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Impact of unplanned power flows in interconnected transmission systems – Case study of Central Eastern European region

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HIGHLIGHTS

- Assessment of unplanned power flows in European interconnected transmission grid.
- Main reasons are German renewables, inadequate grid and coupled German–Austrian market.
- Multivariate model of unplanned flows and optimal power flow studies are presented.
- Up to 25% higher line loading in sections of Poland's grid due to unplanned flows.

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ABSTRACT

The unplanned power flows at the interconnections of the Central Eastern Europe and Central Western Europe electricity markets are assessed. The assessment is accomplished using optimal power flow simulations of the linked transmission systems of Germany, Poland, the Czech Republic, Austria and Switzerland. The unplanned flows are modeled using a multivariate model that is a function of time series of wind- and solar-generated electricity, power demand and commercial power flows. It is shown that for the case of Poland there is a 25% higher loading on sections of transmission grid in Poland due to the unplanned flows. The unplanned power flows are largely a consequence of the wind-generated electricity in northern Germany that must be routed to southern Germany through the grid in Central Eastern Europe region due to an inadequate grid capacity along the north–south German corridor. It is shown without the planned 2020 developments of the grid, Poland's grid will be very susceptible to congestion and destabilization.

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1. Introduction

The third energy package (European Parliament, 2009a, 2009b) of the European Union (EU) prioritized the creation of a unified market for gas and electricity in 2009. This package issued mandatory directives to EU member states in order to achieve the necessary development of infrastructure and adequate policy reforms. The reforms proposed the un-bundling of energy generation, supply and markets in order to ensure availability of energy to end users at the most economic prices, while advancing the greater integration of renewable energy within the EU.

In order to simultaneously achieve price reductions and equality across the geo-political boundaries of the EU, an increased integration of electricity markets and interconnections is required (Fürsch et al., 2013; Schaber et al., 2012; Rodríguez et al., 2014; Becker et al., 2014; Martinez-Anido et al., 2013). Until a few years ago, European power markets were organized as national systems with limited interconnections and exchanges. However, since liberalization began in the 1990's, European electricity markets have been progressively developed and integrated. A continental-scale integration of infrastructure and markets by the end of 2014, as shown in Fig. 1, was however anticipated (Swissgrid, 2014). However by 2014, only limited progress has been achieved in the form of the consolidated regional electricity markets in Central Western Europe (CWE), Central Eastern Europe (CEE), Nordpool,

Abbreviations: CEE, Central Eastern Europe; CWE, Central Western Europe; ENTSOE, European Network of Transmission System Operators – Electricity; EU, European Union; FBMC, Flow Based Market Coupling; GIS, Geographical Information System; NTC, Net Transfer Capacity; NWE, North Western Europe; OPF, Optimal Power Flow; PST, Phase Shift Transformers; SWE, South Western Europe; TRM, Transmission Reliability Margin; TSO, Transmission System Operator; TTC, Total Transmission Capacity; WRF, Weather Research and Forecasting

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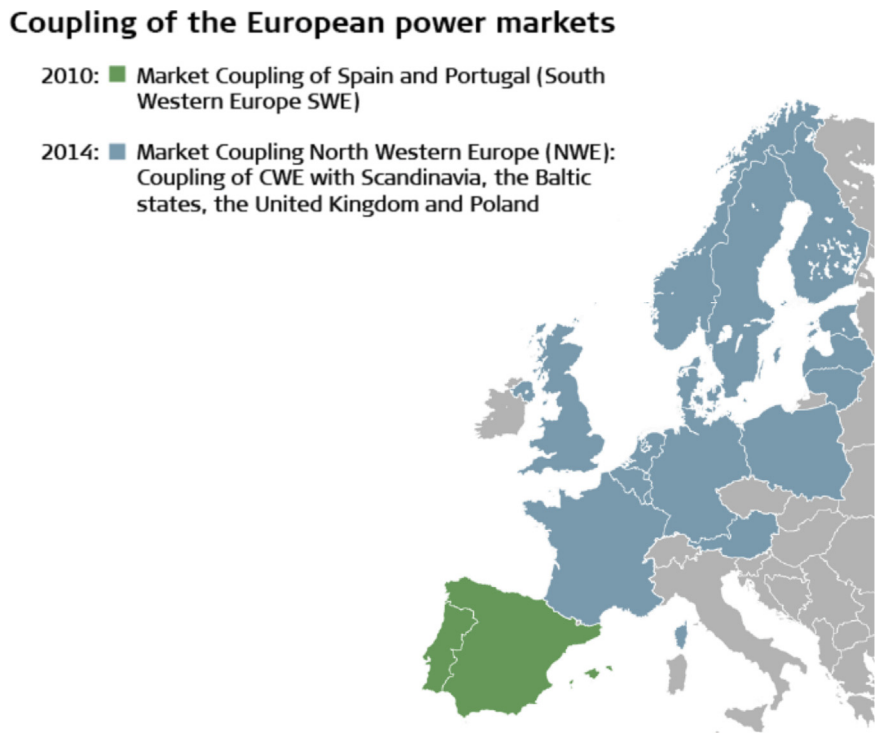

Fig. 1. Timeline for coupling electricity markets in EU (figure reproduced from Swissgrid (2014)).

South Western Europe (SWE), etc. In February 2014, grid operators and power exchanges from a number of EU member states established the day-ahead market coupling to manage cross-border electricity flows in an optimal way, and smoothening out the price differences across the regions. Since May 2014, the SWE market was coupled with Northwestern European market. The open and competitive market structures together with policy instruments, such as feed-in tariffs, have leveraged the integration of renewables within these markets; the most notable examples are the Nordpool and CWE markets. While the markets and policies continue to evolve, in recent years there had been a profound increase in the penetration of renewables in the CWE region, as the EU member states strive to meet the target of 20% renewables in their energy mix by 2020 (European Parliament, 2009a, 2009b). As an example, Germany's National Renewable Energy Action Plan mandates an increase of the installed wind power capacity by 31.5% from 35 GW in 2013 to 45.7 GW in 2020 (Beurskens and Hekkenberg 2011). Moreover, the countries in the CEE region strive to meet the EU targets and to reduce the dependency of fossil fuels and have emerged in recent years as favored destinations for new investments. Therefore, there is need for a re-assessment of the transmission grid infrastructure in order to efficiently integrate and transmit these new renewable energy sources, which are intrinsically variable and concentrated in specific geographic areas. However, the necessary developments of the transmission grid infrastructure take place at a much slower pace than the deployment of new renewable energy power plants. Thus, the targeted growth rates for renewables are constrained due to lagging developments in markets, legislation and transmission infrastructure, and thus within regional markets there is often an inadequate balance between the demand and supply of electricity since renewables do not react to market signals as they enjoy feed-in priority in several EU member states (German Energy Agency, 2011; Bartels, 2006).

The term unplanned flow refers to difference between commercial and physical flows that are due to transactions realized outside the cross-border capacity allocation mechanism at a border (MAVIR et al. 2013). Today, the actual physical power flows differ from the commercially scheduled flows, due on one part to the segregated regional markets and on the other part to the increased penetration of renewables in a transmission grid that has insufficient capacity for the produced power to be transmitted through desired paths. Fig. 2 shows that over the past two decades the increased physical flows from Germany to the CEE region (that is comprised of Poland, Czech Republic, Hungary, and Slovakia) are linked to the increase in Germany's installed wind power capacity. In the context of the CEE region, power flows originating from lower priced North Germany follow the paths of least resistance in the interconnected grid to reach demand centers that are located in Central Germany, South Germany and Austria, and often these flows cross other market regions that are not party to the transactions. These unplanned power flows have an undesirable impact on the markets' efficiency, and destabilize the operation of transmission infrastructure, including generators in the CEE region, thereby increasing risks and costs. As the unplanned power flows continue to rise, unchecked by necessary measures, they threaten the sustainable growth of renewables in the CEE region.

A joint study of the CEE's transmission system operators (TSO) (MAVIR et al., 2013) estimated that up to about 50% of commercially scheduled transactions between Germany and Austria, in the CWE region, flow through interconnections with other countries, with Poland and the Czech Republic in the CEE region being the most affected. The study estimated that the unplanned power flows from Germany into the CEE region occur approximately 17% of the time in a year when the commercial schedules between Germany and Austria exceed 3000 MW. The primary reasons identified for the unplanned flows in grids of CEE region are insufficient coordination of cross-border markets and allocation of transmission capacity. It is emphasized that further delays in preventive actions will adversely affect operations of regional markets and pose risks to security of transmission systems.

A recent European Commission study (Skånlund, 2013) made recommendations to delimit bidding zones, develop Flow-based Market Coupling (FBMC), and coordinate grid development to

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