CZECH ELECTRICITY GRID CHALLENGED BY GERMAN WIND

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Transmission systems in continental Europe are synchronously interconnected and represent one physical network over a very large area - from Portugal to Poland and from Denmark to Turkey. This interconnection allows electricity trading and mutual assistance among transmission system operators (TSOs). On the other hand, it may cause problems like system failures or instability spreading from one system to another. This interconnected system is now subject to the integration of large amounts of intermittent electric power and has to be technically upgraded and economically re-positioned [1].

It is important to realise that commercially agreed electricity trading between two countries create physical power flows, which do not fully follow scheduled ways of commercial flows, especially in the meshed network of Central and Eastern Europe (CEE). Power flows follow a path of least electrical resistance. When there is a lack of infrastructure for direct transmission of flows (as it is now the case in Germany, with insufficient north-south interconnections) [2], they flow in a parallel way to the areas of electricity load. If the wind blows in the northern part of Germany, power surplus generated in wind farms there seeks its way to consumption centres in southern Germany and further southward and south-eastward. This spontaneous effect is due to the so-called rule of horizontal balancing of wind generation in Germany, causing the electricity produced by renewable energy sources (RES) to be distributed and consumed uniformly within the entire territory of Germany. Thus, the power flows from north to south through lines of least resistance, causing parallel flows in the Benelux countries in the West and in Poland and the Czech Republic in the East. The situation is further aggravated by electricity exports from Germany to Austria, which are limitless due to the common German-Austrian market area. These unplanned flows cause an extra load on transmission lines in the neighbouring systems and may even cause extreme overloading [3] and [4].

The geographical position of the Czech Republic in the centre of continental Europe has a significant impact on the operation of the Czech transmission grid (ČEPS). Five interdependent cross-border interconnections together with a strong internal national network determine the ČEPS grid as a natural transit system that is strongly influenced by external impacts such as transit flows [5].

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Extreme transit flows in winter 2011/12

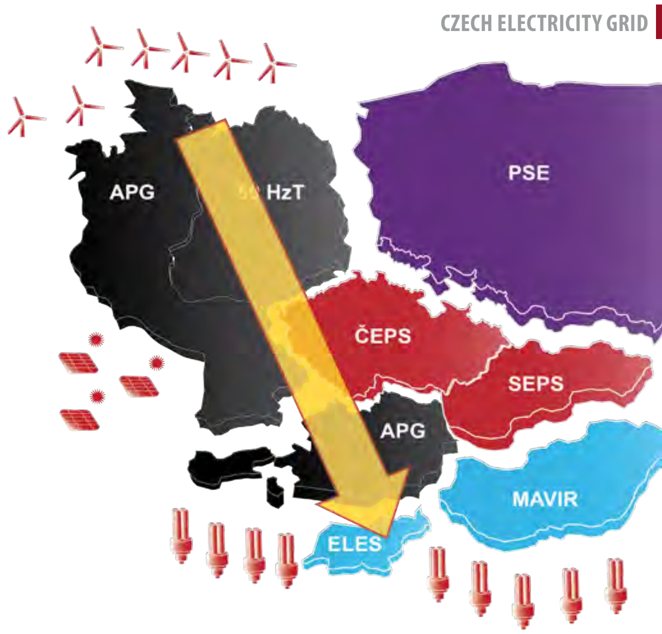
In the period from mid-November until mid-December 2011 and in January and February 2012, ČEPS and other CEE TSOs faced exceptionally high transit flows over their grids. The main cause was increased wind feed-in from the northern part of Germany and the subsequent transit of this electricity to the centres of consumption located in Austria and areas further south and southeast. From ČEPS's perspective the situation was extreme both in its duration (almost three weeks in November/December) and in volume (historical maxima of unplanned flows over 3500 MW).

The situation was aggravated by a shortage of hydro power from Austria and the Balkan countries due to a long dry weather period. During this period the import balance of Austrian TSO APG reached 4000 MW, overproduction in Germany resulted in export levels up to 8500 MW, while the scheduled exchange between Germany and Austria increased up to 6000 MW. Also, due to the commissioning of new generation capacities in Poland (Belchatow power plant), a significant increase in cross-border export from Poland (by approx. 1000 MW) took place in this period as well. Such scenarios surpassed worst cases investigated in the EWIS study (2010) [1], with levels which were projected for the target year 2015 being reached already in 2011.

Regarding the cross border interface between ČEPS and the German TSO 50HzT during this period, the maximum secure operational limit of 1700 MW was exceeded several times (see Fig. 2), by up to 260 MW. The commercial and physical flows had different directions and the difference between them was up to 2000 MW.

The most critical day in that period was December 3rd, 2011. Cross-border capacities (trading limits) were deliberately reduced (both from the ČEPS and 50HzT side) to lower market transactions during disturbed operation, but it had very limited impact on the physical cross border flows. Furthermore, intraday trading sessions had to be stopped both in the export and import directions.

All remedial actions available (both costly and non-costly) were exhausted and there was a risk of a cascading collapse if one line accidently tripped. The situation would have ended up in a local blackout.



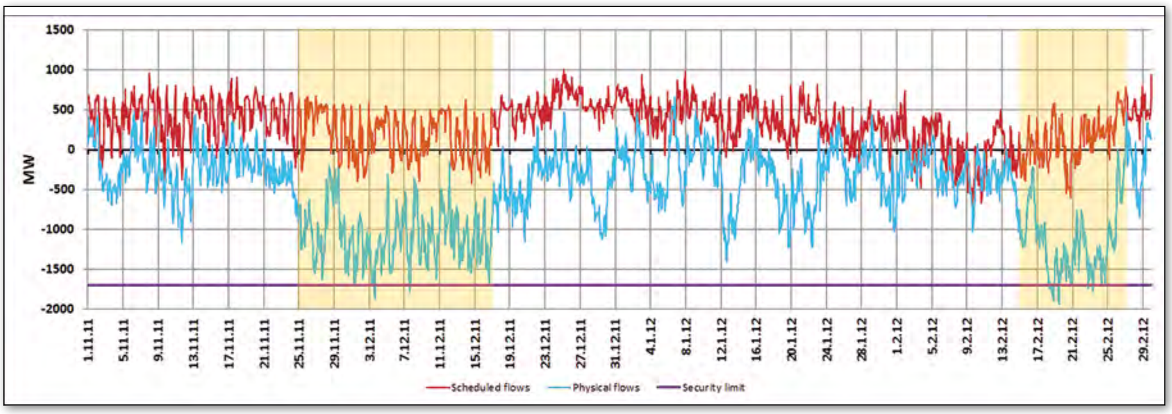
▲ **FIG. 1:** Power flow in the Central and Eastern Europe (CEE) region with the national transmission system operators of the Czech Republic (ČEPS), the Slovak Republic (SEPS), Poland (PSE), Austria (APG), Hungary (MAVIR), Slovenia (ELES) and the two German regional operators (50HzT and TTG). The symbols schematically indicate the dominant locations of wind and photovoltaic power and that of the consumers in the south.

Challenges of the operational situation on August 22nd, 2012 in the CEE region

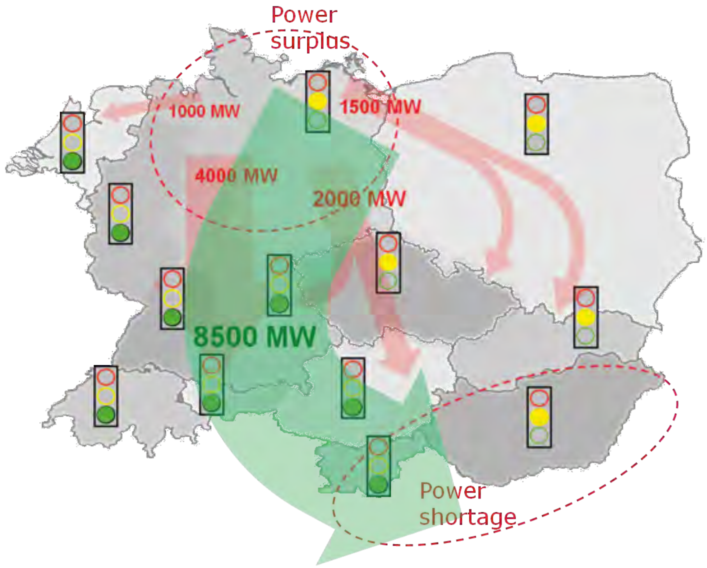
A similar situation may also occur in the summer period, when photovoltaic power comes into play. Some TSOs from the CEE region again faced difficulties in connection with transit flows.

Although high wind and solar productions were predicted (and recorded, see Figure 4) for August 22nd, 2012, no major problems were anticipated as simulated power flows on D-1 (one day before) were lower than the ones observed during operation. On that specific day, scheduled maintenance took place (outages of several cross-border lines and the whole cross-border profile between Poland and Slovakia). High transiting flows worsened operational conditions and simultaneously affected some CEE grids (PSE, ČEPS, SEPS) on this day. This led finally to the activation of Multilateral Remedial Actions in which four TSOs were involved, in the framework of which APG was requested to make a production volume of 800 MW available. In parallel, production was reduced in the 50HzT control area by up to 900 MW to compensate for the aforementioned power increase.

During the critical hours on August 22nd, the export balance of Germany exceeded 9 000 MW, while import balance of Austria was more than 3 000 MW. Regarding the German-Austrian profile of ca. 5 300 MW of scheduled commercial transactions, only half of this flowed physically through this



◀ **FIG. 2:** Scheduled and physical flows on the ČEPS-50HzT profile. Plotted is the power for the period from 1.11.2011 to 29.2.2012. The red line represents the scheduled flows, the blue line represents physical (measured) flows and the violet straight line represents the physical limit of the interconnector between 50HzT and ČEPS



▲ **FIG. 3:** General power flows on December 3rd, 2011 and activation of the Real-time Awareness and Alarm System (yellow lights)

border. The other half transited through neighbouring states on both the western and eastern neighbouring systems. Subsequently, the physical flow across the Polish-Czech border was at the level of 2 400 MW, although almost no commercial exchange was scheduled from ČEPS to PSE.

After the event, the effect of a possible tripping of the overloaded tie line between the Czech Republic and Slovakia Nošovice-Varín was also simulated (see Figure 5). The neighbouring lines in the region would have taken the extra load; however, due to their overloading, cascading trips could also have occurred in the western part of the Czech Republic as a consequence. A potential result would have been a fatal overloading of lines also across the border in neighbouring Germany and Austria.

Conclusions

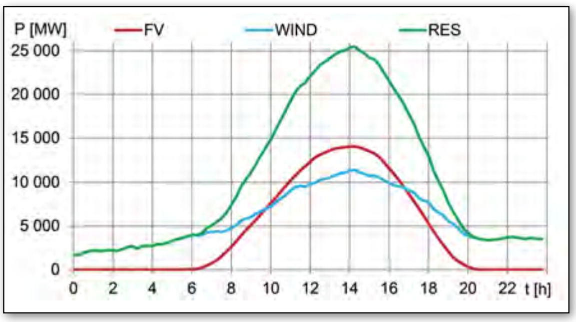
A mix of

- steady increase in intermittent sources, especially wind installations not backed by sufficient transmission infrastructure development in Germany, and
- a single market zone Germany–Austria enabling unlimited market transactions within these countries

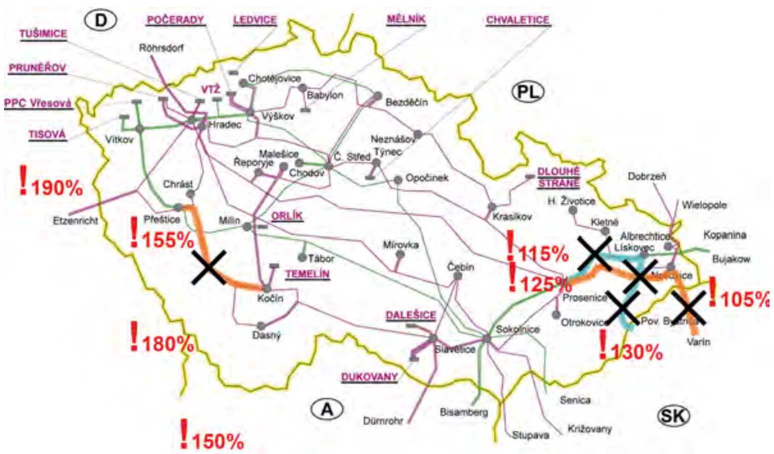
results in physical power flows that bypass Germany through the Polish and Czech systems. These eastern German neighbours experience overloading of their transmission systems especially during periods of high-wind production in Germany.

Substantial improvements, both modernisation of the transmission grid and construction of new lines are under preparation. However, these measures, due to time-consuming permitting procedures, are rather long-term. Due to current and especially future operational challenges related to RES and market arrangements in Germany/Austria, ČEPS decided in favour of a costly, but indispensable medium-term measure – the installation of phase shifting transformers on the ČEPS-50 Hertz profile to be put into operation in 2016. By controlling the power flows and seeking their optimisation, transformers will contribute to the secure operation of the systems and also enhance transmission capacities in this region. Finally, optimisation of the amount and proportion of intermittent renewable energy sources would also help to tackle grid and electricity system-related challenges in a long-term perspective, as shown in [6].

▼ **FIG. 4:** Production from German renewable energy sources (RES) on August 22nd, 2012. Red denotes the photovoltaic, blue the wind power; the green curve is the sum.



▼ **FIG. 5.** Overloading of lines and their possible cascading tripping can end up in unmanageable congestions and cause a blackout. Black crosses indicate tripping of lines, exclamation marks indicate congested lines / regions with values of flows in % of physical line limits.



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