Modelling the wake effect

Words: Dr. Shane Butler, Principal, Data Science and David O'Hare, Director, Europe

External wakes could reach further than the offshore wind industry previously predicted, bringing financial implications for wind farm developments.

For offshore wind to live up to its full potential, developers and investors must have full visibility over the impact of wind farms on one another, or risk financial and decarbonisation targets being missed.

The issue of wake effects over longer distances became an industry talking point in late 2019, when Ørsted downgraded its financial targets. The revision was in response to improved understanding and modelling of the impacts of both blockage effects and external wake effects on annual energy production and financial performance.

Compared with onshore wind farms, wakes generated by offshore wind farms are understood to travel much further distances, due to lower surface roughness and higher atmospheric stability values offshore.

In recent years, a growing body of research has revealed that, under certain conditions, wakes can travel potentially tens of kilometres, much further than older analytical models might have assumed. This has potentially far-reaching implications for crowded waters like northern Germany and south east England, as well as new, high density wind developments such as Bight and ScotWind.

As we continue the transition from fossil fuels to a future of renewable energy production, the impact of external wakes between wind farms, rather than just between individual turbines, needs to be better understood. A failure to do so could risk inflating expected returns from offshore wind, dissuading future investors from putting their capital into such projects. This could subsequently impact the amount of clean energy contributing to national grids.

The issue with external wakes

Since optimal locations for offshore wind farms are limited, based on wind resource and seabed depth, farms are typically clustered in close proximity in units of several hundred turbines.

While previous industry analysis has assumed that offshore wakes do not travel far distances, Clir Renewables' empirical analysis, using data

from a significant percentage of the UK's offshore wind farms, demonstrates that wakes can impact the energy generating capability of neighbouring wind farms sited more than 20km downwind. This can have significant consequences on the financial prospects of these projects, particularly when compared with pre-construction assumptions, upon which financial expectations are based.

The lack of understanding on the true distance of offshore wake effects is due to multiple factors, including incorrect assumptions in analytical models used to estimate wake propagation distance and a lack of access to large data sets from multiple neighbouring wind farms to quantitatively evaluate the impact of external wakes on individual offshore wind farms.

Furthermore, the average size of turbines has increased, approximately doubling in the past five years and expected to increase even further. This has amplified the magnitude of the wakes generated and increased the impact of external wakes on tightly clustered offshore wind farms.

A growing threat

With 300 GW of projects set to be installed across Europe's coastline by 2050, developers and investors are becoming increasingly aware of financial risks linked to external wakes. As more turbines are installed, existing neighbouring projects will see diminished returns on energy production with a subsequent impact on predicted revenue from their investments.

External wakes look to be one of the harder issues for the industry to tackle head on. Unlike many other causes of underperformance, the wake effect cannot be prevented without hindering the offshore wind industry's growth.

While solutions such as wake steering exist to help mitigate the impact of internal wakes, the solution for external wakes remains much more elusive, owing to the need for cross-company collaboration. Often, project stakeholders compete for the rights to develop and build future projects based on the financial merits of their project proposals. To ensure a level playing field, it is critical that there exists an industry-wide understanding and consistent modelling of the expected impacts of external wake effects.

Constraints such as shipping lanes, fishing and protected maritime habitats already limit the areas where offshore wind projects can be built. To add a requirement for wind farms to be built a minimum of 30 kilometres apart would make siting an even more challenging endeavour.

Other options need to be explored that ensure financial models are updated to reflect the reality of the impact of wakes on current projects and those entering the

market, as well as ensuring enough offshore wind farms continue to be connected to the grid in order to meet net zero targets.

Legal implications

As the offshore wind industry continues to grow, the impact of wakes cannot be ignored. The limited space allotted for offshore wind, coupled with the wakes extending further downwind over water than over land, raises the question of how new projects will encroach upon established assets and their ability to meet financial and energy production targets. The implications of external wakes therefore have the potential to stir up a legal hornet's nest.

There have already been legal cases that explored the issue of wakes between wind farms onshore. For example, the Høg-Jæren project in Norway was the subject of a legal challenge by a neighbouring landowner. The challenge was based on a claim that the existence of this established project blocked wind flow to their potential wind project development site and demanded the turbines be relocated. While the challenge was dismissed as the claimant's project was hypothetical, there is concern in the industry that in cases wherein real financial harm can be proven, existing projects are going to have a stronger standing in court.

Ultimately, the market is still lacking a compensation system between different project owners and competitors around the impacts of external wakes. This is where the true tension will lie, as global offshore wind capacity continues to grow.

The need for data

The offshore wind industry is on the cusp of unprecedented growth and, as assets require a large, upfront injection of capital, the prospect of entering complex, arduous legal proceedings have the potential to discourage investors, stifling an easy means to achieve clean energy targets.

What can the industry do to help prevent this pitfall? Coupled with solutions such as wake steering for internal wakes, a key element to alleviating potential risks is by collecting data from across projects and OEMs that would allow for effective and accurate benchmarking of the wakes' impact on not only current wind farms, but also future ones.

Wakes and the future of offshore

With a benchmarking platform available, wind farm owners are more informed and able to better forecast the impact of wakes, both internal and external, in financial models. The ability to quantify potential future losses that offshore wind farms could encounter allows developers to accurately forecast the potential energy production of a new site amongst established farms. Access to data surrounding wakes would reassure current asset managers, allowing them to account for the impacts of neighbouring farms in development.

It is obvious that, in order to not hinder financial backing and therefore growth in the offshore wind industry, leaders need to reduce risk as the market further develops. With countries' desire and need for energy independence rapidly increasing, wake effects are no longer something that can be mitigated, but instead estimated and planned for.

Increasing industry understanding on external wakes through benchmarking allows owners to prepare for the development of neighbouring farms and incorporate its potential impacts into their financial modelling. It also has the ability for countries to gain greater insight into permitting, allowing for optimal energy production and encouraging investment into the sector by standardising a compensation process for new offshore developments.

What is becoming progressively more evident is the need for benchmarking insights to optimize performance and improve investments, helping to effectively transition away from fossil fuels towards clean energy, something Clir is very excited to be a part of.

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Dr Shane Butler, principal, data science

Shane is a recognised industry expert in the application of data science skills to real world problems to enable and support informed decision making. For the past six years, Shane has been applying his big data analytics skill set within the domain of wind farm operations, performance analytics, and predictive maintenance. He is an expert user of Matlab, Python, Tableau, and cloud-based computing platforms.

David O'Hare, director, Europe

David has several years' experience in the renewables, smart grid, and software development industries with key account management responsibility across renewables, utility, banking, and government sectors. Working with clients spanning Europe, East Asia, and Sub-Saharan Africa, David has been involved in the delivery of product roll-out, software development, organisational digital transformation, and data-driven consultancy services.