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The role of electricity transmission and interconnectors

New interconnectors will play an important role in the ongoing processes of integrating the European electricity markets and handling the increase in renewable and intermittent sources of electricity production, such as wind power. The strengthening of the European electricity infrastructure has been identified as an area of priority in a recent communication by the EC (European Commission 2010). This has also been confirmed by the interdisciplinary research project Pathways to Sustainable European Energy Systems, where the need for new interconnector investments across the EU was estimated to almost 30 GW by 2030. The Pathways project used an integrated modelling approach for addressing the complexitym of generation and grid planning issues. This model toolbox will be utilized for further analyses also in the NEPP project.

Substantial need for new interconnectors in Europe

The research conducted in the Pathways project using the ELOD model indicates that it is profitable for the European electricity system to expand significantly the interconnector capacity between the Member States, from the existing 42 GW (existing interconnector capacities are taken from ENTSO-E public online data) to almost 60 GW in the Policy scenario[1)] or to 55 GW in the Market scenario[2)] by 2020. Figure 1 presents the results of the Policy scenario. However, such investments require substantial lead times, which are not fully taken into account in the modelling. It should be noted that the new interconnection capacities identified are based on the economic and environmental consideration of the projects. The technical feasibilities of those interconnections capacity in terms of locations of grid connection points, network loading as well as overall system stability will be subjects of further detailed investigations.

An approach to evaluate the profitability of new interconnectors

The ELOD model was used to evaluate the power transmission capacity (trade) required between EU member countries during the coming 40 years. In this analysis, investments in new transmission capacity occur if they are found to be profitable. The evaluation method is similar to the "value-based" planning method which is available in the literature. It should be noted that the methods for transmission charges are different in different countries in Europe. In this study it has been assumed one common method based on locational marginal pricing. If the difference in wholesale electricity prices between the two ends of an interconnector is sufficiently large to motivate investments in interconnector capacity, these investments will be made. Consequently, the price difference will be reduced when the transmission capacity becomes more available. These investments are made until the differences in electricity prices between the countries are reduced to the annualised investment costs of the interconnector capacity. As a result, the interconnector would be able to recover its investment cost.

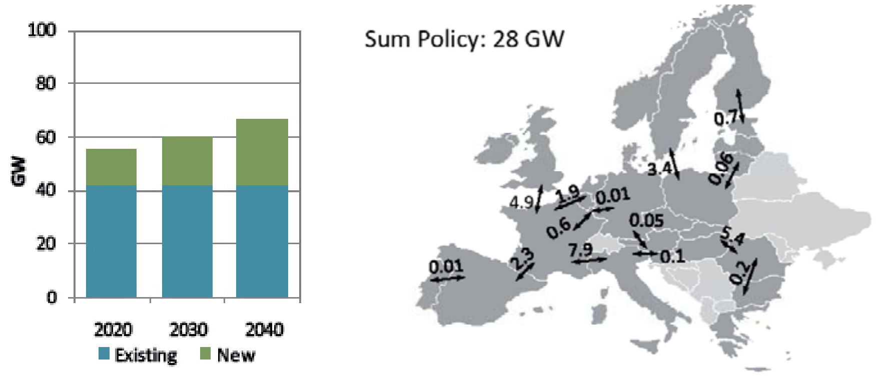

Figure 1: European interconnector capacities (the sum of net transfer capacities between EU Member States, and including Norway) in the Policy scenario in 2020, 2030, and 2040 (left), and the regional distribution of new capacity (in addition to those existing in 2010) in 2030 (right).

1) The Policy scenario reflects a future development including several specific policy measures directed towards renewables and efficiency measures, thus a greater share of responsibility is given to politics.

2) The Market scenario reflects a route with few if any technology preferences, i.e. the choices of technology means to meet stated climate targets are left to the market.

Identification of internal bottlenecks in Germany's transmission network

This example is intended to illustrate a simple power flow calculation using DC Power Flow model to evaluate the effects of the future estimated generation plan (taken from the model calculated scenarios for Europe as reported above), on the transmission network in Germany. Figure 2 shows the power flow result of Germany's transmission grid for a Baseline scenario and for a peak load hour in 2015. In this case, Germany's network has been made isolated from the rest of the interconnected network using system equivalence technique, so that the analysis of the effects of generations on the transmission networks in Germany alone can be studied. It is important to note that the power exchange between countries (i.e., between Germany and other connected neighbouring countries) will have effects on actual power flow within a country. The red circles in Figure 2 show the lines which are overloaded during the studied hour. Note that not all the overloaded lines are shown. It is possible to use the model to evaluate the effects of the power exchange program over the planned interconnectors, as shown in this example on the internal grids. Based on this information it is, thus, possible to make an adjustment in the plan in an iterative manner.

For the power flow calculations, the locations of the generation and load centers have to be known. In order to perform the power flow calculations, assumptions on locations of generations and loads have been made since the new generation capacity as well as the generation dispatch schedule (obtained from previous ELOD/EPOD model runs) are the aggregated values according to types of generation technologies. The new generation capacities except wind power are assumed to be located in the same locations as the existing ones of the same types. The generation locations are identified in the model using the actual network map of ENTSO-E and the extensive Chalmers power plant database. For the load data in the future, it is assumed that the loads will increase equally in different regions. The forecasted load used by ELOD is then used to calculate the load scaling factors from the existing loads. The loads in the peak hours for different years are used in the calculation since the high load conditions would most likely lead to high load in the transmission systems. This can of course vary with different distributions of power generations and loads. In the power flow calculation, only active power is considered and transmission lines are considered lossless. The reactive power is neglected due to unavailability of reactive power generation and reactive power demand data, as well as the reactive power consumption devices in the system. Hence, the name DC Power Flow model of the model used here.

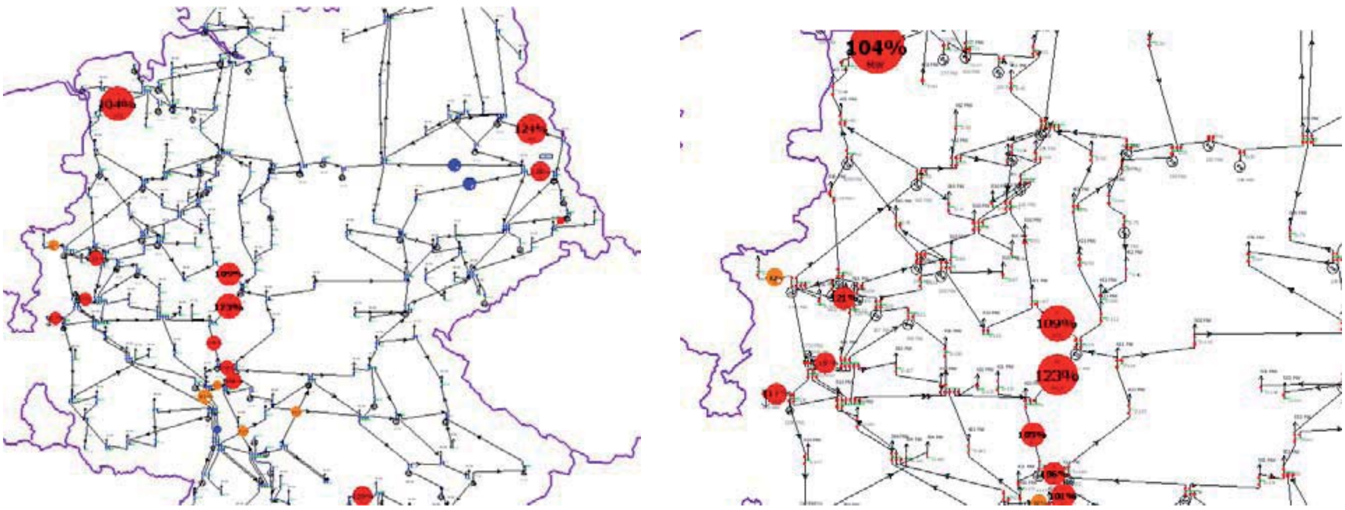

Figure 2: Power flow in Germany's transmission network for a peak load hour in the Baseline scenario in 2015.

THE MODEL TOOL BOX

Within the framework of the Pathways project, a modelling package has been developed for the complete power generation and delivery system, comprising ELOD, EPOD, and DC Power Flow models. ELOD models the future development of the EU electricity supply system up to 2050, while the EPOD model allows a more detailed analysis of electricity production for a given year in the future. DC Power Flow models the electrical transmission network that connects the generation facilities and loads considered in both the ELOD and EPOD models. The transmision network model DC Power Flow is linked to the electricity-generation models ELOD and EPOD through a soft-linking approach. This means that the DC Power Flow model takes the inputs from the ELOD and EPOD model. These inputs include the investment plan for new generation capacities of different types of generation technologies from the ELOD model and the generation dispatch schedules of the peak load hours, i.e., snapshots, for different years from the EPOD model. The aim of this approach is to assess the interactions between the future pathways for power generation systems and power delivery systems, so as to identify major bottlenecks in the systems and measures to overcome such bottlenecks in the future.

For further information: Tuan Le Anh, Mikael Odenberger, Chalmers and Thomas Unger, Profu