Flow within and around a large wind farm

Today, the need for renewable sources of energy is more urgent than ever. However, the clustering of turbines in existing wind farms leads to inefficiencies. Researchers at Imperial College London have used the power of ARCHER2 to perform one of the largest wind farm simulations to date to investigate this issue.

In the UK, wind power is the largest source of renewable electricity, and the UK government has committed to a further major expansion in capacity by 2030. In a recent press release, the UK government set out its plans to "make the UK the world leader in clean wind energy".

Imperial College London

epcc

THE UNIVERSITY *of* EDINBURGH

UKRI Engineering and Physical Sciences Research Council

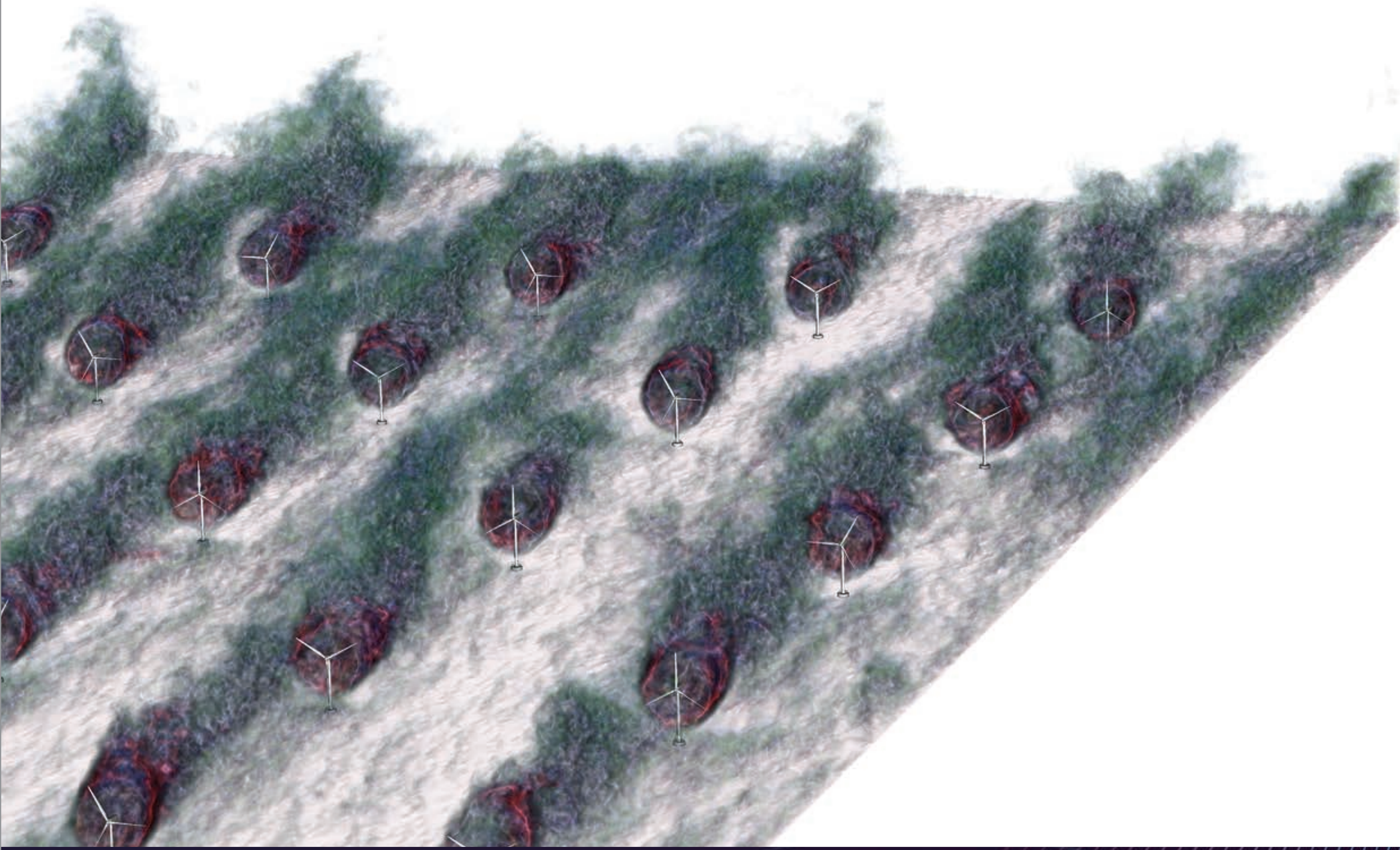
Getty Images

www.archer2.ac.uk

Power losses due to wake effects were recently reported to be in the order of 10–40%

To make the transition to a sustainable society a reality, renewable energy technologies need to mature in efficiency and resilience. Modern wind farms consist of multiple turbines clustered together in wind-rich sites.

Such a clustering suffers a number of drawbacks as downstream turbines operate within the wake of upstream ones. A wind turbine operating within a wake field is an issue for two reasons. First, the reduction of its power output due to wind speed deceleration and second, the increase of fatigue loads due to increased wind velocity fluctuations. Power losses due to wake effects were recently reported to be in the order of 10–40% while fatigue-related failures were reported to be around the same levels owing to a limited understanding of the wind turbulence. To summarise, currently installed wind farms do not produce as much power as expected. Optimising the power output of wind farms cannot be achieved without a better understanding of the wind flow around wind turbines in operation. Wind farm simulators (WFS) are physics-based simulation tools that can replicate realistic scenarios of wind farms in operation. A distinct advantage of WFS compared to wind tunnel experiments is the possibility of conducting studies at full scale. However, in order to replicate all the details of the complex flow within and around a wind farm, WFS require a considerable amount of computational resources and therefore rely heavily on supercomputers.



A research group at Imperial College London uses the open-source WFS Winc3d to perform high-fidelity turbulence-resolving simulations of wind farm flows on ARCHER2. Winc3d is part of the Xcompact3d framework of high-order finite-difference solvers dedicated to the study of turbulent flows using supercomputers. Winc3d has been validated against reference data, e.g. using operational scenarios from the Horns Rev offshore wind farm, showing that its predictions are reliable and representative of real-life operational measurements. In terms of computational efficiency, it can scale with thousands of computational cores thanks to a powerful 2D Domain Decomposition strategy.

KanawatTH via Getty Images

The group's investigation considers a wind farm composed of 25 wind turbines and simulates the flow within and around it at a very high level of detail. It is one of the largest wind farm simulations to date, with a computational mesh consisting of more than 1.5 billion mesh nodes, and was run on 16384 ARCHER2 CPU cores. The simulation enables the researchers to visualise and study the dynamics of the interacting turbine wakes in great detail, and provides insight into complex flow phenomena such as wake meandering, tip and hub vortex breakdown, and the interaction of the wind farm with the atmospheric boundary layer.

It is hoped that the obtained insights will contribute towards maximising the efficiency of energy extraction from wind farms as these grow in size, number, and density.

Acknowledgement:
Grant No. EP/V000942/1, EP/R029326/1, EP/W026686/1

Author:
N. Bempedelis & S. Laizet (Imperial College London)

Contact Details:
PI: Prof Sylvain Laizet **s.laizet@imperial.ac.uk**
Turbulence Simulation group:
https://www.turbulencesimulation.com/

About ARCHER2
Archer2 is the UK's National Supercomputing Service, a world class advanced computing resource for UK researchers. ARCHER2 is provided by UKRI, EPCC, HPE and the University of Edinburgh. ARCHER2 is the latest in a series of National Supercomputing Services provided to UK researchers.