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Identifying, characterising and forecasting large ramps in offshore wind farm power output

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In recent years there has been a significant change in the distribution of wind farms in Great Britain, with a trend towards very large offshore wind farms clustered together in zones. For example, in the Thames Estuary alone there is approximately 1.7 GW of capacity. This trend looks set to continue with a number of offshore clusters either in planning or under construction. However, these clusters can produce large ramping events on time scales of less than 4 hours as local meteorological phenomena simultaneously impact the production of several wind farms. Ramps on these temporal scales provide challenges for the transmission system operator who schedule reserve holding in advance and require long term strategies for system balancing. Consequently there is a need to (1) quantify the possible high frequency ramps which could occur and (2) identify the meteorological cause and predictability of the extreme events.

This study uses metered generation data from the cluster of wind farms in the Thames Estuary to determine the ramps in power for three temporal scales which are critical for managing the power system (30 minute, 60 minute and 4 hours). Over a 4 hour time window, the largest ramp in capacity factor was 86.2% (which equates to a power ramp of 1.3 GW). This, along with the other extreme 4 hour ramping events was caused by the passage of a cyclone and the associated weather fronts. On shorter time scales, the largest ramping events over 30 minute and 60 minute time windows were 21.3% (or 360 MW) and 57.9% (or 985 MW) respectively. The extreme events on these time scales were caused by three main meteorological mechanisms; (1) very high wind speeds associated with a cyclone causing turbine cut-out (2) gusts associated with thunderstorms and (3) organised band of convection following a front.

To minimise the balancing costs associated with the extreme high frequency ramping events it is important that the meteorological features are captured by the wind power forecast. This is likely to be increasingly important following the planned development of even larger clusters (e.g. Dogger Bank which could have a capacity in excess of 4 GW). This study shows that state-of-the-art high resolution forecast models are capable of capturing the features which cause local ramping. However, careful interpretation of the forecast is required. For example, due to possible errors in the position of small scale meteorological features in the models, a wind power forecast derived from the predicted wind speeds at the exact location of each turbine can contain large errors. It is therefore recommended that wind power estimates are based on the maximum wind speed within a given area of the turbines. Furthermore, the ensemble mean power forecast is not suitable when considering ramping events due to the smoothing that occurs when averaging over the ensemble members. This highlights the importance of considering the trajectory of individual ensemble members when estimating ramp events as well as the information about forecast uncertainty that they provide.