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Wind tunnel simulation of wind turbine wakes in stable and unstable wind flow

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A programme of work is underway on simulation of wind turbine wakes in neutral and non-neutral conditions, in the context of large offshore wind farms. This includes investigating how stable and unstable flows should be generated in the wind tunnel, bearing in mind the issues associated with a suitable scaling from full to model scale. Rather than using naturally evolving rough-surface boundary layers, as used in meteorological studies, the boundary layer has been developed using flow generators at the working section inlet, as commonly used in neutral-flow wind engineering studies. For both unstable and stable flows an iterative approach has been used to determine the working section inlet temperature profile, using the 'developed-region' temperature profile in the downwind flow to guide the shape of the inlet profile. For unstable boundary layers it was found that three iterations were sufficient, while for stable boundary layers as many as nine were needed, before the developed-region profiles of temperature, velocity, Reynolds stresses, heat flux etc ceased to change.

So far, only the wake of a single turbine has been investigated, referenced to the wake in neutral flow, for weakly stable and weekly unstable, where for the former the 'imposed' condition above the boundary layer also needs to be taken into account. An unexpected feature of the weakly unstable stratification was that the turbulence levels are substantially higher than given by current meteorological 'laws' for the mixed layer, which could have significant implications for the expected loading imposed on turbines in this flow condition. Future experiments will include experiments on multiple turbines. The EnFlo wind tunnel is unique in the UK and, globally, is one of the few facilities that is capable of simulating stably and unstably stratified ABLs at a physically large enough scale (1:300) for the simulations of multiple wind turbine wakes.