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Koivisto, Matti Juhani; Sørensen, Poul Ejnar; Maule, Petr; Nuño Martinez, Edgar; Traber, Thure

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Integration in the energy system, offshore wind energy:

Needs for Flexibility in Energy Systems Caused by the Increasing Share of Variable Renewable Energy Generation in 2020, 2030 and 2050 Scenarios

M. Koivisto^a, P. Sørensen^a, P. Maule^a, E. Nuño^a, T. Traber^b

The growing share of variable renewable energy (VRE) is expected to increase the need for flexibility in the energy systems in many countries. VRE generation is highly variable because it is determined by weather conditions. The geographical distribution of installed wind generation affects the probability distribution (PD) of the aggregate generation, including the probabilities of very low or high generation¹. A combined modelling of wind and solar power has been presented in². Here, a combined analysis of wind and solar power in multiple Nordic and Baltic countries is presented. The analysed scenarios are the baseline scenarios from³.

Variable renewable energy generation is analysed using the CorWind tool developed at DTU Wind Energy^a. In addition to analysing VRE generation, the variability of net load (electricity consumption subtracted by VRE generation) is analysed.

Compared to 2014, the relative variability in VRE generation decreases in the future scenarios, as the overall geographical dispersion of the installed VRE generation increases. The correlation between solar and wind generation is generally slightly negative, which can reduce the variability of the aggregate generation compared to only having wind generation in the VRE generation mix (however, the installed solar generation capacities in the analysed scenarios are low³, so this effect is small).

Figure 1 shows the probability distribution functions (PDFs) of the aggregate net load in the different scenarios. The standard deviation (STD) of the hourly net load increases notably in 2050 (22% higher than in 2014). At the same time, the expected value of the net load decreases. Thus, there will be less energy to be generated by the other generation types, such as hydro power, while the need for flexibility increases. Alternatively, the variability in the net load can be managed by demand-side response, transmission of power to or from surrounding countries or by storing energy.

With more VRE generation installed, the probability of very high net load decreases (as some VRE generation is usually available during peak consumption). However, there is always some probability that the aggregate VRE generation is zero, so the highest possible net load is determined by peak consumption. This may raise questions considering the incentives to hold enough other generation capacity to meet the rare peak net load.

Compared to the hourly ramp rates in consumption, the increasing VRE generation increases the ramp rates in the aggregate net load only moderately in the future scenarios; STD of the net load ramp rate in 2050 is expected to be 14% higher than in 2014. However, while ramp rates in consumption happen usually at well-known times (i.e., ramping up in working day mornings), the hourly changes in VRE generation are less predictable.

^a Technical University of Denmark, Department of Wind Energy, Roskilde, Denmark

^b Technical University of Denmark, Department of Management Engineering, Kongens Lyngby, Denmark

¹ Koivisto et al., *Wind Energy*, **19/4**, 665 (2016)

² Marinelli et al., *IEEE Transactions on Sustainable Energy*, **6/3**, 916 (2015)

³ Nordic Energy Technology Perspectives 2016: <http://www.nordicenergy.org/project/nordic-energy-technology-perspectives/>

⁴ ENTSO-E hourly consumption data for 2012: <https://www.entsoe.eu/data/data-portal/consumption/Pages/default.aspx>

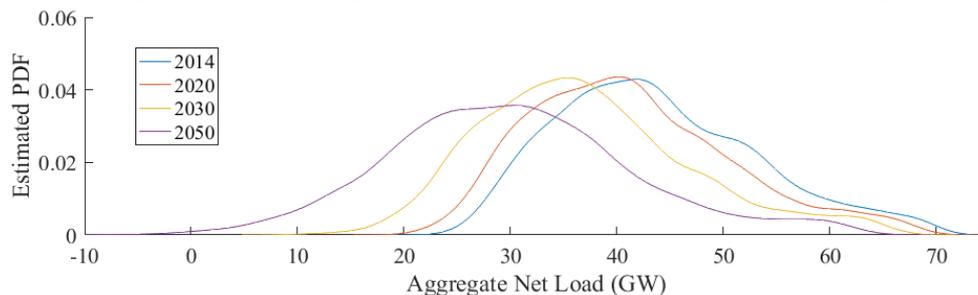


Figure 1: Estimated PDFs of hourly net load in the different scenarios (using 2012 meteorological and consumption⁴ data).