

# **Analysis of Electricity Network Capacities and Identification of Congestion**

**Final Report**

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## Executive Summary

In the context of the creation of an internal European electricity market, the existence of sufficient cross-border transmission capacities and their efficient utilisation gain crucial importance. Historically, transmission system operators (TSOs) have not designed the interconnections between their networks primarily to facilitate bulk power trade, but rather to achieve better reliability and efficiency of supply through co-operation among them. Hence, the introduction of open access to transmission networks has made a number of bottlenecks in cross-border transmission capacity visible that can have an adverse effect on competition and thus on the integration of the internal market.

On this background, the European Commission has assigned us to carry out a comprehensive investigation on electricity transmission capacities between the EU member states plus Norway and Switzerland, with the objectives

- to analyse the approaches applied by TSOs to determine the operationally utilisable levels of cross-border transmission capacity, among others for the purpose of publishing net transfer capacities (NTCs), and to propose possible improvements,
- to identify bottlenecks in the cross-border transmission systems and to categorise them into critical and less critical ones,
- to investigate the present and future demand for additional transmission capacity specifically at the locations of the critical bottlenecks, and
- to identify and evaluate possibilities to increase the level of usable cross-border transmission capacity at the critical locations, including so-called “soft measures” that require no or only insignificant investments, investment options other than new lines, like the installation of power flow controllers or the reinforcement of existing connections, as well as the construction of new lines, taking into account also projects that have been identified as projects of common interest in the context of the “Trans-European Networks” (TEN) programme.

We have subdivided the work on this study into two phases:

- In the first phase that has been completed by the submission of an interim report, we have gathered information about the operational methods, definitions, etc. applied to determine cross-border transmission capacity, and about the occurrence and severity of congestion of the existing capacity, mainly in personal meetings with TSOs and network users.
- In the second phase, we have on the one hand investigated the demand for additional transmission capacity at the critical bottlenecks based on diverse approaches. On the other hand, we have evaluated possibilities to increase usable transmission capacity across these bottlenecks by a range

of measures as outlined above. This has involved further intensive communication with TSOs, complemented by our own investigations including load flow modelling and other approaches.

The attempt to derive quantitative information on the demand for additional capacity at the critical bottlenecks has turned out to be a particularly difficult task, and we could hardly gather any relevant information on this issue from TSOs and market participants. Moreover, it is not even clear how to define transmission demand properly, because this is not only an engineering or economic question, but also a political one. Therefore, instead of seeking for a unique approach to this task, we have carried out several fundamentally different investigations to highlight different possible viewpoints to this issue. We have included the following approaches, some of which focus only on one or few of the critical bottlenecks due to limitations of time and data availability:

- an investigation of the short-term marginal value of transmission capacity based on a generation dispatch model, carried out by the Institute of Energy Economics (EWI) at the University of Cologne, acting as a subcontractor;
- an investigation of the results of transmission capacity auctioning procedures, also aiming at evaluating the short-term value of transmission capacity;
- an evaluation of publicly available energy forecast documents with the objective to identify key trends in the development of load and generation in the relevant countries that might lead to significant changes of cross-border transmission demand in the longer term; and
- an evaluation of the network density inside countries and across borders, independent from locations, capacities and dispatch of generation units.

The conclusions that we have drawn from the whole of our investigations can be subdivided into observations, general recommendations and border-specific recommendations. Essential observations about the determination of cross-border transmission capacity are:

- There is an important difference between indicative, non-binding NTC values published by ETSO twice a year, and capacity values used for the actual allocation of transmission rights at individual borders. Since the degree of coherence between these types of capacity figures differs considerably from TSO to TSO, the discussion on the further development of rules and standards for capacity determination should not only be focused on the official ETSO NTCs.
- All TSOs apply a uniform basic concept for the determination of cross-border transmission capacity. There is however significant space for individual interpretation and parameterisation of this concept. This leads to a large variety of the concrete details of the actually applied approaches, which not only makes their comparison very difficult, but also can have a considerable impact on the resulting capacity values.

As regards the identification of bottlenecks, we could gather sufficient information on the frequency and severity of congestion to come to a relatively clear distinction between critical and less critical bottlenecks. Taking into account that we have excluded bottlenecks that can only be relieved by adding new DC sea cables which is on the one hand a very expensive and long-term measure and whose impact on available capacity can on the other hand be determined very easily, we have identified the following five interconnections as “critical”, being relevant for the further investigation:

- France → Spain,
- France → Belgium & Belgium/Germany ↔ Netherlands (to be analysed in combination),
- Denmark ↔ Germany,
- France/Switzerland/Austria/(Slovenia) → Italy, and
- Norway ↔ Sweden.

As stated above, our recommendations with respect to the necessity and possibilities of measures to increase transmission capacity can be split into general and border-specific ones. The general recommendations can be summarised as follows:

- Our analysis has revealed a fundamental problem regarding the applicability and meaningfulness of bilateral capacity values like NTCs: the assumptions for “base case exchanges” (BCE) included in the network model used for NTC determination are of significance for the resulting NTCs, and they can change due to changing trading relations, without any change of the physical load flow situation. To mitigate this problem, we recommend in the short term to request TSOs to publish the assumptions made for BCE, and in the long term to switch to a more coordinated concept of capacity allocation that would reduce the importance of NTC values.
- The fact that a variety of aspects in capacity determination are treated very differently among TSOs promises a potential for improvements through harmonisation. However, due to the strong interdependencies between these aspects, it would not be recommendable to identify the “best practice” with respect to each single aspect and to synthesise a best practice solution as a basis for harmonisation, because this would probably not lead to a uniform “quality level” of transmission services. Instead, we recommend to aim at a harmonising the overall level of “risk” associated to the determination of transmission capacity, with risk being defined as the probability of undesired measures like re-dispatch or supply interruptions, multiplied with the respective cost or damage. This would leave the specification of single aspects of capacity determination up to subsidiarity, but harmonise the resulting quality level as seen by the network users.

- Since a complete and unified risk assessment as proposed above will not be achievable in the short term for several reasons, concrete efforts should be spent on an improved assessment of single contributions to the overall risk, as far as possible on a probabilistic basis. Even without having defined target levels for these risk contributions, improvements could be achieved by levelling the partial risks over time or among TSOs. This requires first of all that TSOs separate more properly the treatment of the relevant factors that influence this risk. On this basis, several approaches for improvement can be taken, two of which are outlined below:
  - The actual transmission capacity of overhead lines varies over time, because it depends on the prevailing environmental conditions. Encouraged by the good experience of several TSOs, we recommend to take the systematic influence of ambient temperature on the transfer capacity of lines explicitly into account, by applying seasonally varying transfer limits as far as possible.
  - TSOs can influence the quality level of transmission by applying corrective measures in the operational phase (corrective switching; re-dispatch) when unexpected events occur or simply a number of unfavourable influences accumulate. We recommend to take this possibility of *occasional* countermeasures into account in the process of capacity determination in a more systematic way, because this could lead to increased capacity values.
- Besides technical aspects that we have mainly focused on, several TSOs have indicated that also legal issues can be obstacles to the implementation of approaches that are already applied in other countries or that are suggested on the basis of our results. This should be kept in mind when discussing the possibilities of improvement, and the affected TSOs should be requested to highlight such obstacles when they are confronted with the approaches discussed in this study.
- An issue that is often raised in the context of capacity determination is the potential benefit of additional transparency by more comprehensive publication of details about the methods applied, about underlying definitions and statistical evaluations, and about retrospective evaluations of the actual utilisation of capacity. Although not directly influencing available capacity, we agree that such publications can be expected to have an indirect positive effect both by influencing the behaviour of TSOs and by giving network users better insight into the relevant interdependencies.

In the following, we briefly summarise our findings related to individual borders identified earlier as critical bottlenecks, presented in the order of decreasing priority as regards measures to increase transmission capacity:

- At the **Italian border**, the economic value of transmission capacity has been identified to be remarkably high, and the network density appears clearly lower at this border than inside the adjacent countries. Therefore we come to the conclusion that besides two promising soft measures, specifically the abolishment of the (n-2) criterion applied for a French-Italian double circuit line

and the application of seasonally differentiated line ratings for internal Italian lines, also investment measures should be pursued. Apart from a new phase shifting transformer on the French side, we have analysed a number of new tie line projects from France, Switzerland or Austria to Italy whose cost/benefit ratios are roughly in the same magnitude and which should therefore be assessed rather in the light of authorisation issues.

- Based on rough estimations of the economic value of transmission capacity and on the evaluation of network density, we conclude that also the **French-Spanish border** is a relatively urgent candidate for measures to increase transmission capacity. Since the potential of soft measures is already more or less fully exploited at this border, this implies the need to consider investment measures. Besides a few minor reinforcements to be implemented in the short term, a significant capacity increase can only be achieved by constructing new tie lines, of which we have analysed three alternatives with similar cost/benefit ratios but different chances of being realisable.
- Regarding the **Dutch border**, our investigations indicate a relatively high economic value of transmission capacity today, but a limited need of adding new interconnection capacity in the long term. Therefore, besides the implementation of the phase shifter project in Meeden that has already started, we recommend to strive for application of the soft measure of increasing the thermal current limits on the German side in the colder periods of the year.

The fact that there is no direct interconnection at the **German-Belgian border** does in our opinion not necessarily lead to the conclusion that such an interconnection should be constructed. Rather, a co-ordinated approach of capacity allocation appears particularly promising for this network area.

Regarding the **French-Belgian border** which is also frequently congested, we have analysed different investment projects whose benefit depends on the assumptions for the import demand of Belgium and the Netherlands. Besides French-Belgian tie lines, these projects include also the reinforcement of a French-German tie line.

- For the **German-Danish border**, the economic value of transmission capacity according to capacity auctioning results has turned out to be relatively low in both directions. In the longer term, the demand for transmission capacity might however grow due to transits and wind generation. We recommend mainly to clarify some details in the context of capacity determination that might reveal potential for soft measures. An investment project that we have analysed appears hardly recommendable at the moment due to its high cost and difficult authorisation situation.
- According to our own considerations and those of the TSOs, the demand for additional transmission capacity at the **Swedish-Norwegian border** appears rather low at the moment. Taking into consideration a number of projects that will soon be implemented, we do not see an urgent need to identify further measures to increase capacity at this border.