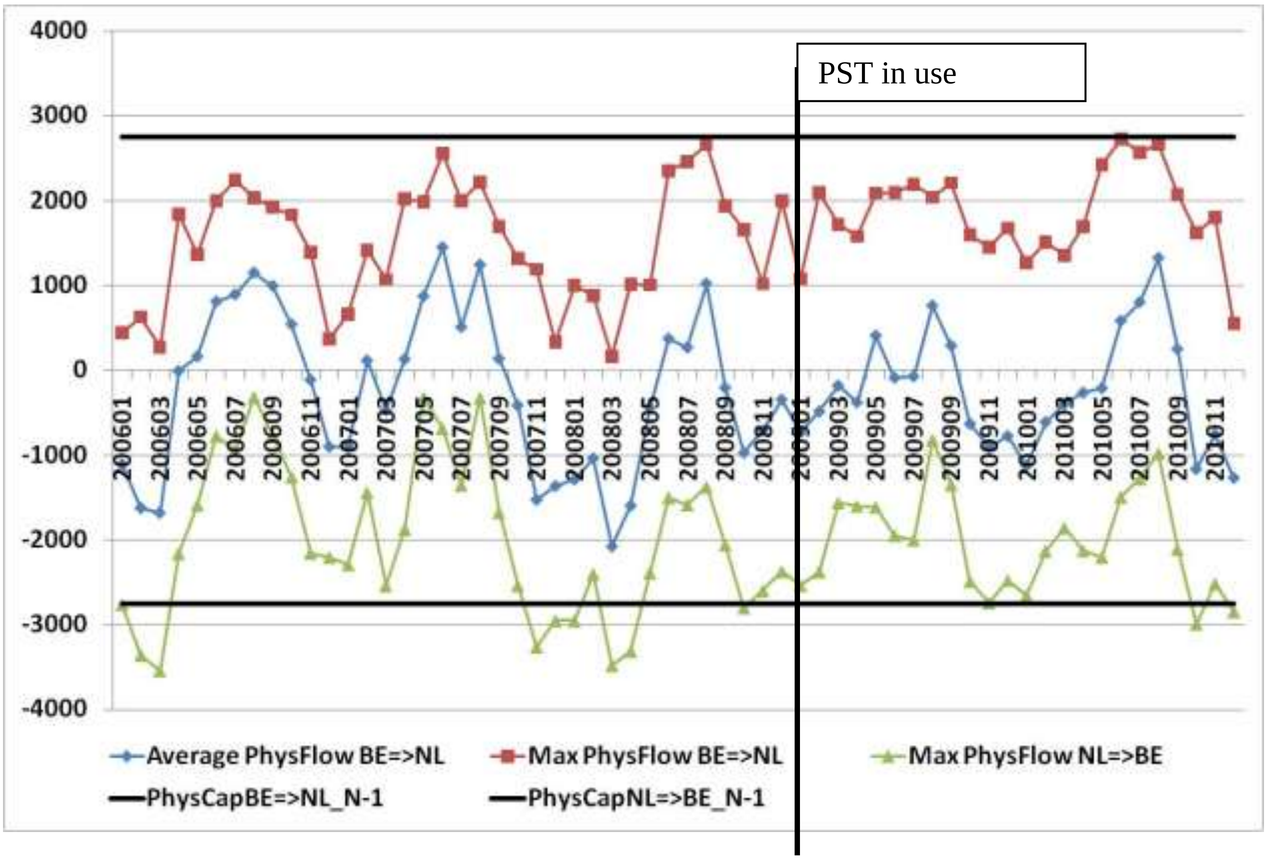

Figure 2: Physical flows at the Belgium-Netherlands border in comparison with physical capacity in accordance with the N-1 criterion

20. The table below gives the average physical flow in the four directions, as well as the average flow in absolute terms. The average flow in absolute terms at the southern border was 941 MW[6] during the period 2006-2010. Taking into account a theoretical available physical capacity of 3,500 MW, this is a degree of utilisation of 27%. The average flow in absolute terms at the Dutch border was 930 MW during the period 2006-2010. Taking into account a theoretical available physical capacity of 2,750 MW, this is a degree of utilisation of 34%.

		BE-FR	**BE-NL**
export	**Average if > 0**	753	823
	Number if > 0	75,090	74,832
import	**Average if > 0**	-1,082	-1,010
	Number if > 0	100,186	100,440
total	**Total average**	941	930
%	**% theoretical FysCap N-1**	27%	34%

Table 5: Average physical flow per border and per direction (source: Elia + own calculations)

21. On the basis of this degree of utilisation of 27% and 34% alone, however, it cannot be concluded that this interconnection is under-utilised (and that therefore too little commercial capacity was made available). After all, it may be that a great deal of commercial capacity was made available, but that this was simply not nominated by the market players. To illustrate this, consider the fictitious example in Table 3 for the direction from Belgium to France: two days in advance (D-2) a loop flow of 2,000 MW *was predicted* from Belgium to France. Consequently, in principle capacity of only 1,500 MW can be made available to the market in the direction from Belgium to France (‘commercial capacity’). In the direction, from France to Belgium, 2,000 MW more can be offered: 5,500 MW. On D-1, the market players in this example nominate just 100 MW of the 1,500 MW. In real time, a physical flow of only 1,100 MW is measured, which means that the loop flow is just 1,000 MW, rather than the predicted 2,000 MW. All this results in a degree of utilisation for this fictitious hour of 31%, whereas the grid operator had in fact made as much commercial capacity as possible available to the market, given the information in D-2.

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[6] This average absolute value is calculated by considering the absolute value of the physical flow for each quarter and then taking the average. For this calculation, account is taken of all quarters from 2006 to 2009.

example	**BE=>FR**	**FR=>BE**
physical capacity	3,500	-3,500
predicted loop flow BE=>FR (D-2)	2,000	2,000
commercial capacity (D-2)	1,500	-5,500
nominated capacity (D-1)	100	-100
actual loop flow BE=>FR (D)	1,000	-1,000
physical flow (D)	1,100	-1,100
percentage of utilisation (%)	31%	31%

Table 6: Example in figures for the calculation of the percentage of utilisation

22. However, it is not the degree of utilisation actually achieved that is important, but rather what this could have been if the market players had nominated all the available commercial capacity. This is why a *theoretical potential degree of utilisation* is calculated on the basis of the commercial capacity that was made available, calculated as the commercial capacity that *was* made available divided by the physical capacity that *could* be made available. This latter capacity, that is the potential physical capacity, is illustrated for the four interconnection directions in the following table.

MW	**southern border**		**northern border**	
	export	**import**	**export**	**import**
	BE=>FR	**FR=>BE**	**BE=>NL**	**NL=>BE**
physical capacity	3,500	-3,500	2,750	-2,750
predicted loop flow from north to south	X	X	X	X
potential commercial capacity	3,500-X	-3,500-X	2,750+X	-2,750+X
theoretical potential degree of utilisation	**100%**		**100%**	

Table 7: Illustration of theoretical potential degree of utilisation

23. This table shows that the commercial capacity that can be made available has to be adapted to the predicted loop flow X, but in both directions. In other words, in the one direction the capacity has to be reduced by X, and in the other direction it has to be increased by X.

24. One major consequence of this is that if we can predict the loop flows exactly, the theoretical potential degree of utilisation must be 100%. After all, the predicted loop flow X does indeed reduce the available commercial capacity by X in one direction, but this also increases in the other direction by the same amount, X. This may be expressed as a formula as follows:

$$\frac{FysCapExport - X - (FysCapImport - X)}{FysCapExport - FysCapImport} = 100\%$$

FysCapExport is the physical capacity in the export direction. This is opposed to FysCapImport, namely the physical capacity in the import direction.

25. The theoretical potential degree of utilisation at the southern border and the northern border is just 52% and 49% respectively, as indicated in the last line of the following table. This is far less than the theoretical potential degree of utilisation of 100%.

(MW)		**southern border (FR)**		**northern border (NL)**	
		export	**import**	**export**	**import**
average available commercial capacity	**2006**	1,286	-2,593	1,264	-1.323
	2007	1,003	-2,578	1,316	-1.333
	2008	899	-2,532	1,344	-1.350
	2009	1,089	-2,507	1,373	-1.376
	2006-2009	1,069	-2,553	1,324	-1.345
potential capacity		3.500	-3,500	2,750	-2,750
degree of utilisation		**51.7%**		**48.5%**	

Table 8 : Theoretical potential degree of utilisation for the period 2006-2009 (source: Elia + own calculations)

26. Neither, however, can it be concluded purely on the basis of these degrees of utilisation of 52% and 49% that the interconnections are under-utilised, and that therefore too little commercial capacity is made available. After all, this theoretical potential degree of utilisation assumes that the loop flows can be predicted exactly. This is in no way the case. Loop flows are caused by the consumption and production patterns in an operator’s own grid and in all the other grids in the interconnected network. This pattern is in itself somewhat unpredictable; moreover, in the past few years energy production has become more unpredictable as the proportion of wind energy has risen sharply recently, mainly in Denmark and northern Germany. Consequently, it may be expected that the loop flows have also become more unpredictable.

27. Account therefore has to be taken of the unpredictability of the loop flows. For this purpose, an uncertainty factor Δ (delta) is used. The predictable loop flow is now X ± Δ. The loop flow is consequently on average X, but this can vary, which means that with a certain level of reliability (for instance 99%), the loop flow lies within the range (X-Δ; X+Δ). Table 9 reproduces Table 8 with the introduction of an uncertainty factor Δ (delta).

	southern border		**northern border**	
	export	**import**	**export**	**import**
MW	**BE=>FR**	**FR=>BE**	**BE=>NL**	**NL=>BE**
physical capacity	3,500	-3,500	2,750	-2,750
predictable loop flow from north to south	X ± Δ	X ± Δ	X ± Δ	X ± Δ
potential commercial capacity	3,500-X - Δ	-3,500-X + Δ	2,750+X-Δ	-2,750-X + Δ
potential degree of utilisation Δ = 500 MW	**86%**		**82%**	
potential degree of utilisation Δ = 1000 MW	**71%**		**64%**	
potential degree of utilisation Δ = 1500 MW	**57%**		**45%**	

Table 9: Potential degree of utilisation with various levels of uncertainty

If account is taken of the unpredictability of loop flows, then the potential degree of utilisation falls; in this case, it is no longer 100%, but falls as the level of unpredictability increases.

28. Clearly, the (possibly implicit) uncertainty margin of the loop flows applied is very important.

29. It is, however, not necessary to know the extent of the uncertainty margin in order to examine whether adequate account is taken of the loop flows. As explained above, the following applies:

- An actual loop flow X from north to south reduces the interconnection capacity from north to south by X, but increases the interconnection capacity in the opposite direction (from south to north) by X, if we assume that the load on the interconnection lines is equal.
- An uncertainty factor Δ reduces the interconnection capacity in both directions by Δ in each case.

30. This means that the total commercial capacity at a border (= sum of the commercial import and export capacity) displays the following relationship:

*Total Commercial Capacity = 2 * physical capacity – 2 * uncertainty factor Δ*

Or in practical terms, bearing in mind the TRM (250 MW), but leaving aside seasonal effects (as regards the physical capacity) and assuming that the load on the interconnection lines is equal:

- French border: Commercial FR import+export = 2*3,250 – 2 * Δ = 6,500 – 2*Δ
- Dutch border: Commercial NL import+export = 2*2,500 – 2 * Δ = 5,000 – 2*Δ.

31. This leads us to the following principles, assuming that the load on the interconnection lines is equal:

a. if the uncertainty factor Δ is constant, the sum of the commercial import and export capacity at one border must be constant over time, and the difference between the sum at the French border and the sum at the Dutch border must be constant and equal to 1,500 MW

b. if the uncertainty factor Δ is not constant, the sum of the commercial import and export capacity at the Dutch and French must follow the same pattern over time because the loop flows, and hence their uncertainty factors, are the same for both borders, and the difference between the sum at the French border and the sum at the Dutch border must be constant and equal to 1,500 MW.

If we take seasonal effects into account, there should be a difference between winter and summer of approximately 10%. The difference between the sum at the French border and the sum at the Dutch border may therefore vary by 10% over summer or winter.

32. The figure below gives the monthly average total commercial capacity at the French border (blue line) and at the Dutch border (red line). The data are in MW. The grey areas indicate the winter months (defined as the period from November to February). For this analysis the important thing is not the absolute level but the evolution over time and the difference between the French and the Dutch border. The figure shows that the sum of the commercial capacity at the French border (blue line) varies sharply, while the sum of the commercial capacity at the Dutch border (red line) hardly varies at all. The evolution of the commercial interconnection capacity between both borders varies considerably.

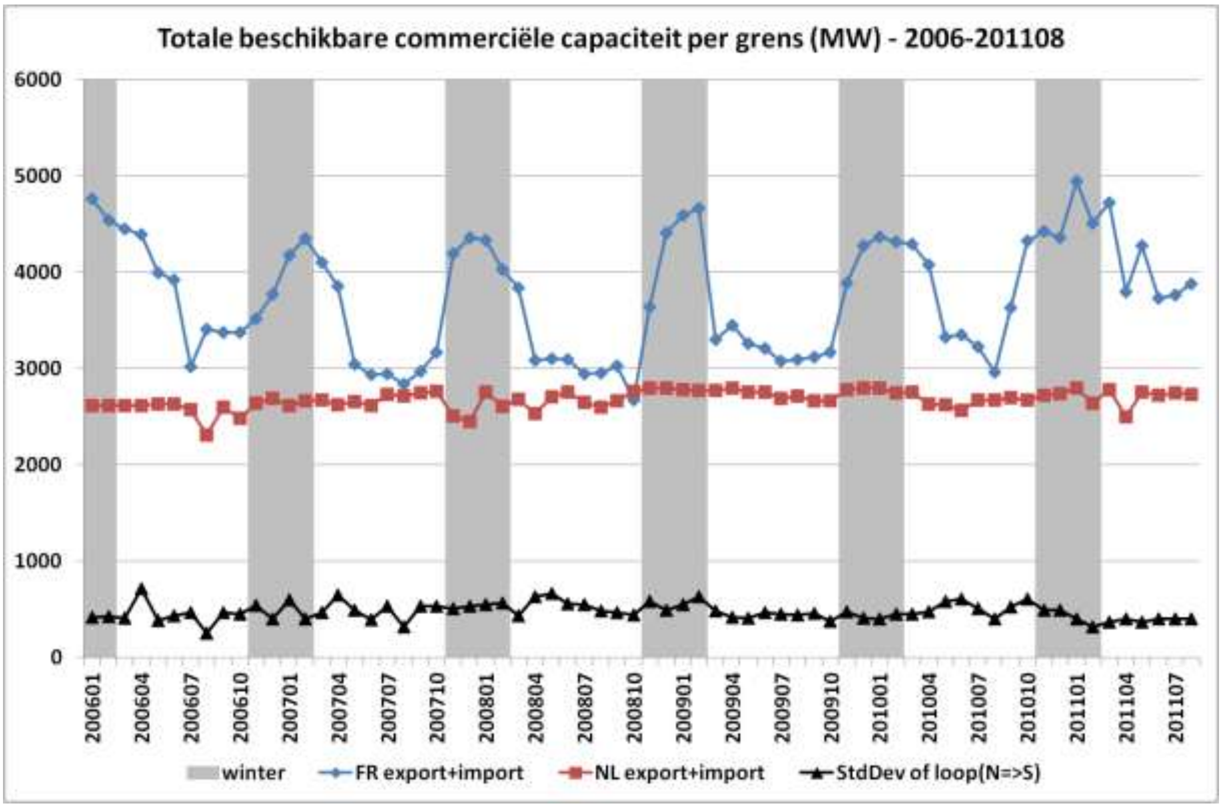

Figure 3: Total available commercial capacity of the Belgian interconnections per border.

33. The total commercial capacity at the French border (blue line) is 26% higher in the winter period compared with the summer period. About 10 percentage points of this can be explained by the atmospheric conditions that differ in summer and winter. The remainder, or 16 percentage points, can in principle be explained by the fact that the uncertainty factor Δ varies. This varying uncertainty factor Δ in connection with the loop flows is the same for the two borders. Consequently, this implies that the same pattern should be seen at the Dutch border (red line). This is clearly not the case: the variation is 1%, less than the seasonal variation of approximately 10%. The table below gives the average capacity for the winter and summer period.

2006-201108	FR to	NL to
winter (Nov-Feb)	4,295	2,699
summer (May-Aug)	3,309	2,668
difference	986	31
% difference	26%	1%

Table 10 : Average total commercial capacity for the winter and summer period (source: Elia + own calculations)

34. The above pattern cannot be explained by the uncertainty factor Δ, or by seasonal effects. What is more, there are indications that the uncertainty factor Δ is fairly stable over time across

loop flows: the figure above gives the monthly standard deviation of the loop flow: this is a means of measuring the variability of the loop flow for the month in question. This seems to be more or less constant over time (the correlation with the total commercial capacity at the French border is even slightly negative). The standard deviation is not the same as the predictability, but it is an indication of the assumption that the uncertainty factor Δ does not vary significantly.

35. There is, however, another possible explanation for the differing pattern of the total commercial capacity at the Dutch and the French border, namely an unequal load on the interconnection lines that changes through the year. An unequal load on the interconnection lines can mean that more capacity can be given in one direction than in the other. If this unequal load is, in addition, seasonally dependent, then seasonal effects may occur in the total commercial capacity. According to Elia, an unequal load on the interconnection lines is essential for the direction from Belgium to France, whereby the 220 kV lines via Aubange and the Gramme-Achène-Lonny line will already be carrying the maximum load while the lines from Avelgem still have a considerable margin. This is a consequence of the location of major production sites and loads on both sides of the border. As a result, the capacity from Belgium to France is significantly lower than from France to Belgium, according to Elia.

36. However, this does not explain the fact that the total commercial capacity (sum of exports and imports) varies over time. To explain this, the unequal distribution of the interconnection lines must alter through the year, i.e. be more (un)equal in the winter than in the summer.

37. Both phenomena, the unequal load and the seasonal aspect of this, are examined empirically below with regard to the French border. The following lines are analysed:

- ‘Avelgem’: has two lines, and the line with the heaviest load is considered
- ‘Achène’: has one line that is considered

38. The figure below gives a scatter plot of the physical use in percentage terms of ‘Avelgem’ versus ‘Achène’ for the year 2009, with a distinction made between the winter period (red - November-February) and the summer period (blue – May-August). The black continuous line and the black dotted line indicate the trend for winter and summer respectively (simple regression line). On the basis of the position of the trend lines, it is calculated in the annex that the export capacity is in reality lower than the import capacity, as can actually be observed with regard to the commercial capacity. It may also be seen that the trend is seasonal, with a lower capacity in the summer than in the winter (summer trend is flatter, which leads to lower capacity – see annex for a formal explanation). However, if the effect is quantified, then the trend lines imply a difference in percentage terms between the summer and the winter capacity of 15%, of which 11 percentage

points are explained by the atmospheric conditions and just 4 percentage points by the asymmetry of the grid. The calculated difference of 15% is noticeably lower than the observed difference of 26%.

39. The use of the one line is, however, not perfectly correlated with the use of the other line: in reality there is a great deal of variation in the relationship between the physical use of the two interconnection lines: the correlation is far from perfect. The R² is 56% for the winter period and 61% for the summer period. The actual situation therefore differs from the theoretical situation examined in the annex. It is, however, important to know that this variation is only slightly seasonal and tends to favour the summer period (as the R² is higher then). In other words, the fact that the actual situation differs from the theory in the annex cannot be used to explain why the total commercial capacity is 26% lower in the summer than in the winter.

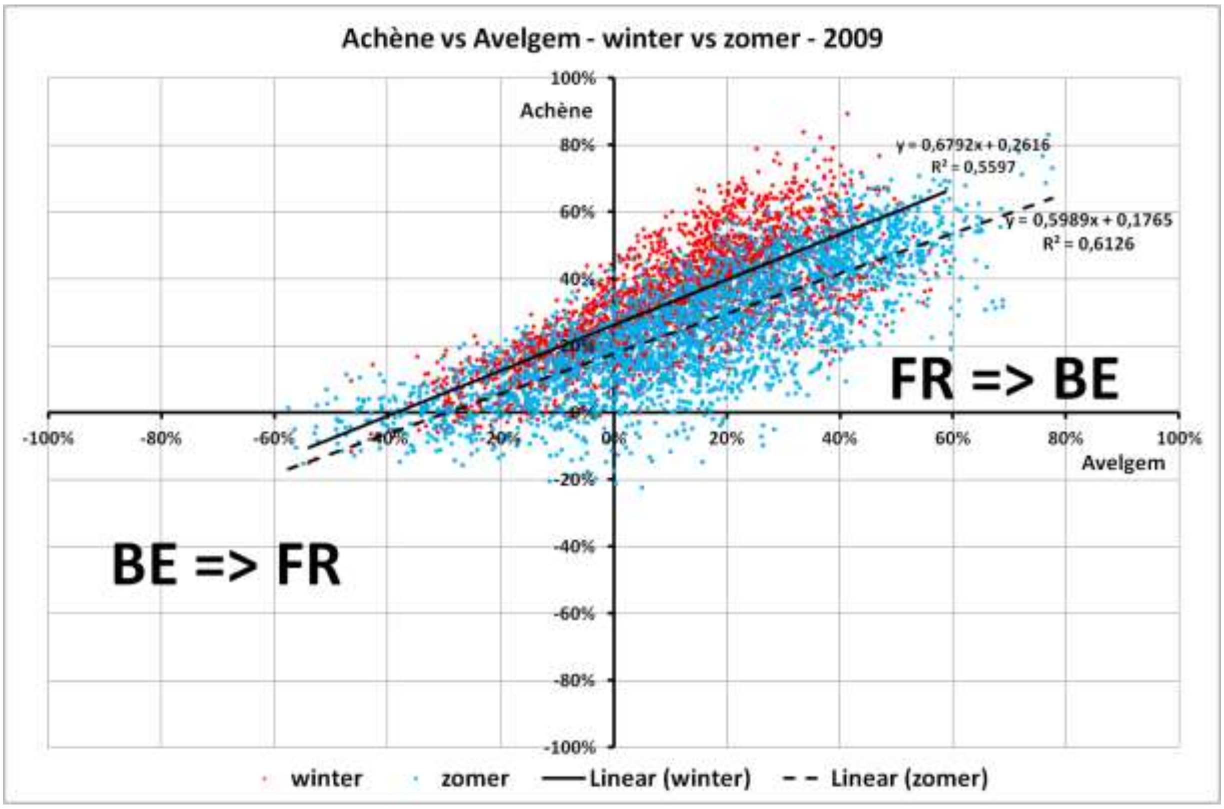

Figure 4: Physical use of two transmission lines

40. The figure above shows that Achène is more often the limiting line in the winter than in the summer. This is confirmed by the table below, which indicates for what percentage of the time

Avelgem and Achène have more than a 60% load. In the direction from Belgium to France, Achène seems to be loaded more above the level of 60%.

41. In the other direction, from Belgium to France, neither of the lines carry a load of over 60%, not even if account is taken of the reduced physical capacity of the lines in the summer period (threshold at 54% relative load rather than 60%)[7]. The figure shows that Achène in the direction from Belgium to France is in fact never loaded more than 22%. So Achène is never the limiting factor in this direction.

	Physical load > 60%					
	Avelgem		**Achène**		**Avelg+Achène**	
	summer	**winter**	**summer**	**winter**	**summer**	**winter**
(BE=>FR)	1.2%	0.0%	2.7%	5.7%	3.5%	5.7%
(FR=>BE)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 111: Percentage of time when certain lines have a physical load in excess of 60%

42. The explanation for the evolution of the commercial import and export capacity at the Dutch border is as follows: it is the Dutch *Grid Code* that results in a maximum capacity of 1,401 MW. The CREG would like to obtain a better understanding of Elia’s view of the restrictions of commercial capacity on the Belgian interconnections. The CREG asks the following questions, among others: what is the result of the calculation done by Elia for the commercial interconnection capacity for the Dutch border? What is the impact of the Dutch legal restriction of 1,401 MW on this calculation? Is it correct to state that this “legal restriction” by the Netherlands is the main restriction for the commercial interconnection capacity at this border? Would the commercial interconnection capacity be greater for a significant number of hours without this legal restriction? The CREG has not yet received any conclusive answers to these questions.

43. With regard to the French border, the CREG asks whether Elia considers that the restriction of the export capacity at the French border is caused mainly by restrictions in the French grid. Would the commercial interconnection capacity in the French grid be greater for the majority of the time without these restrictions (and how much?)? What investment plan or plans does RTE have in this area?

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[7] For the sake of completeness: with a cut-off of 54% Avelgem bear a heavier load for 0.1% of the time.

PART III INTERCONNECTION CAPACITY UTILISATION – LINE PER LINE

44. In this part the utilisation of the interconnection capacity is examined on the basis of data per transmission line. This brings the analysis more closely into line with the physical reality of the use made of the electricity grid.

45. The data relate to 2009 and have been obtained from Elia. They concern all individual lines at 380 kV, as well as the interconnection lines at 380 kV and at 220 kV. This analysis uses data per hour, which means that an average is calculated per hour of the data per quarter. The phase-shifter transformers (PSTs) had already been taken into use in 2009.

46. The data show that only three lines had a <u>maximum</u> utilisation of 90% or more (and none of these was an interconnection line). Nine other lines had a maximum load of 80% or more, including three interconnection lines. The average of the maximums per hour is 62.5%.

47. The data show that only two lines had an <u>average</u> degree of utilisation of 50% or more (and none of these was an interconnection line). The average utilisation is less important in this context and is only given for illustration purposes here. Two other lines had an average load of 40% or more, but none of these was an interconnection line. The average of the averages of all lines is 20%.

48. A line of reasoning is developed below to be able to examine whether, and to what extent, the entire Belgian grid is used efficiently and to what extent the commercial use of the interconnection capacity has an impact on the physical use of the Belgian transmission grid. The following principles are assumed here:

a. A grid is as strong as the weakest link. Whether or not a grid has reached its limits is therefore determined on the basis of the line that is used closest to its maximum capacity. For this purpose, per hour the maximum is taken of the degrees of utilisation of all lines; this maximum is the ‘grid maximum on the basis of the weakest line’. The maximum physical use of the Belgian transmission grid during hour x is defined as the use of the most heavily loaded line in relative terms during hour x (expressed in %). So if one line is used at 90% and the other at just 50% then the maximum physical grid use is considered to be 90%.

b. An analysis is made of the physical use of the grid in accordance with the various intervals of commercial use of the interconnection directions.

49. The CREG has conducted an analysis of the relationship between the commercial use of the interconnections (the “nominations”) on the one hand and the physical use of the grid on the other, whereby the physical line carrying the maximum load is examined every hour. This analysis consists of three parts, whereby the relationship of the nominations on the interconnections and the physical use of three different subsets of the grid is examined. These three subsets are as follows:

1. the ‘total grid’ (all lines at 380 kV + the interconnections at 220 kV).
2. the ‘interconnection lines’
3. the ‘critical lines’: the interconnection lines + nine internal lines (on the advice of Elia).

The last subset was added upon the advice of Elia: they reported that we ought not to use the entire grid or the interconnections only for the analysis in question. Elia then gave the CREG a list of nine lines which should be examined together with the interconnections. This list of nine lines, together with the interconnections, are considered to be the ‘critical lines’ and therefore form the third part of the analysis.

50. The analysis is carried out for the three subsets of the grid using the same plan: hour by hour the commercial use in the four interconnection directions (the “nominations”) is compared with the physical use of the grid in question. The aim is to examine what impact the commercial use has on the physical use:

- does a higher commercial use of the interconnections mean a higher physical use of the grid?
- to what extent is the physical use of the grid determined (explained) by the commercial use?

51. To answer the first question, the nominations (the commercial use) per interconnection direction are divided into intervals: from moderate commercial use (a nomination of 0-60% of the available capacity) to maximum commercial use ((virtual)-congestion 99-100%). Per interval, the physical use of the grid is calculated in each case on the basis of the average maximum grid use. In this way a quantitative relationship can be established between the commercial use of the interconnections and the physical use of the grid.

52. To answer the second question, for each interconnection direction a simple regression is carried out with the commercial nomination as the explanatory variable and the physical use as the explained variable. The R^2 (determination coefficient) is then calculated. This R^2 then gives the proportion of the variability in the physical use of the grid that is explained by the commercial use. The higher this value, the more the commercial use of the interconnections determines the physical use of the grid. However, if the R^2 is low, then there are other factors which (together or separately) have a far more important impact on the physical use of the grid.

53. The analysis above only yields reliable results if adequate data are available per interconnection direction and per interval (in this case, enough hours). The table below gives the number of hours per interconnection direction and per nomination interval. All interconnection directions seem to include enough hours, except for the import direction at the French border (‘FR import’) for the intervals with a high commercial use (70-80%, 80-90%, 90-99% and 99-100%). The figures for these intervals in the French import direction are therefore less reliable in statistical terms.

	# hours	**FR export**	**FR import**	**NL export**	**NL import**
Commercial use (nomination) compared with commercial capacity	**0-60%**	2157	2315	2437	2582
	60-70%	443	104	391	380
	70-80%	442	51	300	317
	80-90%	560	27	270	285
	90-99%	691	18	212	261
	99-100%	1927	25	751	574
	total	*6220*	*2540*	*4361*	*4399*

Table 12: Number of hours of commercial use per interconnection direction and per nomination interval

1. Total grid

54. The table below gives the average maximum physical use of the ‘total grid’ according to the various nomination intervals per interconnection direction. The last row gives the difference (in percentage points) between low commercial use (0-60%) and congestion (99-100%).

55. The table shows that the maximum physical use of the grid for all interconnection directions is higher with high commercial use than with low commercial use. The difference is greatest, 7 percentage points, for the import direction at the French border. Note: this border only has 25

hours with high commercial use (see also §53), which means that this figure is less reliable in statistical terms. The difference is smallest for the export direction at the French border, i.e. just 1 percentage point.

	Physical use of 'total grid' according to commercial use				
		FR export	**FR import**	**NL export**	**NL import**
Commercial use (nomination) compared with commercial capacity	**0-60%**	62%	62%	60%	63%
	60-70%	63%	64%	60%	64%
	70-80%	63%	63%	61%	66%
	80-90%	63%	66%	61%	67%
	90-99%	63%	67%	61%	66%
	99-100%	63%	69%	64%	67%
	cong-no cong	*1%*	*7%*	*4%*	*4%*

Table 13: Physical use of 'total grid' according to commercial use

56. The absolute level of the average maximum physical use of the ‘total grid’ lies between 60% and 69%.

57. The figure below represents the information from the table for the lowest and the highest commercial use, as well as the number of hours when a given situation occurred (grey/black bars on the vertical axis).

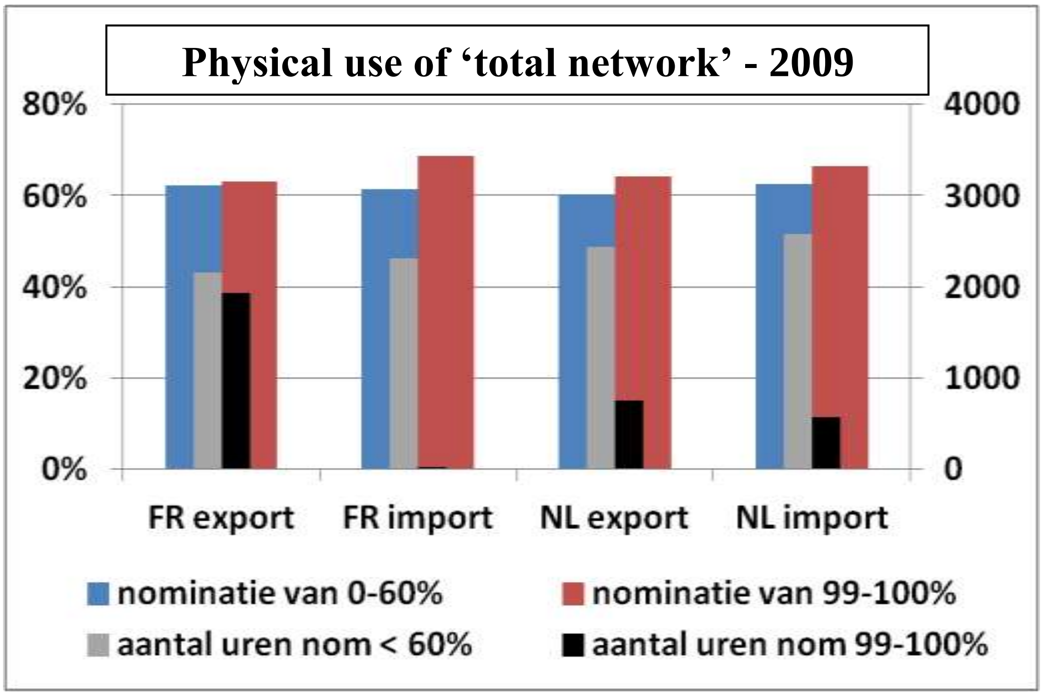

Figure 5: Physical use of ‘total grid’

58. Both the table and the figure show that the relationship between the use of the ‘total grid’ and the commercial capacity is very weak, particularly if the less statistically reliable ‘FR import’ direction is not included in the calculation: if the commercial use goes from low (0-60%) to maximum (99-100%), the physical use increased only very slightly. In other words, the physical use of the ‘total grid’ is not very sensitive to changes in the observed commercial use of the interconnections.

59. This is also confirmed by the linear regression and the explanatory power (R²) of the commercial use with regard to the variation of the physical use. This gives the following table.

Total grid	**R²**
FR export	0.1%
FR import	0.1%
NL export	0.9%
NL import	3.2%
weighted average	1.1%

Figure 6 : Explanatory power of commercial use with regard to the variation of the physical use for the ‘total grid’

60. The R² is particularly low, never more than 4%, and on average 1.1%, which means that the commercial capacity does not have a significant impact on the variation in the physical use of the total grid. This is highly remarkable.

2. Interconnection lines

61. The table below gives the average maximum physical use of the ‘interconnection lines’ according to the various nomination intervals per interconnection direction. The last row gives the difference (in percentage points) between low commercial use (0-60%) and congestion (99-100%).

	Physical use of 'interconnection lines' according to commercial use				
		FR export	**FR import**	**NL export**	**NL import**
Commercial use (nomination) compared with commercial capacity	**0-60%**	42%	40%	41%	43%
	60-70%	45%	47%	45%	46%
	70-80%	46%	43%	46%	46%
	80-90%	47%	45%	46%	47%
	90-99%	48%	43%	46%	47%
	99-100%	49%	52%	50%	50%
	cong - no cong	*8%*	*12%*	*8%*	*7%*

Table 14: Physical use of ‘interconnection lines’ according to commercial use

62. The table shows that the maximum physical use of the interconnection lines for all interconnection directions is higher with high commercial use than with low commercial use. The difference is greatest, 12 percentage points, for the import direction at the French border (Note: this border only has 25 hours with high commercial use – see also §53). The difference is smallest for the import direction at the Dutch border, namely 7 percentage points.

63. The absolute level of the maximum physical use of the ‘interconnection lines’ lies between 40% and 52%, which is far lower than when the ‘total grid’ is considered.

64. The figure below presents the information from the table, for the lowest and the highest commercial use, as well as the number of hours when a certain situation occurred (grey/black narrow bar on the vertical axis).

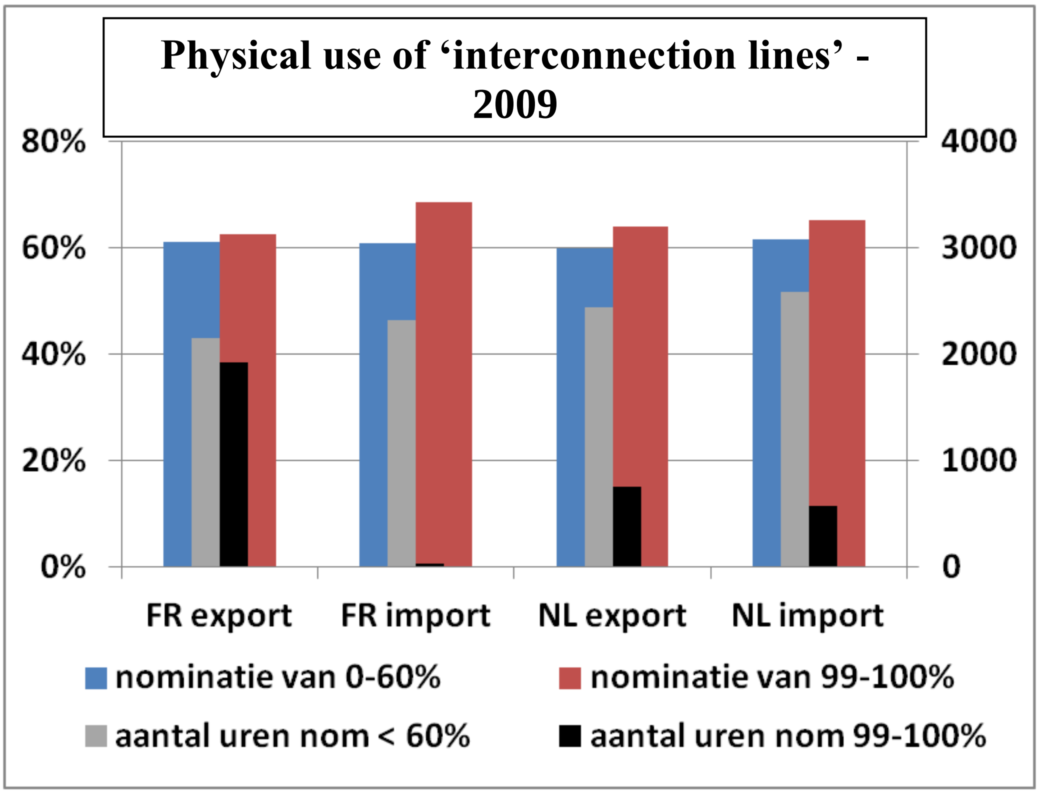

Figure 7: Physical use of the ‘interconnection lines’

65. Both the table and the figure show that the relationship between the use of the ‘interconnection lines’ and the commercial capacity is stronger than if this is compared with the ‘total grid’, but nevertheless, the relationship remains weak: if the commercial use goes from low (0-60%) to maximum (99-100%), the physical use increases only slightly. In other words, the physical use of the ‘interconnection lines’ is not very sensitive to changes in the commercial use of the interconnections.

66. This is also confirmed by the linear regression and the explanatory power (R²) of the commercial use with regard to the variation of the physical use. This can be seen in the following table.

Interconnection lines	R²
FR export	7.6%
FR import	2.9%
NL export	5.8%
NL import	6.3%
weighted average	6.1%

Table 15: Explanatory power of commercial use with regard to the variation of the physical use for 'interconnection lines'

67. The R² is very low, never more than 8% and on average 6.1%, which means to say that the commercial capacity has very little impact on the variation in the physical use of the 'interconnection lines'. This is highly remarkable.

3. *The 'critical lines' ("subgrid" proposed by Elia)*

68. The maximum physical use of the total grid can be determined by a transmission line on which the commercial use of the interconnections has very little impact. This is why in this section, on the advice of Elia, only the interconnection lines are considered, together with nine critical lines. The analysis shows that the results for this subgrid are very similar to the results when the 'total grid' is considered.

69. The table below gives the average maximum physical use of the 'critical lines' according to the various nomination intervals per interconnection direction. The last row gives the difference (in percentage points) between low commercial use (0-60%) and congestion (99-100%).

	Physical use of 'critical lines' according commercial use				
		FR export	**FR import**	**NL export**	**NL import**
Commercial use (nomination) compared with commercial capacity	**0-60%**	61%	61%	60%	62%
	60-70%	62%	64%	59%	63%
	70-80%	62%	63%	61%	65%
	80-90%	63%	66%	61%	66%
	90-99%	63%	67%	60%	64%
	99-100%	63%	69%	64%	65%
	cong-no cong	*1%*	*8%*	*4%*	*4%*

Table 16: Physical use of 'critical lines' according to commercial use

70. The table shows that the maximum physical use of the ‘critical lines’ for all interconnection directions is higher with high commercial use than with low commercial use. The difference is greatest, 8 percentage points, for the import direction at the French border. N.B.: this border only has 25 hours with high commercial use (see also §53), which means that this figure is not all that reliable. The difference is smallest for the export direction at the French border, namely just 1 percentage point.

71. The absolute level of the maximum physical use of the ‘critical lines’ lies between 60% and 69%, which is in line with that found when the ‘total grid’ was considered, but considerably higher than when only the ‘interconnection lines’ were taken into account.

72. The figure below presents the information from the table for the lowest and the highest commercial use, as well as the number of hours when a given situation occurred (grey/black narrow bars, on the vertical axis).

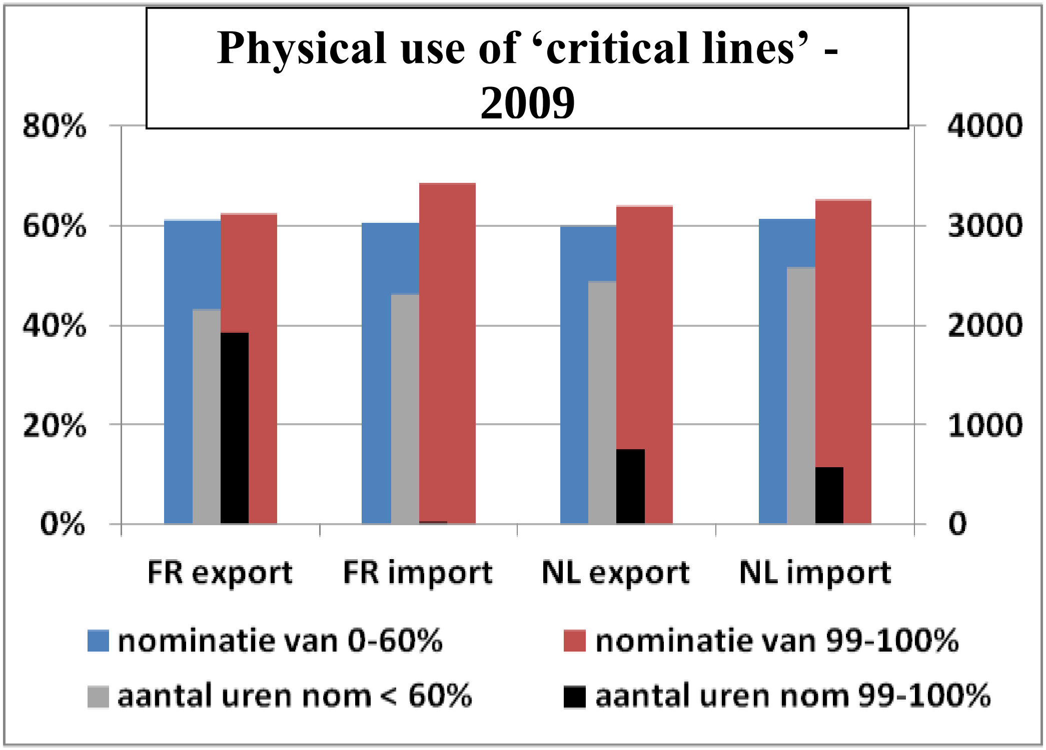

Figure 8: Physical use of ‘critical lines’

73. Both the table and the figure show that the relationship between the use of the ‘critical lines’ and the commercial capacity is very weak: if the commercial use goes from low (0-60%) to maximum (99-100%), the physical use increases only very slightly. In other words, the physical

use of the ‘critical lines’ is not very sensitive to changes in the commercial use of the interconnections.

74. This is also confirmed by the linear regression and the explanatory power (R^2) of the commercial use with regard to the variation of the physical use. This can be seen from the following table.

Critical lines	**R^2**
FR export	0.3%
FR import	0.4%
NL export	1.2%
NL import	2.2%
weighted average	1.0%

Table 17: Explanatory power of commercial use with regard to the variation of the physical use for ‘critical lines’

75. The R^2 is particularly low, never more than 3% and on average 1.0%, which means to say that the commercial capacity does not have any significant impact on the variation in the physical use of the ‘critical lines’.

4. Additional analyses

76. The table below gives, for the various grids considered, the average maximum load for two situations:

- ‘nom < 50%’: these are the hours with a low commercial use at both borders, namely the hours when the commercial nominations at both borders are lower than 50% of the available commercial capacity. In 2009 this situation occurred during 2,158 hours (25% of the time).
- ‘nom > 90%’: these are the hours with a high commercial use at both borders, namely the hours when the commercial nominations at both borders are higher than 90% of the available commercial capacity. In 2009 this situation occurred during 808 hours (9% of the time).

Average maximum load according to commercial use at both borders together - 2009				
	#hours	**total grid**	**critical lines**	**interconnections**
nom < 50%	2158	61%	60%	38%
nom > 90%	808	65%	65%	51%
difference		*4%*	*4%*	*13%*

Table 18: Average maximum load according to commercial use at both borders together

The table shows that with regard to the ‘total grid’ and the ‘critical grid’ (proposed by Elia), moving from low commercial use of a maximum of 50% at both borders to high commercial use of a minimum of 90% at both borders prompts an increase of just 4 percentage points in the physical use. This difference provides a measure for the average sensitivity of the physical use in terms of the commercial use.

As regards the interconnections, the sensitivity is far greater: here an increase in the physical use of the grid of 13 percentage points is observed. However, the general level of use is far lower, namely on average 51% with a high commercial load.

77. The following two tables give the same information, but divided up into two periods of time in 2009: winter and summer[8].

Average maximum load according to commercial use at both borders together - WINTER 2009				
	#hours	**total grid**	**critical grid**	**interconnections**
nom < 50%	843	64%	62%	41%
nom > 90%	404	65%	64%	49%
difference		*2%*	*2%*	*8%*

Table 19: Average maximum load according to commercial use at both borders together, winter 2009

Average maximum load according to commercial use at both borders together - SUMMER 2009				
	#hours	**total grid**	**critical grid**	**interconnections**
nom < 50%	472	58%	57%	37%
nom > 90%	176	66%	65%	56%
difference		*8%*	*8%*	*19%*

Table 20: Average maximum load according to commercial use at both borders together, summer 2009

The striking thing to note between the winter and the summer period is the extent to which the physical use differs depending on whether the commercial use is low or high. In the winter this sensitivity to the commercial use is far lower: 2 percentage points for the ‘total’ and the ‘critical’ grid, and 8 percentage points for the ‘interconnections’. However, in the summer period the figures are 8 percentage points and 19 percentage points respectively. This difference in sensitivity is, moreover, even more pronounced if the lower physical grid capacity during the summer, compared with the winter, is taken into account.

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[8] ‘Winter’ is defined as the months November to February; ‘summer’ refers to the months May to August.

5. *Conclusion*

78. Elia has given the CREG a list of critical lines. The results of the analysis when the ‘critical lines' are considered is very similar to the results when the ‘total grid’ is considered: the commercial use of the interconnection capacity (‘nominations’) has a very slight impact on the maximum physical use of the grid. This impact is somewhat higher when only the ‘interconnection lines’ are considered, but the interconnection lines have a generally lower maximum physical load.

FURTHER RESEARCH

79. The aim of the CREG is to be able to understand the observations made in relation to the calculation of the interconnection capacity by Elia, which is done on the basis of grid safety analyses. The analysis conducted by the CREG in this study concerns the year 2009 and in the future the CREG will further expand and refine this analysis with regard to the following points:

- The study will be expanded to cover 2010 and 2011.
- Variable physical capacity of the lines: according to Elia, the physical capacity of a line may be up to 12 % higher in winter than in summer, depending on the atmospheric conditions.
- Unavailability of grid elements: not all grid elements are always available. This has to be taken into account.
- N-1 versus N-situation: the N-1 situations have to be separated from the N-situations.
- Phase-shifter transformers (PSTs). The use of the PSTs also has to be taken into account.
- Loop flows and predicting these flows: the calculation of the loop flows is more complex than is assumed in this study.

The CREG has already requested the necessary data from Elia for the years 2009 and 2010.

CONCLUSION

80. On the basis of the analysis in this study, the CREG makes the following observations:

a. Paragraph 33 demonstrates that the average monthly total commercial interconnection capacity[9] at the French border varied sharply during the course of 2009, with a difference between the average summer and winter capacity of 26%. This variation is only partly explained by the seasonal nature of the physical capacity and the unequal distribution of the load of the interconnection lines.

b. Paragraph 33 also demonstrates that the average monthly total commercial interconnection capacity at the Dutch border hardly varied at all during the course of 2009, which runs counter to the seasonal nature of the physical capacity of approximately 10%.

c. The development of the average monthly total commercial interconnection capacity at the French border differs sharply from that at the Dutch border (see paragraph 32).

d. The relationship between the physical use of the ‘critical lines’ of the Elia transmission grid and the commercial use of the interconnections with France and the Netherlands is very weak: if the commercial use at both borders goes from low (0-50%) to high (90-100%), the physical use increases only very slightly. In other words, the physical use of the ‘critical lines’ shows virtually no sensitivity to changes in the commercial use of the interconnections (see Part III.3+4).

e. In the winter the relationship between the physical use and the commercial use is weaker than during the summer (see paragraph 77).

81. To be able to understand these observations in relation to the calculation of the interconnection capacity by Elia, the CREG is continuing to expand and refine its analyses, as described in paragraph 79.

82. The CREG has also put additional questions to Elia, still with a view to being able to understand and interpret the above observations in relation to the calculation of the interconnection capacity by Elia. In paragraph 42 the CREG describes its questions with regard to the determination of the commercial interconnection capacity for the Dutch border. As regards the French border, the CREG asks additional questions in paragraph 43. The aim of the CREG is to

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[9] The total commercial interconnection capacity at a border is the sum of the import and export capacity at this border.

gain a better understanding of Elia ‘s view of these points. The CREG has not yet received adequate answers to these questions.

* * *

For the Commission for Electricity and Gas Regulation:

Dominique WOITRIN
Director

François POSSEMIERS
Chairman of the Management Board

Appendix

Seasonal variations in the asymmetry between import and export capacity at the French border.

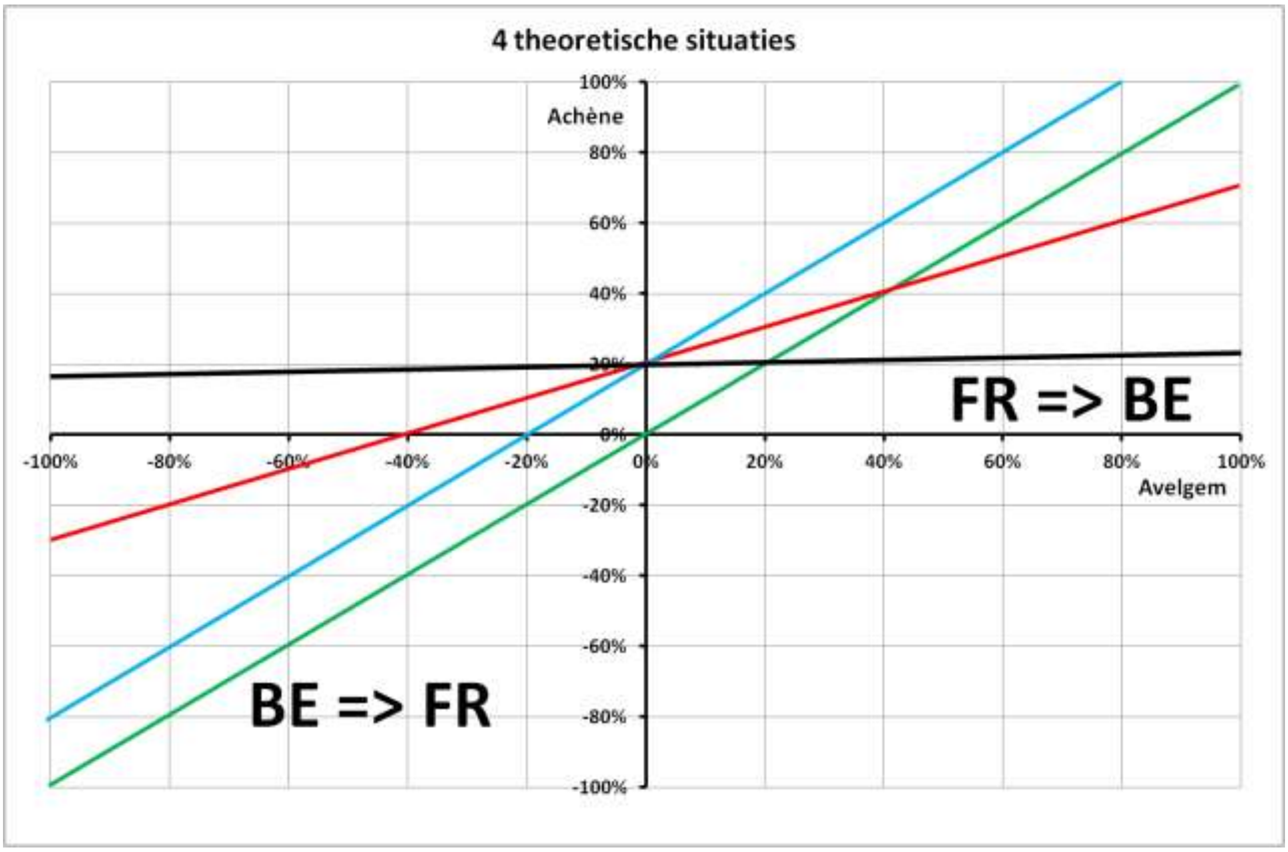
First of all, four simple theoretical situations are presented between the use of the ‘Avelgem’ and ‘Achène’ lines. The actual use of the ‘Avelgem vs. Achène’ pair is then analysed’.

83. The four coloured lines in the figure below give four possible theoretical situations of the relationship between the physical use of the ‘Avelgem’ line and ‘Achène’:

- ‘green line’: this is the ideal situation, because both lines bear an equal load (1 to 1, or a slope of 1). If Avelgem bears a 60% load, the Achène also bears 60%. The maximum capacity that can pass through the two lines is equal for both directions. Both for export and for import, the maximum capacity adds up to twice 100% of the nominal capacity, in this case 1,528 MW + 1,316 MW = 2,844 MW, or export + import = 5,688 MW.
- ‘blue line’: this situation is less good, because Achène always bears a load 20% heavier in the direction from France to Belgium, and Avelgem bears 20% more in the other direction; however, the load on both lines is still 1 to 1 (a slope of 1). If Avelgem has a load of 60%, then Achène has a load of 80%. The maximum capacity that can be carried by the two lines is different for the two directions. For the import direction (FR=>BE), this amounts to 80% of the capacity of Avelgem + 100% of the capacity of Achène, or 80% * 1,528 + 100% * 1,316 = 2538 MW or 306 MW less than in the ideal situation. For the export direction (BE=> FR), this is 100% of the capacity of Avelgem + 80% of the capacity of Achène, or 100% * 1,528 + 80% * 1,316 = 2581 MW or 263 MW less than in the ideal situation. For export + import this comes to 5,119 MW.
- ‘red line’: this situation is even less ideal, because Achène initially bears a load 20% heavier in the direction from France to Belgium and because the load on both lines is no longer 1 to 1. If Avelgem carries 20% more load, Achène only carries 10% more load, i.e. 2 to 1 (a slope of 0.5). The maximum capacity that can be carried by the two lines is different in the two directions. For the import direction (FR=>BE) this is 100% of the capacity of Avelgem + 70% of the capacity of Achène, or 100% * 1,528 + 70% * 1,316 = 2,449 MW or 395 MW less than in the ideal situation. For the export direction (BE=> FR) this is 100% of the capacity of Avelgem + 30% of the capacity of Achène, or 100% * 1,528 + 30% * 1,316 = 1,923 MW or 921 MW less than in the ideal situation, and the export direction therefore has almost 500 MW less capacity than the import

direction. Export + Import comes to 4,372 MW. The Avelgem line is always the limiting factor.

- 'black line': this is least ideal situation of the four: in this case, the Achène line is loaded to an almost constant level of 20%, which means that any variation in the flows has to go through the Avelgem line. The maximum capacity that can be carried by the two lines is different for the two directions. For the import direction (FR=>BE) this is 100% of the capacity of Avelgem + 20% of the capacity of Achène, or 100% * 1,528 + 20% * 1,316 = 1,791 MW or 1,053 MW less than in the ideal situation. For the export direction (BE=> FR) this is 100% of the capacity of Avelgem + 0% of the capacity of Achène, or 100% * 1,528 + 0% * 1,316 = 1,528 MW or 1,316 MW less than in the ideal situation. For export + import this is 3,319 MW. The Avelgem line is always the limiting factor.



Four theoretical situations

84. The relationships can be expressed in general terms as follows, the assumption being that Avelgem is the limiting line:

CapExport = CapAV + slope * CapAch – cut-off
CapImport = CapAv + slope * CapAch + cut-off

‘CapExport’ is the export capacity at this border, ‘CapAv’ is the average physical capacity of the line ‘Avelgem’, ‘rico’ is the direction coefficient of the straight line that gives the relationship between the physical use of the ‘Avelgem’ and ‘Achène’ lines, ‘CapAch’ is the average physical capacity of the ‘Achène’ line and ‘cut-off’ is the load of the ‘Achène’ line when the ‘Avelgem’ is not bearing any load.

To be able to explain the seasonal variation of the total capacity (import+export), all variables are given a seasonal nature, indicated by the subscript ‘winter’ or ‘summer’. The total physical summer capacity is then compared with the winter capacity. This gives the following table:

	WINTER	SUMMER
CapExport	$\text{CapAV}_{\text{winter}}+\text{slope}_{\text{winter}}*\text{CapAch}_{\text{winter}}-\text{cut-off}_{\text{winter}}$	$\text{CapAV}_{\text{winter}}+\text{slope}_{\text{summer}}*\text{CapAch}_{\text{summer}}-\text{cut-off}_{\text{summer}}$
CapImport	$\text{CapAV}_{\text{winter}}+\text{slope}_{\text{winter}}*\text{CapAch}_{\text{winter}}-+\text{cut-off}_{\text{winter}}$	$\text{CapAV}_{\text{summer}}+\text{slope}_{\text{summer}}*\text{CapAch}_{\text{summer}}+\text{cut-off}_{\text{summer}}$
TotCap	$2 * (\text{CapAV}_{\text{winter}}+\text{slope}_{\text{winter}}*\text{CapAch}_{\text{winter}})$	$2 * (\text{CapAV}_{\text{summer}}+\text{slope}_{\text{summer}}*\text{CapAch}_{\text{summer}})$
∆TotCap	$2 * (\text{CapAV}_{\text{winter}} - \text{CapAV}_{\text{summer}}) + 2 * (\text{slope}_{\text{winter}}*\text{CapAch}_{\text{winter}} - \text{slope}_{\text{summer}}*\text{CapAch}_{\text{summer}})$	

The following conclusions can be drawn from this:

- the smaller the slope, the lower the import and export capacity.
- if the cut-off is negative, then according to this convention the import capacity is reduced and the export capacity increased.

To take account of the different atmospheric conditions in winter and summer, it is assumed that:

$\text{Cap}_{\text{winter}} = 100\% * \text{Cap}$

$\text{Cap}_{\text{summer}} = 90\% * \text{Cap}$

This gives:

$$\Delta\text{TotCap}_{\text{winter-summer}} = 2 * 10\% * \text{CapAV} + 2 * (\text{slope}_{\text{winter}} – 90\% * \text{slope}_{\text{summer}}) * \text{CapAch}$$

To determine the seasonal variations as percentages ($\%\Delta\text{TotCap}_{\text{winter-summer}}$), this has to be divided by the total average capacity of the two lines $\text{TotCap} = (\text{TotCap}_{\text{winter}} + \text{Cap}_{\text{summer}})/2$

The table below calculates a number of values for %∆TotCap for various levels of the slope (a seasonal cut-off does not have any impact) and with the known values for CapAV and CapAch. The following observations may be made:

%ΔTotCap			slopeSummer - CapSummer					
			1	**0.9**	**0.8**	**0.7**	**0.6**	**0.5**
		MW	*5.119*	*4.882*	*4.645*	*4.409*	*4.172*	*3.935*
slopeWinter - CapWinter	**1**	*5.688*	11%	15%	20%	25%	31%	36%
	0.9	*5.425*	6%	11%	15%	21%	26%	32%
	0.8	*5.162*	1%	6%	11%	16%	21%	27%
	0.7	*4.898*	-4%	0%	5%	11%	16%	22%
	0.6	*4.635*	-10%	-5%	0%	5%	11%	16%
	0.5	*4.372*	-16%	-11%	-6%	-1%	5%	11%

85. The slope in the summer and the winter for the Avelgem and Achène lines that are examined in the study are respectively 0.60 and 0.68. This implies a difference in percentages terms between the summer and winter capacity of 15%, of which 11 percentage points can be explained by the atmospheric conditions. The calculated difference of 15% is considerably lower than the observed difference of 26%.