Extreme and long-lasting events of high demand and low renewable generation with long climate model simulations and rare event algorithm

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Objective & Background

One of the challenges of future power systems is to balance demand and production over long periods. A prolonged period of low wind generation and high temperature-driven demand could prove challenging in winter for the security of supply. In this presentation, we will focus on such events, with a focus on extreme and rare events. Indeed, events with a return time of 100 years, i.e., a 1 in 100 probability of occurring each year, are relevant from a risk analysis perspective when designing the power system. However, there is very limited data to study these events. For example, we have only about 4 decades of reanalysis data to make such assessments. It is therefore very important to correctly understand these extreme events and estimate their probability of occurrence.

Method

First, extremely high residual load events (i.e., electricity demand minus wind and solar generation) are studied based on a 1000-year state-of-the-art stationary climate simulation coupled with a simple energy model. Such a long climate simulation allows us to observe more events, and therefore more extreme events. We focus on long events (15, 30, and 60 days) at the European scale. To study the effect of their spatial distribution at the European scale, 8 scenarios of installed wind and PV capacities are investigated. Second, we use a rare event algorithm to sample more extreme events. This is a tool that belongs to the family of genealogical algorithms. Its core principle is to use computation power to simulate only those trajectories of our climate model that lead to extremely high residual loads, the probability of which can be quantified. It makes it possible to simulate climate configurations that lead to extreme events with a return time of more than 1000 years. These events could not be observed with a standard long climate model simulation. Similarly, rare events with return times of 100 to 1000 years are sampled with unprecedented statistics.

Principal Findings

We show estimates of return time curves for different classes of extreme events (15-, 30- and 60-day events with return times of 100 years and longer, for different scenarios of installed capacity). The results of the rare event algorithm are compared with the 1000-year stationary climate simulation. We find that, for all classes of extreme events, the associated composite maps show a clear dominant NAO- pattern. Short and long extreme events are therefore similar in terms of dynamics. Furthermore, the climate configurations found by our rare event algorithm with a single scenario lead to extreme events for all scenarios.

Conclusion

Long and extreme residual load events have received less attention due to a lack of data. More events can be observed, and the statistics of extreme events can be improved with very long simulations. In addition, the rare event algorithm we present allows the sampling of more rare events that cannot be observed with long simulations. This allows us to obtain more extreme events to produce better statistics, which makes it a very promising tool.