Net Transfer Capacities (NTC)

and

Available Transfer Capacities (ATC)

in the

Internal Market of Electricity in Europe (IEM)

Information for User

Table of contents

I INTRODUCTION

The European Transmission System Operators Association (ETSO) has agreed common definitions on transfer capacities for international exchanges of electricity in the Internal Market of Electricity of Europe (IEM). They include the following notions [1]:

- ⇨ **Net Transfer Capacity (NTC)**
- ⇨ **Available Transfer Capacity (ATC)**
- ⇨ **Transmission Reliability Margin (TRM)**
- ⇨ **Notified Transmission Flow (NTF).**

Especially NTC and ATC are an important basis for market participants to anticipate and plan their cross-border transactions and for the Transmission System Operators (TSOs) to manage these international exchanges of electricity.

Based on these European-wide recognised definitions, the TSOs in European countries will calculate and publish transfer capacities between their area of responsibility and adjacent regions. The definitions for transfer capacities will also be an important basis for establishing market rules in some countries, especially rules concerning the allocation of transfer capacities to market participants in case of congestion management.

ETSO has decided to publish twice a year a table "Indicative Values for Net Transfer Capacities (NTCs) in Europe" [4]. This publication aims to:

- Give a general overview of the cross-border transmission capacity situations in the IEM for typical summer and winter scenarios, in terms of Net Transfer Capacities.
- Show the general development of Net Transfer Capacities in the IEM, e.g. due to changing market behaviour, network extensions and construction of new interconnection tie-lines.
- Promote the general understanding of the new definitions.
- Help the market participants to use the new notions for the planning of their desired cross-border exchanges. This may be especially important when TSOs base congestion management rules on the published transfer capacities.

This document explains the most relevant general properties of Net and Available Transfer Capacities (NTC and ATC). The information is given as answers to " frequently asked questions", and will be continuously updated.

This document refers to the following ETSO-publications, available on the ETSO Intranet system:

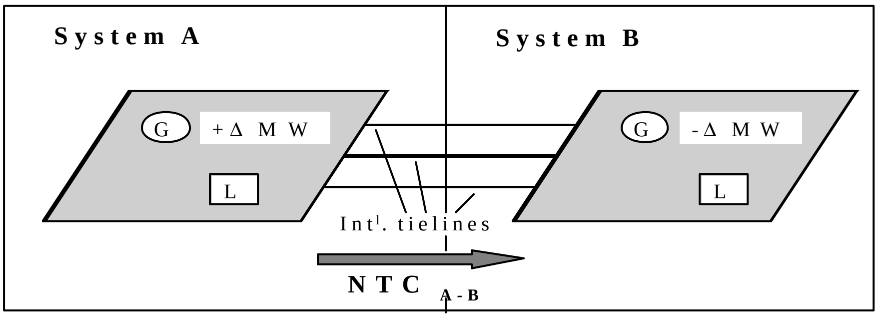
- Definition of Transfer Capacities, ETSO, November 1999
- A technical oriented NTC/ATC user's guide, ETSO, February 2000
- A note on TRM evaluation, ETSO, February 2000
- Indicative values for Net Transfer Capacities (NTC) in Europe, ETSO, published twice a year.

II BASIC EXPLANATIONS RELATED TO THE NTC CONCEPT

In this section some fundamental questions concerning the NTC concept are treated. NTC calculations require that TSOs perform extensive studies of load flows in the interconnected European electricity transmission systems. It is the aim of this chapter to explain the way these calculations are generally carried out, using a very simple example and to explain roughly the complexity of the problem for the European situation that consists of a number of highly interconnected and well meshed transmission systems.

1. How do TSOs calculate NTC? Simple example

Figure 1 shows a simple example of two countries A and B, interconnected by several tie lines.



G: generation
L: load

Figure 1: Simple example of two interconnected transmission systems

Important questions to be answered by the TSOs in this case are:

- What is the maximum power that can be transmitted from system A to system B? This question is equivalent to: What is the Net Transfer Capacity (NTC_{A-B}) between A and B?
- What is NTC for the opposite direction (NTC_{B-A}) ?

The calculation of NTC will normally be performed in three steps:

a) Calculation of the Total Transfer Capacity (TTC):

TTC is set by physical realities that may impede operation of the system according to security rules:

- Thermal limits: The electrical current causes a heating of the conductors of the transmission overhead lines and cables. Depending on the design of lines and cables there is a maximum permissible current. Higher currents would endanger the components of the transmission system itself or the environment, e.g. as a consequence sagging of the conductors of a transmission line towards the ground as a result of thermal expansion of the material of the conductors.

- Voltage limits: The components of a transmission system are designed for specific voltage ranges according to international standards. The voltages must be kept within these ranges to prevent flashover, to maintain an adequate quality supply and to avoid fast dynamic phenomena known as “voltage collapses” which may cause major black outs.
- Stability limits: In large interconnected electric power systems there are many electrical, mechanical and magnetic interactions due to the dynamic behaviour of the generation plants, the characteristics of the loads and the physical properties of the components of the transmission system. As a result significant power, voltage and frequency oscillations can occur within the electric power systems. Because of the danger of partial or total system collapses (black outs) these oscillations must strictly be avoided or managed within an acceptable range and they may induce limitations on operating conditions of transmission interconnections.

Taking into consideration these security constraints, TTC represents the maximum feasible power exchange, which can be transmitted between the systems A and B reliably and without affecting the system security.

To determine TTC *ex ante*, modelling and simulation of the effects of power exchanges between the two systems A and B are necessary. This is generally done simulating the load flows within the two systems and between them. Starting from expected configurations of networks, power generation, cross-border exchanges and consumption scenarios, the generated power is shifted between both systems in order to cause additional cross-border flows: This is done by increasing the generation in system A step by step and decreasing the generation in system B by the same steps. The consumer loads in both systems remain unchanged. The shifts of generation are stopped when security problems occur in system A, in system B or on the interconnection tie-lines.

The resulting TTC-value in this case is to be interpreted as the expected maximum volume of generation that can be wheeled through the interface between the two systems, which does not lead to network constraints in either systems, if future network conditions and especially generation scenarios were perfectly known in advance.

b) Calculation of the Transmission Reliability Margin (TRM):

TRM covers the forecast uncertainties of tie-line power flows due to imperfect information from market players and unexpected real time events. Information from market players is imperfect at the time the transfer capacities have to be communicated. This comes in addition to the uncertainty on some power system parameters, as well as the uncertainty of tie-line flows due to unexpected real time events, which are always possible. Both of the latter can be regarded as probabilistic events at the time of forecasting the transfer capacities. The evaluation of TRM can be done by the TSOs according to past experiences or using statistical methods. Some possibilities are shown in the note on TRM-evaluation [2].

c) Calculation of the Net Transfer Capacity (NTC):

NTC is given by the following equation:

NTC = TTC - TRM

The resulting NTC value in this case is to be interpreted as the expected maximum volume of generation that can be wheeled through the interface between the two systems, which does not lead to network constraints in either systems, respecting some technical uncertainties on future network conditions.

When these calculations are done by increasing the generation in system A and by decreasing the generation in system B, the result will be $NTC_{A\text{-}B}$. When the generations in the two systems are shifted in the opposite direction $NTC_{B\text{-}A}$ will be calculated.

2. How is NTC calculated for more complex transmission system structures?

(Highly meshed interconnected European transmission system)

In meshed networks like for example in the interconnected transmission system on the European continent (UCTE-System) a power cross-border exchange between two countries A and B (that originates from additional power injection in country A and correspondingly reduced power injection in country B) does not only result in power flows between these two countries. According to the physical laws governing the flow of electricity (the electrical flow prefers the way of "least effort"), some of the additional power flows through third countries. Large parts of the interconnected transmission system are considerably affected by such electricity transports, known as "parallel flows".

The following figure 2 shows an example of a load flow calculation when generation in Belgium is increased by 100 MW and correspondingly decreased in Italy by 100 MW. This represents (in a particular case which corresponds to a frequent situation) a simulation of a 100 MW export of electric power from Belgium to Italy. The figure shows the percentages of electrical flows through the European countries.

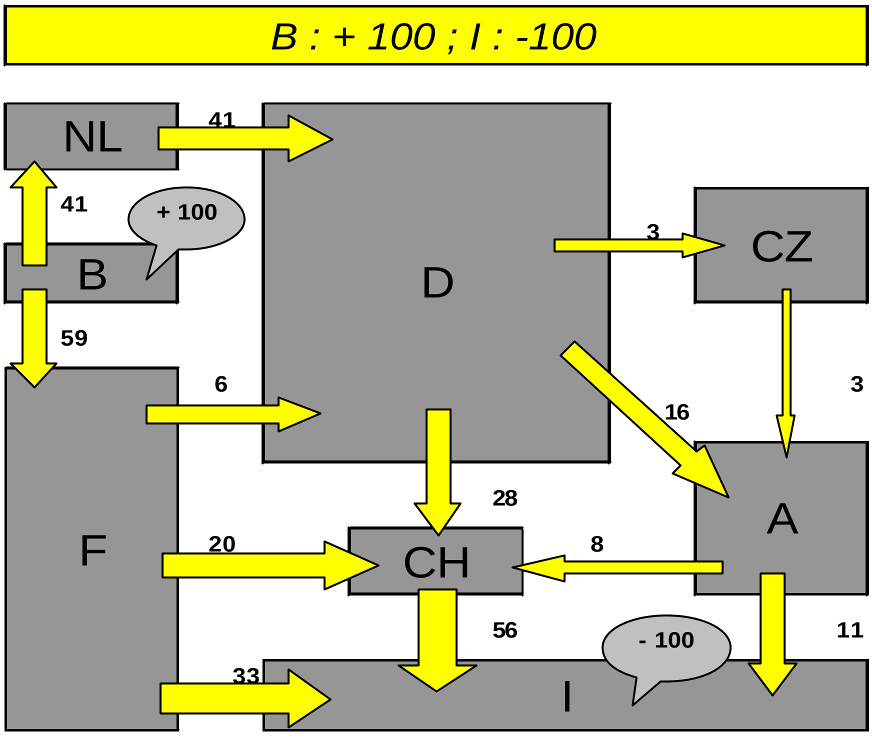


Figure 2: Example of a European load flow for an export of 100 MW from Belgium to Italy

The most important consequences of these physical facts are:

- Every international transaction (cross-border exchange) between two countries in a meshed network affects, to a greater or lesser extent, the system loading in all other interconnected transmission systems.

- Thus, the NTC-values in a meshed network are so strongly interdependent that a publication of realistic international exchange scenarios for the whole IEM is practically impossible. An infinite number of combinations would have to be analysed. This would be completely non-transparent, and impossible to handle or interpret for either market participants or TSOs.

- In order to give an understandable picture of the electricity transfer possibilities to market participants, the TSOs will therefore normally calculate NTCs for a forecasted time frame only between pairs of regions without considering the effects on the NTCs in other regions. They will also use simplistic assumptions for simulating the international exchanges between these two considered regions. Normally the simulations are done increasing step by step the generation in one region and reducing correspondingly the power injection in one other region (see question 1 of this chapter). This procedure will be carried out for all pairs of adjacent regions. The result is the NTC-table that is published by ETSO [4].

- If a market participant wishes to realise transactions between two regions for which NTC-values have been calculated, the resulting electrical power flows may differ considerably from the simulation results if the real export/import-scenario (location of increased generation in the exporting region and location of the reduced generation in the importing region) is different from the simulation assumptions. The calculations of NTC become even more complex for TSOs when simulations for trading companies with a large portfolio of geographically spread generation plants and electricity purchases have to be included. It may be necessary that generation schedules are provided by the market participants to a big number of concerned TSOs ex ante – e.g. on a day-ahead time frame. Without these data it will be hardly possible for the TSOs to perform realistic load flow calculations and forecasts, and to manage congestions.

- Therefore in moving from forecasted situations and indicative NTC calculations towards real time operation and execution of transactions, it is insufficient to assess NTCs and forecast eventual congestion problems by taking into consideration only exchanges between two adjacent regions. In most cases on the continental transmission network, a European wide view of the system status is needed. An important consequence for market participants is the following. **If a market participant wishes to have detailed information on transfer capacities and a forecast of possible congestions, it is always necessary to contact the TSOs. They will be able to give an actual overview of the forecast network situations based on the latest status of announced/accepted transactions by all involved market participants.**

- In the process of planning international transactions the market participants should use the ETSO-NTC-table very carefully, bearing in mind that every transaction affects to some extent all the power flows in European countries, and thus also all other NTC values.

- Furthermore, it makes no sense to add or subtract the NTC values given in the NTC table [4], as each value corresponds to a specific set of assumptions regarding power inputs and outputs. Some major properties of the interdependencies of NTCs are given in the Technical oriented NTC/ATC user's guide [3].

- Considering all these facts, the half yearly ETSO publication of NTCs can only give a general overview over the transmission capacities in the European interconnected transmission system, according to a limited number of specific assumptions. **The NTC-values published by ETSO are therefore generally indicative, not binding values.**

Summarising the above-mentioned considerations, market participants have to recognise:

It is generally not possible for market participants to plan exactly their transactions in the IEM by using only the ETSO-NTC-table [4]. The table gives indications about Net Transfer Capacities (NTC) in Europe, and can indicate in which regions congestion may occur more often than in other regions. These indications are generally more accurate for peripheral countries in the IEM, and less accurate in the centre of the IEM where the network tends to be highly meshed, and to complex network situations. **The only way to get better information of actual transfer capacities for a particular time frame is to contact the responsible TSOs, or to study their regional NTC/ATC-publications.**

3. What is the meaning of NTF and ATC?

To give an answer to this question, the very simple example given in figure 1 is taken as a basis. For simplicity, it is also assumed that there are only exports from system A to system B and that the TSOs in system A and B have agreed on congestion management rules. It is also assumed that some capacity booking process has been established. This means that the market participants have to announce their exports from A to B to the TSOs. The TSOs will order the transactions according to the priority rules of the allocation process, and they will accept them, until there is no more transfer capacity available between the two systems A and B.

In parallel with new information on weather, topology, etc. the booking process in each TSO's area gives additional market information to the TSOs. The additional information helps not only to distinguish the "already allocated" from the "still available" capacities, but also allows improved simulation of the coupling effects between NTCs across the ETSO-area or regions. During this booking process, and if all data have been exchanged between market participants and TSOs, the accuracy of the ex-ante calculations of transfer capacities becomes better as real time operation is approached.

As shown before, the desired transactions from A to B will result in a surplus of generation in system A and a deficit of generation in system B. On a strict confidentiality basis, TSOs may require from market participants the planned generation schedules – (e.g. on a day-ahead basis) - in order to perform the load flow calculations corresponding to the already allocated cross-border capacity. The planned generation scenarios will result in load flows over the tie-lines between A and B. These are called Notified Transmission Flows (NTF).

The Notified Transmission Flow (NTF) can be interpreted as the already occupied part of NTC by the already accepted transfer contracts at the studied time frame.

As the booking/allocation process proceeds, the new information on generation schedules which becomes available to the TSOs will allow them to update their load flow calculations in order to refine their assessment of security problems. As a result, the TSOs will evaluate the remaining Available Transfer Capacity (ATC) between systems. Maintaining good communication of NTC and ATC during the period of planning and applying for international exchanges will be important for market participants.

The Available Transfer Capacity (ATC) for a specific time frame is finally given by the following equation:

$$ATC = NTC - NTF$$

where the value of NTF results from prior allocations.

The Available Transfer Capacity (ATC) is the transfer capacity remaining available between two interconnected areas for further commercial activity over and above already committed utilisation of the transmission networks.

4. How are NTC and ATC typically used as a basis for market rules?

The notions of NTC and ATC can be used in many different ways by national authorities, regulators and TSOs for defining electricity market rules, especially for organising the interconnector access and for congestion management. In this section two typical examples that show the possible range of solutions are outlined:

a) The day-ahead procedures based on ATC in the Nordel-area

b) The NTC-based seasonal and annual rules for access to the Italian electricity market in the year 2000.

a) The day-ahead procedures based on ATC in the Nordel-area

In Nordic countries transfer capacities are communicated to market participants as indicative planning NTC values on a half yearly basis or in a week-ahead time frame. The information is presented on NordPool web pages or on respective TSOs own web pages.

In the day ahead time frame, are issued NTC/ATCs are computed according to the network situation, (i.e. taking outages into account), and they are issued as firm values for bilateral and spot-market electricity trade. When the trading volumes have been allocated and confirmed, the TSOs guarantee the confirmed transactions and manage physical flows by means of counter-trading at TSOs' own cost. Normally counter-trading is used in response to disturbances. In Nordic countries counter-trading is not used to increase NTC/ATCs before spot-market splitting.

The day-ahead principle is illustrated in the following figure.

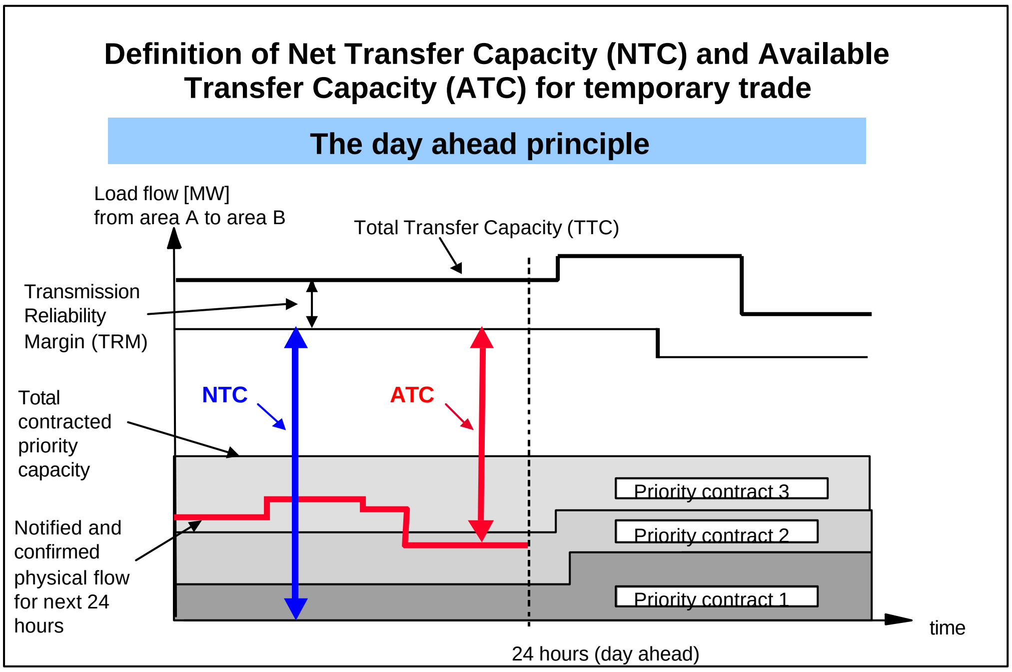


Figure 3: Day-ahead principle using NTC and ATC in the Nordel-area

b) The NTC-based seasonal and annual rules for access to the Italian electricity market in the year 2000.

For the year 2000 procedure, the Italian regulator has chosen to use the NTC-concept on a seasonal basis to allocate the import capacity to Italy. Based on extensive load flow simulations performed by the Italian TSO, the regulator has formalised TTC, TRM and NTC values between Italy and its adjacent countries for summer and winter periods. The month of August will be addressed separately; it needs special treatment because of the maintenance activities in the transmission system. The Italian TSO was advised to consider these NTC values as the maximum possible import capacities, and to allocate import contracts into Italy for the year 2000 on this basis.

On shorter time frames, the Italian TSO delivers import capacity to market participants when this becomes available due to changing circumstances.

III FREQUENTLY ASKED QUESTIONS CONCERNING THE ETSO–PUBLICATION ON INDICATIVE NTC-VALUES

1. Why does ETSO publish NTC-values from (or to) a group of regions instead of individual countries?

The reasons for this procedure are the physical interdependencies in meshed interconnected transmission systems that are explained in detail in chapter II, question 2. Due to these strong physical interdependencies in some central and well meshed parts of the European transmission system, for typical forecasted scenarios the TSOs are not able to calculate separate NTC values for each border. The ETSO-publication gives in these cases only indicative NTC-values for regions comprising multiple countries, e.g. “from Belgium + Netherlands to Germany” and “from France to Belgium + Germany”. If the interdependencies are stronger in one direction than in the other one, groups of regions are only formed in one case.

2. What is the meaning of the footnote of the ETSO-NTC-table?

A detailed explanation is given in chapter II, question 2. Due to the physical interdependencies in meshed interconnected transmission systems simplistic assumptions are necessary for the simulation of expected international exchanges. For reasons of transparency it is only possible to calculate NTC values between pairs of adjacent countries. Each of these values has to be considered separately and no cumulative prediction is attempted.

In some cases there exists a predominant power flow from one region to another region, i.e. from France, Switzerland, Austria or Slovenia to Italy. Consequently NTC values for importing electric power to Italy are important for market participants and are given in the ETSO-NTC-table. Major international exchanges in the opposite direction (i.e. large exports from Italy to France, Switzerland, Austria or Slovenia) are not realistic for the next half-year. The necessary generation capacity to serve consumer loads in Italy and to export additional power to foreign countries is not available in Italy. Even a theoretical simulation does not make much sense because the possible location of additional power plants and their size cannot be estimated. A calculation of NTC values for exports from Italy is therefore not meaningful. For smaller and realistic quantities of exports from Italy to foreign countries there is no known limitation due to the predominant import power flows, and there is plenty of capacity available for trading in that direction. This is indicated by the remark “no realistic limit”:

3. What is the meaning of the column “Value provided by”?

NTC-calculations are performed by the two TSOs on both sides of a border. These results may differ, perhaps because of different security standards in the two transmission systems or different basic assumptions, concerning generation and load patterns. Additionally, the TSOs may have different estimates for the Transmission Reliability Margins (TRM) according to their specific operating regimes.

Due to these and other factors different calculation results are common. In these cases, for the purpose of giving indicative NTC-values the TSOs may agree on the publication of one single number in the ETSO-table. The column “Value provided by” then contains the names of both adjacent countries. The other possibility is to put into the ETSO-table one of the two calculated values (e.g. the lower value), indicating at the same time the responsible TSO for this calculation by giving the name of the respective country.

ETSO does not take any responsibility concerning the published NTC-values. It is up to the TSOs themselves to justify their calculations.

4. Why do seasonal NTC-values sometimes differ so much?

There are two main reasons. First, the patterns of generation and load change from winter to summer. Second the thermal ratings of transmission lines depend on the ambient temperature, being higher in winter than in summer.

5. Why do the NTC-values sometimes change significantly from day to day?

In electric power systems, generation scenarios may differ significantly from day to day during the week and from season to season. The main reasons for these changes are variations in the availability of primary energy sources (e.g. water in case of hydro power plants), economic dispatch of power plants, power plant outages and programmed outages for maintenance. Additionally the load patterns may also change significantly, e.g. higher consumption in winter times and lower loads during holidays. The consequence is that NTC-values calculated for shorter time frames (e.g. day-ahead) may change significantly from day to day and may not be equal to the seasonal values published by ETSO.

6. Why are NTC-values usually much smaller than the sum of the thermal capacities of the tie-lines?

A transmission network consists of a number of transmission elements (e.g. lines and transformers), each one having a definite maximum transport capacity that is mainly determined by thermal limits. NTC values, however, reflect real electricity transport possibilities in the meshed and internationally interconnected transmission systems. Two factors limit transfer capacities at values normally much below the thermal capacities:

- The network element within a transmission system that is the most sensitive to the load flow, compared to its operating limit (i.e. with a loading already quite near to its thermal limit) has the biggest impact on NTC calculations. It may set the limit for NTC even when the loading of the international tie-lines are still much below their thermal ratings.
- Even, if temporary admissible overloads are taken into account, the security criteria related to voltage or frequency stability lead to constraints that may limit physical load flows at significantly lower values than the thermal capacities of lines (see also chapter II, question 2). For example, it is necessary that a fault on a single element such as a line does not jeopardise power system security. Such incidents may occur at any time, although they are more likely during adverse conditions such as thunderstorms.

7. Why, for a given interconnection, do NTC-values in the two directions normally differ?

This has already been mentioned under question 2 of this chapter for the case in which there are published NTC values for one direction, but no realistic limit in the opposite direction. The main reason is that the NTC values in both directions depend on the initial load flow conditions set by the base generation and load patterns due to the already existing transactions. If a sensitive network element regarding NTC limits has an initial load in one direction, additional cross-border transactions that increase the load flow over this element in the same direction result in tighter NTC-limits than cross-border transactions in the opposite direction.

8. Do NTC-values constitute an absolute limit for commercial transactions?

No, NTC-values only set the limit for physical power exchanges (flows) in one direction between adjacent regions. The physical flows however do not follow commercial transactions! Two simple examples are:

- The basis of commercial cross-border transactions (programmed exchanges) is normally a surplus of generation in one region and a deficit in another region. Two cross-border transactions in the opposite direction however would cancel partly or totally the physical flows in the two transmission systems. This is one of the most important properties of electricity transport compared to other transport businesses where the transported volumes in opposite directions remain as separate entities. This feature of electricity can also be explained as follows. The first transaction (contract) leads to a surplus of generation in one region and the second to a deficit in the same region. The generated power of the first contract can therefore be regarded as flowing to the load of the second contract. Summarising, the sum of the two (or in general all) transactions is normally higher than the physical load flows and the load-flow based NTC values.
- The international trade between different market participants may increase significantly in the European electricity market. International trade can, however, result in commercial cross-border transactions without any changes in generation or load patterns, or trades may result in chain contracts where only the first and the last contract define the real input and output of power. Physical load flows in the transmission systems are functions only of the geographical locations and amounts of power inputs and outputs, and not of the possible sequence of commercial contracts.

9. Is it possible to bypass congested regions by a chain of commercial transactions?

Physical flows in transmission networks are independent of commercial agreements (see previous question). TSOs cannot base rules for access to cross-border capacities or for congestion management only on the knowledge of commercial contracts, but must take into account the geographical locations of generation and loads. TSOs may therefore require from their national market participants information on planned generation schedules and load patterns. For example, in a day-ahead time frame this information forms the necessary basis for the day-ahead management of cross-border exchanges.

According to basic rules agreed within ETSO, a single TSO will not grant a transmission contract when a significant fraction of the resulting power flows concerns other TSOs, or whenever power flows have a major impact on another TSO’s congestion problems. More precise rules will be applied for congested areas in Europe, depending on the specific market and network conditions and the agreements on congestion management methods between the concerned TSOs. These will ensure that congestion restrictions cannot be bypassed by any form of commercial arrangements, because this would be a real danger for European power system security.

References:

[1] Definition of Transfer Capacities, ETSO, November 1999

[2] A technical oriented NTC/ATC user's guide, ETSO, March 2000

[3] A note on TRM evaluation, ETSO, March 2000

[4] Indicative values for Net Transfer Capacities (NTC) in Europe, winter and summer, working day, peak hours, ETSO-publication twice a year