THE IMPACT OF FLUCTUATING RENEWABLES ON FLEXIBILITY NEEDS IN ELECTRICITY SYSTEMS

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Overview

The fight against climate change is a central motivation for a quick transition towards decarbonized energy systems and substantial uptake of electricity generation from renewable energy sources like wind and solar energy (vRES). These forms of electricity generation show volatile patterns which result in more fluctuating behavior of the electricity system. Therefore, analyses have been increasingly focused on the corresponding flexibility needs of electricity systems, translating into economic and environmental impacts, policy needs, and technical requirements to adapt to the changing generation patterns. Depending on the research question of interest, the approaches taken and indicators chosen to analyze flexibility vary widely. Based on a sound literature analysis, we develop a theoretic and an empirical model explaining fluctuations (represented by price variance) in the electricity system. We show why increasing shares of vRES in the system do not necessarily lead to increased price variance and evaluate different flexibility options.

Methods

A literature review on i) definitions of power system flexibility, ii) approaches to analyze system flexibility needs, and iii) options to cover those needs builds the basis of our analysis. The electricity day-ahead spot price variance is chosen as an indicator of a power system's ability to react to fluctuations in generation or demand levels quickly. We present a static economic model for the electricity market developed by (Wozabal et al., 2016) and extended by (Schöniger and Morawetz, 2022). Two main factors are identified to impact spot price variance the most in this theoretical model: fluctuations of vRES generation, i.e., distribution of residual load (load minus vRES generation), and the power plant mix of a system, i.e., the shape of the supply curve (Green and Vasilakos, 2010; Möbius and Müsgens, 2015). The hypothesis is tested in an empirical model for nine European countries and the years 2015-2019. A panel model regression (fixed effects), as well as single country regressions are conducted. This approach allows us to derive general conclusions but also country-specific findings. This approach enables the evaluation of the impact of the availability of flexibility options that hardly vary within single countries within a short time span, e.g., the availability of export/import capacities or the share of flexible power plants and hydro (pumped) storage capacities in the power plant mix.

Results

Our analysis shows that in six out of nine analyzed European countries, price variance is higher for low and high shares of vRES than for modest shares.

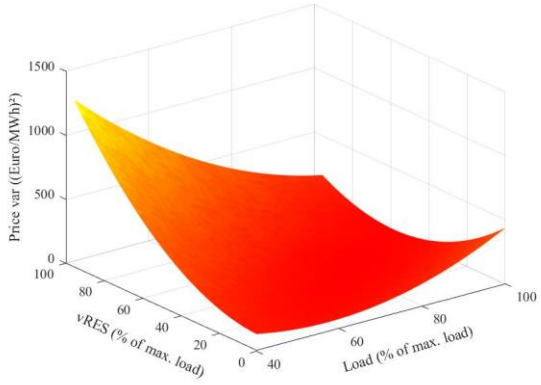
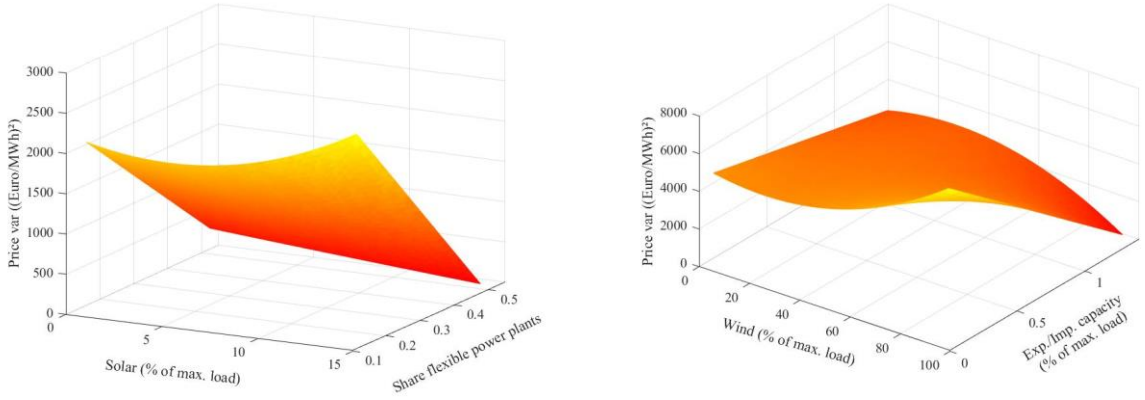


Figure 1: Electricity spot price variance in dependence of share of vRES and load (% of maximal load). Source: Own illustration based on (Schöniger and Morawetz, 2022).

The minimum of this u-shaped relationship between price variance and vRES infeed is found at around 10-40% vRES share in the load in the majority of the countries. The highest flexibility need, i.e. spot price variance, is observed for high levels of load and low levels of vRES infeed (high prices) and – more distinctly – for low levels of load and high levels of vRES generation (low prices) (see Figure 1). These findings can be explained by the convex-concave shape of the supply curve which is steeper for low and high prices. We show that flexibility options like flexible power plants (see Figure 2a), export/import capacities (see Figure 2b), and hydro (pump) storage decreases price variance significantly.



(a) (b)

Figure 2: Electricity spot price variance in dependence of share of flexible power plants (in installed capacities, panel a) and export and import capacities (% of maximal load, panel b). Source: Own illustration based on (Schöniger and Morawetz, 2022).

This effect is more distinct for high than for low vRES levels. Also, the availability of these flexibility options has a higher impact on price variance than the level and variance of renewable infeed itself.

Conclusions

We analyze the effect of fluctuating renewables (vRES) on the flexibility needs in an electricity system. Using spot price variance as an indicator, we find that low and high shares of vRES increase flexibility needs significantly. However, for modest vRES shares (10-40% of the load) – a situation in the early to medium stages of a country's vRES deployment path – average flexibility needs might be even lower than with a low vRES share. Flexibility options like export/import capacities and flexible power plants and hydro (pumped) storage in the system can decrease spot price variance significantly. Their availability is more important for the system's ability to cover flexibility needs than the level and variance of vRES generation themselves. We put our results also in the context of other studies evaluating the contribution of different flexibility options in the overall electricity system and their potential for highly decarbonized power systems. The results have important policy implications: The mentioned flexibility options are required to ensure a stable electricity system with high shares of vRES. However, many of them rely on high price variance (e.g., storage solutions) which cannot be ensured by the market alone since we find that price variance even decreases on the pathway towards higher shares vRES in a system. This U-shaped relationship calls for policies to secure investments in flexibility options in the period of low price variance before it upsurges again in many European countries.

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