EUSUSTEL WP 6.3

Compatibility with liberalisation of the electricity and gas markets

IEM Directives and market development

Even though the Internal Market Directives (96/92/EC and 2003/54/EC) refrain from designing a concrete market architecture, the Internal Electricity Market (IEM) consists of 25 Member State submarkets with similar architectures. Wholesale markets are mainly bilateral, but in most Member States, there is the possibility for anonymous auction trade organized by power exchanges one day before delivery. Since a few months, a coupled power exchange exists in Belgium, France and the Netherlands: Belpex, an example for the rest of Europe. At this moment, the market structure is more European than market architecture. The industry has consolidated into a few big European players, while the market consists of Member State submarkets weakly linked by limited interconnector capacity markets. A vehicle for harmonization is improving the links between submarkets gradually. There are some regional developments in this direction and it is important that enough interconnector capacity is available for such initiatives.

Decoupled investment decisions

Before liberalization, investment decisions were taken centrally and coordinated by linking generation and transmission. Based on demand forecasts, governments chose to build plants of a certain fuel type domestically or to contract long term imports. Grid investments were done in function of generation decisions, import needs and load locations. In a liberalized market, grid and generation investments are legally decoupled due to unbundling. Grid investments are done facing uncertain generation decisions (both for installing new capacity and for closing or mothballing old ones) and accounting for sometimes unstable regulation. An important question is how independent the future grid should be of the current load flow context. In other words, how much should be invested in congestion alleviation relative to interconnectivity? Investing in flow control is very interesting in a liberalized context because of the implied grid flexibility. The current regulatory framework does not ensure that congestion revenues are used for transmission investments that are in the long run beneficial to the market, because regulators are biased towards a short-term tariff reduction. More investment coordination is clearly needed in Europe, either pushed by European regulation or driven by coordinated regulatory actions, because projects presented to national regulators are often not judged on the common European interest involved, even if they have received funding on that basis.

The international network context

Current system

The European grid is made up of 5 synchronous areas, all containing Member States of the European Union but also non Member States are part of these areas. In other words, there is no “European electricity grid”, but there is a lot of voluntary or/and technical cooperation between different groups of States, in combination with different national implementations of the Directives. This situation evidently complicates cross-border investments in Europe severely. The European national grids are only weakly interconnected. In the past, they were after all interconnected for technical stability reasons and to pool generation reserve capacity, and not to become the backbone of the IEM.

Zonal network model

The continental interconnected European UCTE network, or any interconnected meshed network for that matter, consists of thousands of nodes and lines. Each of the UCTE member states controls its own part of the network, called a control area. Due to the freedom given to the member states by the European Commission there is no common market design in Europe and often different rules are applied by the member states. However, one thing is common in Europe – a flat transmission tariff system, often referred to as postage stamp. This means that there is no differentiation between the location of injected power, nor any limits of power that can be injected or withdrawn in a given point of the network. The internal grid of a control area is supposed to be strong enough to cope with any scenario of internal dispatch. Rare cases of technical infeasibilities are solved by the Transmission System Operator (TSO) and the resulting costs are socialized among all users of the domestic transmission system. This model has been adopted in order to avoid discrimination between network users, and as long as the internal grid can indeed handle all possible internal dispatch scenarios, or costs of re-scheduling of generation units to achieve a feasible dispatch are within an acceptable range, the market functions well.

However, the organization of a local market has repercussions for the global one. Each commercial cross border transaction between two areas can be physically realized in a virtually infinite number of ways. Obviously the resulting cross-border flows on individual lines can vary significantly depending on the physical location of the transaction's sources and sinks. This means that even changes in the internal dispatch of a zone do influence the cross-border flows. Moreover, the larger the control zone, the more cross-border flow variations are possible. Especially the geographical shifts of generation can cause very significant changes in cross-border flows.

Loop flows in a zonal network model

One of the most significant consequences of the zonal approach to network management is the phenomenon of loop flows. These are the power flows that were unannounced to the system operator. There are two major causes of loop flows, linked to international contracts and cross-border congestion management. One is the applied network model where hundreds of nodes of a given zone are substituted with one equivalent node. What follows is a loss of information on the actual nodal dispatch within a zone. Therefore, even when the control zones are balanced and there are no imports or exports scheduled, there will always be cross-border flows as the electrons follow the laws of electricity. Secondly, in the European interconnected grid the interaction between the zonal imbalances and cross-border flows is not modelled. Though the correct modelling of such interaction in the presence of a zonal network model is extremely difficult if not impossible, a much worse solution is relying on a contract path approach, where the transaction path can be contractually chosen. This implies loop flows resulting from the mismatch between the contracted path and the actual current path, and loop flows resulting from the lost information when going from zonal to nodal realities.

Predictability is clearly a key issue when applying a zonal network model. However, some sources of electricity are unpredictable, such as wind generation. Wind fluctuations can often cause a geographical shift of generation from one part of the zone to the other, influencing the cross-border flows, and consequently power flows in other zones. The changing internal dispatch of the control zones, increased cross-border trade and the applied zonal network model can form a dangerous mix, making international regulation and coordinated control inevitable.

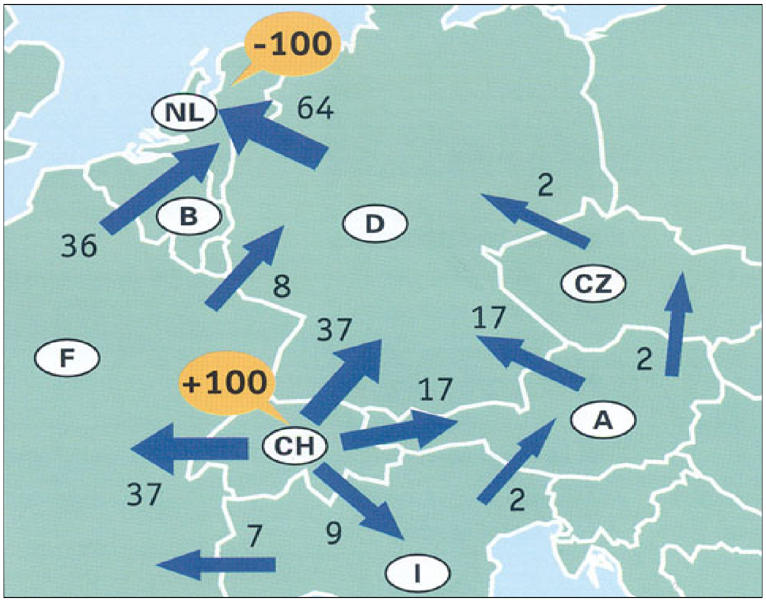
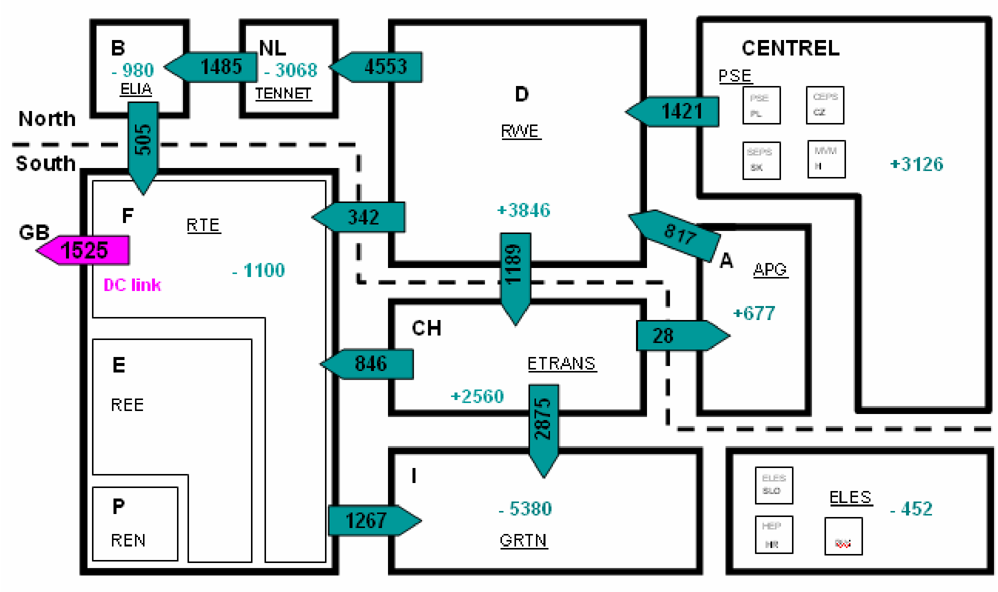


Figure 1: Interdependency of power flows in the European Network

The complex control of wind power

Wind power constitutes a significant problem for the electricity grids in Europe. The massive installation of wind energy systems in The Netherlands and Germany is for example responsible for difficulties in the Belgian grid operation. In case of high wind speeds and consequently high power generation in North Germany, the power has to find its way to the Southern Germany where the load centers are located. As the German grid itself is unable to carry these flows, a significant part of it passes via The Netherlands, Belgium and France, back to Germany. Another part passes via Poland and the Czech Republic, limiting the export of Poland. These flows add to the usual Germany-The Netherlands exports, and stress the already often fully loaded Eastern Dutch border. The often congested south Belgian border is in turn relieved as the flows caused by German winds generally flow in the opposite direction than the scheduled France-Belgium exports. On the other hand, in case of no or very little wind in Germany the wind turbines come to a stop and there is no relieving effect on the southern border of Belgium. However, the most severe situation occurs for very high wind speeds. The turbines come then to a standstill as a result of over-speed protection. Consequently, the power output of such turbine drops from full power to zero in a matter of seconds. As the region where the majority of wind farms are installed covers a rather limited area, the increase or drop of generated power happens virtually instantaneously.

The possible installation of an off-shore wind farm on the Thornton bank (up to 2000 MW) will cause a need for backup reserve power in case of wind fluctuations. One of the most significant sources of the reserve power is the Franco-Belgian border, meaning that a part of the increased capacity of the reinforced Avelin-Avelgem cross-border line would need to be withheld, limiting to a major extend import and trade possibilities needed for the creation of the IEM.



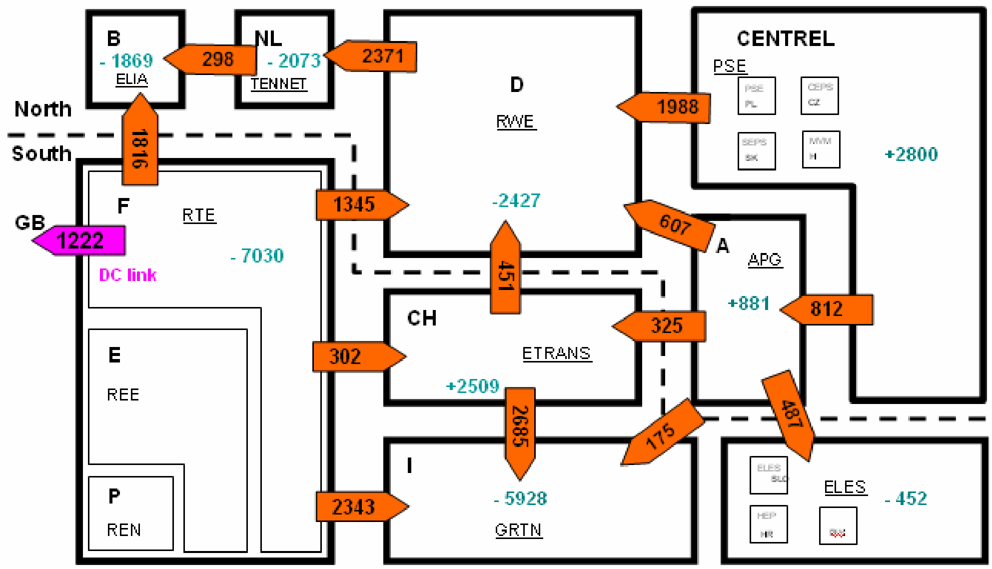


Figure 2: Changing patterns of European cross-border power flows [MW] as a result of wind power (top figure: exchanges as scheduled, bottom figure difference between actual flow (metered) and scheduled ones)

Grids of the future

The ongoing liberalization process and the herewith associated rise in international energy flows, are responsible for an increasing stress on the transmission grid. This occurs in a consumer environment where reliability of supply is expected to stay at the very high level we have known until now and where needed even increase. This mismatch between trends and requirements can in principle be solved by building new transmission lines. However, this is unacceptable in most cases due to social and political circumstances. The use of power flow controlling devices can alleviate the stress on the network at a significantly lower cost and a very limited social cost.

Controlling power flows

Traditional power flow control is realized by means of phase shifting transformers, where the energy flow through a line can be controlled by altering the phase angle between two nodes. By shifting flows from heavily loaded lines to less congested ones, the "stress" on the grid diminishes, at a relatively low social cost. The phase shifting transformer technology is similar to the more frequently used under-load tap changing transformer, and therefore well known and reliable. Phase shifters can be controlled within a time period of minutes.

Control actions of power flow controllers are not local but influence the entire meshed network, including neighboring networks. This could lead to conflicting control actions, lowering overall network security. This implies the need for international coordination of power flow control. Using advanced metering of currents and power flow (phase angles) at different network modes, combined with geographical information, an advanced flow control system can be established, trying to optimize the overall power flow in the meshed grid with respect to for instance increased reliability or improved energy efficiency.

Development of transmission technologies

New materials will allow the construction of overhead lines with composite cores, which are lighter than steel core conductors and could increase the line capacity up to three times. For cable technology, much is to be expected from HTS (High Temperature Superconducting) cables, which would reduce losses up to a factor of 5. Superconductors can also contribute in switching and grid protection, leading to an improved reliability.

Energy storage

Storing electric energy on a large scale is extremely difficult. Consequently, there has to be an instantaneous balance between consumed and generated electric power. This puts large strains on the power generation from less controllable energy sources such as renewables. However, recent developments have provided some possible solutions. Supercapacitors and SMES (Superconducting Magnetic Energy Storage) are two examples of these new developments that can provide a solution to the problem of short term electrical energy storage. Both are in a far state of development and prototypes are already installed, but their capacity remains however limited.

Advanced metering in distribution networks

One of the important changes in the philosophy of the future network management will be the ever more occurring bi-directionality of the electrical energy flow. If an increasing number of Distributed Energy Resources (DER) is connected to the electrical grid, a significant portion of the electrical energy might be generated near to the consumption, resulting in an excess of power being injected locally in the grid. However, some of these energy sources have limited availability, often depending on different meteorological circumstances or external factors such as heat-demand-driven CHP-units. This is responsible for reversing the power flows. Several types of DER are renewable energy sources, for which special tariffs or benefits are applicable in order to encourage the sustainability of the energy supply.

In order to globally optimize generation scheduling within the distribution system, a large amount of information needs to be exchanged among different entities. Both energy and information flows need to be dependable: reliability, availability and integrity requirements are to be fulfilled. Consequently, fault prevention and fault tolerance are key issues in such an environment.

In order to optimize consumption, next to optimizing generation, active Demand Side Management (DSM) is introduced. DSM, sometimes also referred to as demand side participation, implies that loads respond to external signals such as prices. This requires real-time pricing and real-time measurements. The price of the electricity should vary continuously, putting again more requirements on metering data exchange.

Conclusions

This report defines the potential network challenges that arise under the different scenarios of the EUSUSTEL project. Scenarios that are especially demanding for the transmission grid are scenarios with a lot of renewables (which will largely be wind) and scenarios that rely on import to secure supply. Scenarios that are especially demanding for the distribution grid are scenarios with distributed generation and demand response programs to manage demand with real time metering and balancing. Furthermore, it should be underlined that transmission grids are not islands. They are actually more and more interconnected to create an Internal Electricity Market in the European Union (IEM). This implies that policies from other countries and especially neighbouring countries compete for scarce transmission network capacity, and are often conflicting due to a lack of coordination. Certain new technologies could play an important role in the establishment of a true IEM.