Uniting Academia and Industry for Net Zero Ambitions
– An event organised by CIGRE UK Women in Energy
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AI-based modelling, digital twin and control of wind farms

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AI-based modelling, digital twin and control of wind farms

Modelling

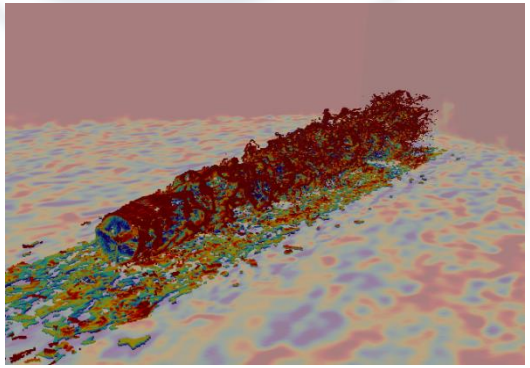
- Current numerical tools for wake predictions

  CFD models - accurate but slow

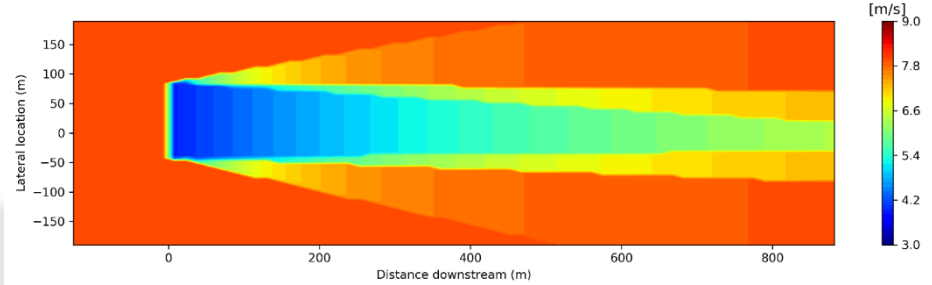
  Analytical wake models - fast but inaccurate

- The **first** deep-learning based dynamic wake model.
- It works in **real-time** on standard PCs, while CFD model takes several days on supercomputers.

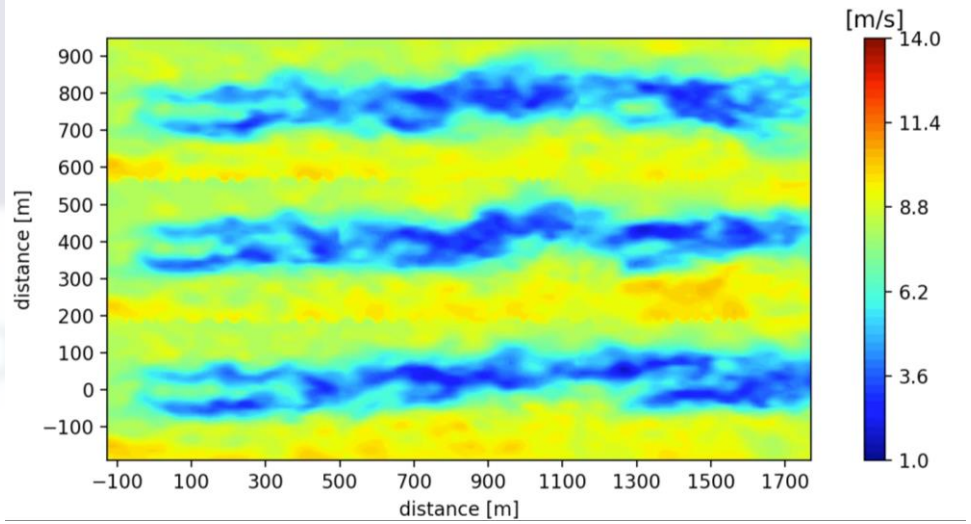
Wakes of Horns Rev



High fidelity LES solver SOWFA



Low fidelity model FLORIS



Simulation of a test wind farm

Zhang, J., & Zhao, X. (2020). A novel dynamic wind farm wake model based on deep learning. Applied Energy, 277, 115552.

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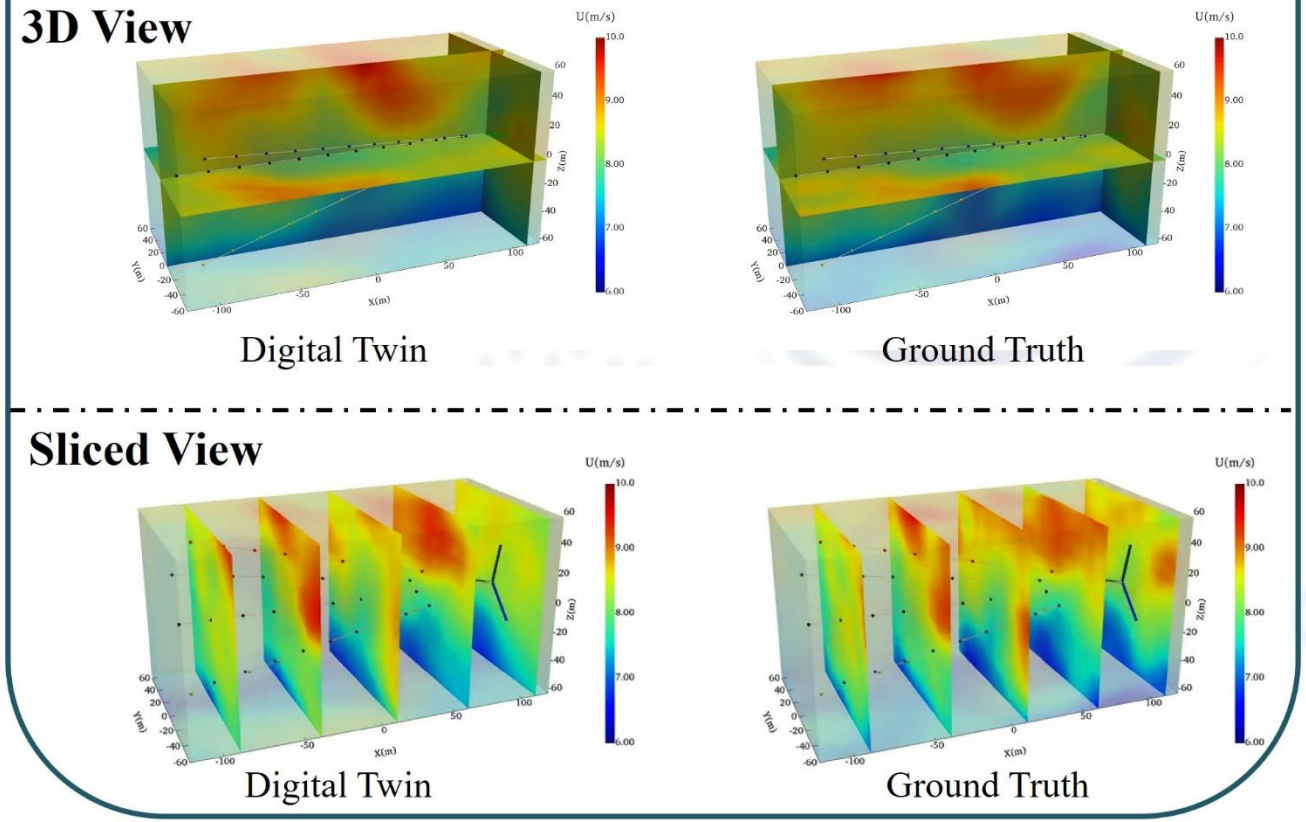
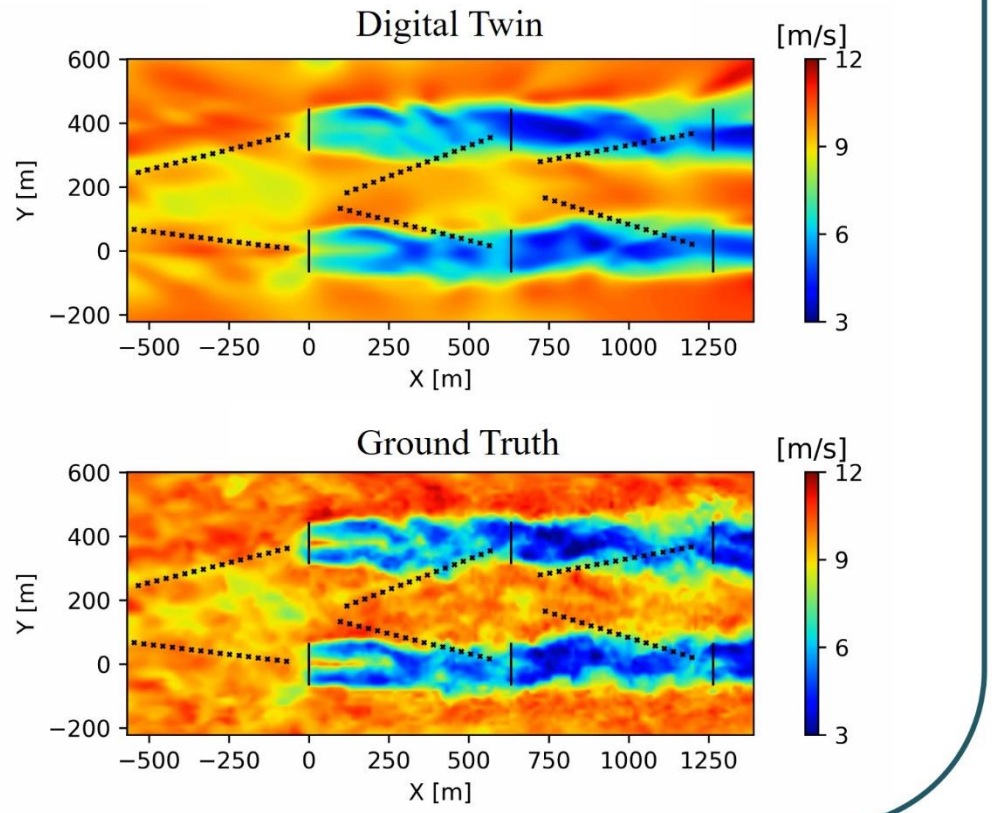
Digital twin

The first digital twin for the spatiotemporal flow fields of a wind turbine/farm

Flow Field in Front of a Wind Turbine



2D View of Flow Field Within a Wind Farm



Zhang, J., & Zhao, X. (2023). Digital twin of wind farms via physics-informed deep learning. Energy Conversion and Management, 293, 117507.

Zhang, J., & Zhao, X. (2021). Spatiotemporal wind field prediction based on physics-informed deep learning and LIDAR measurements. Applied Energy, 288, 116641.

AI-based modelling, digital twin and control of wind farms

Control

- Wakes can significantly reduce the power production of downstream turbines.
- Wake effects can lead to a farm-level production loss of **~10–20%.**
- We aim to design a farm level controller to maximize the power production of the whole farm.

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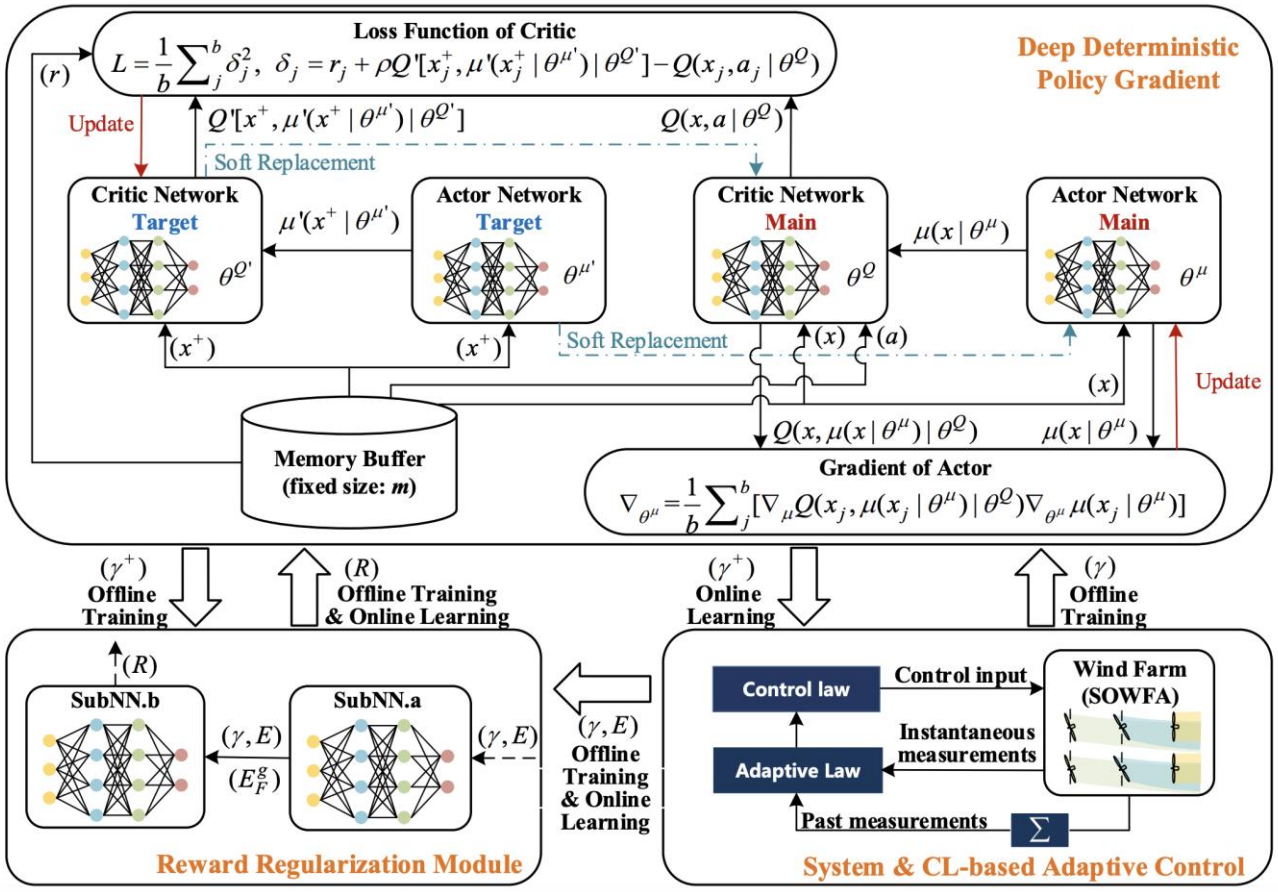
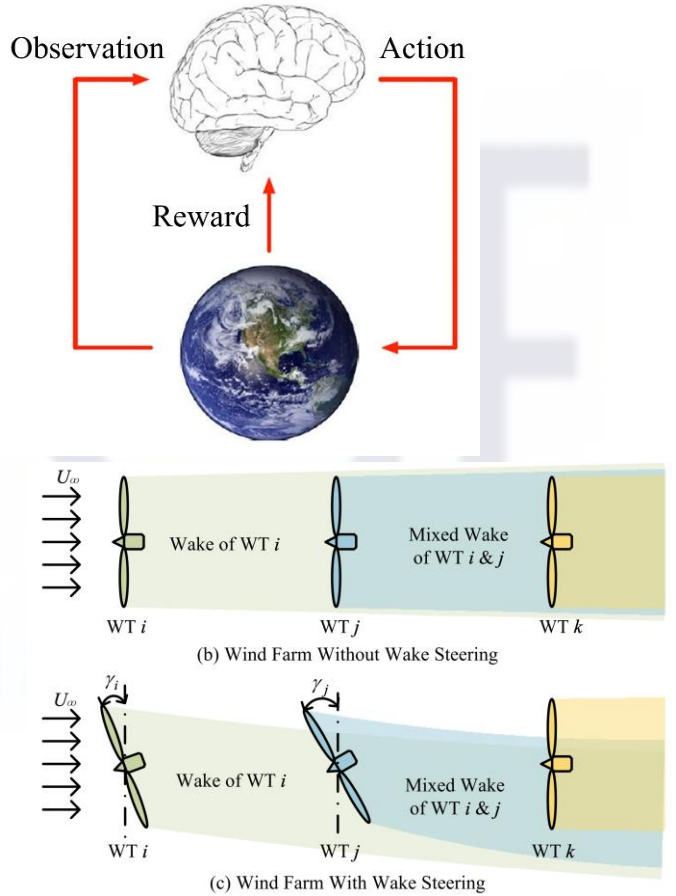
Control

Intelligent Wind Farm Control via Deep Reinforcement Learning





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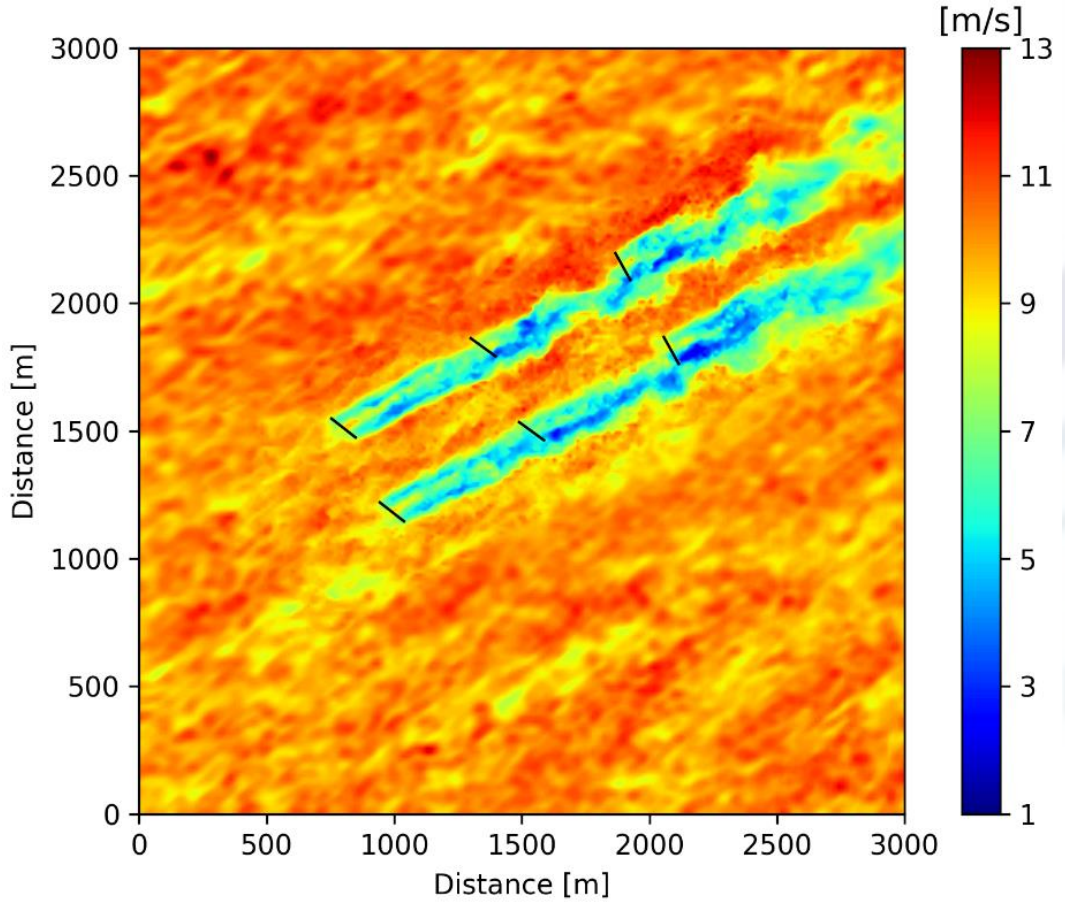
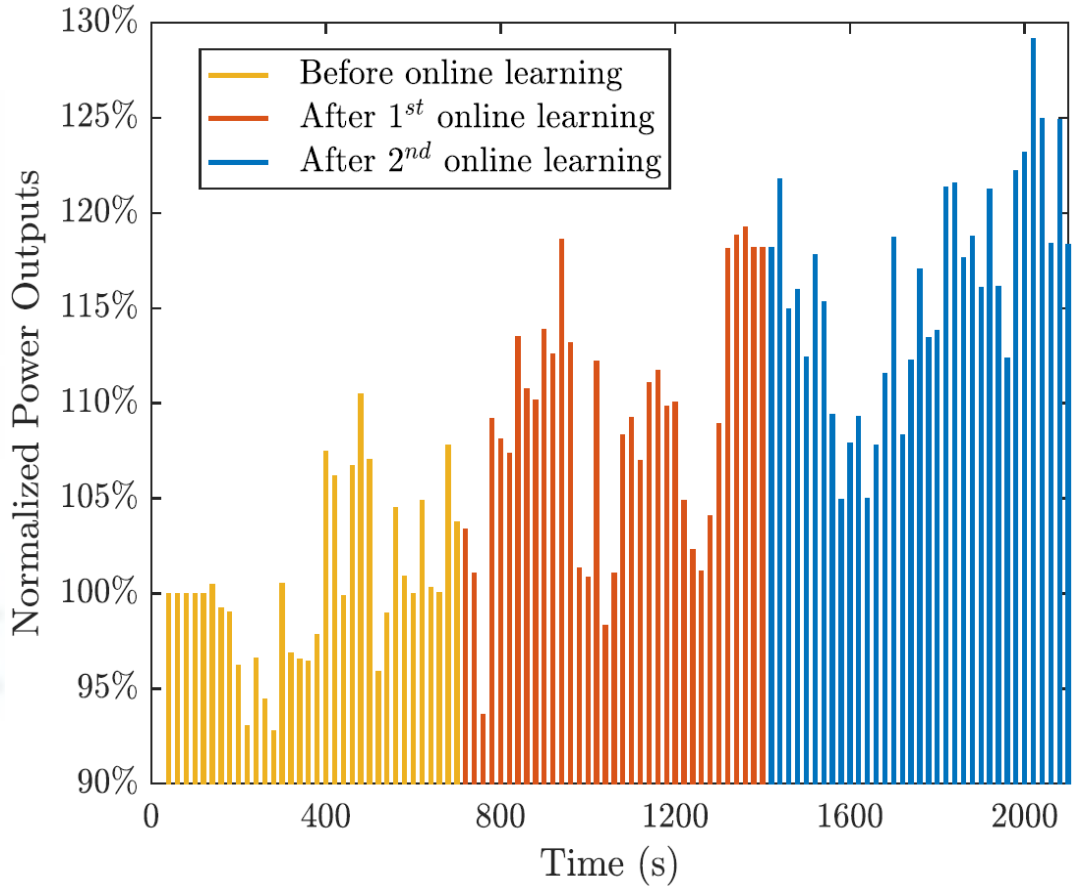
Control

Intelligent Wind Farm Control via Deep Reinforcement Learning

The first one in Europe





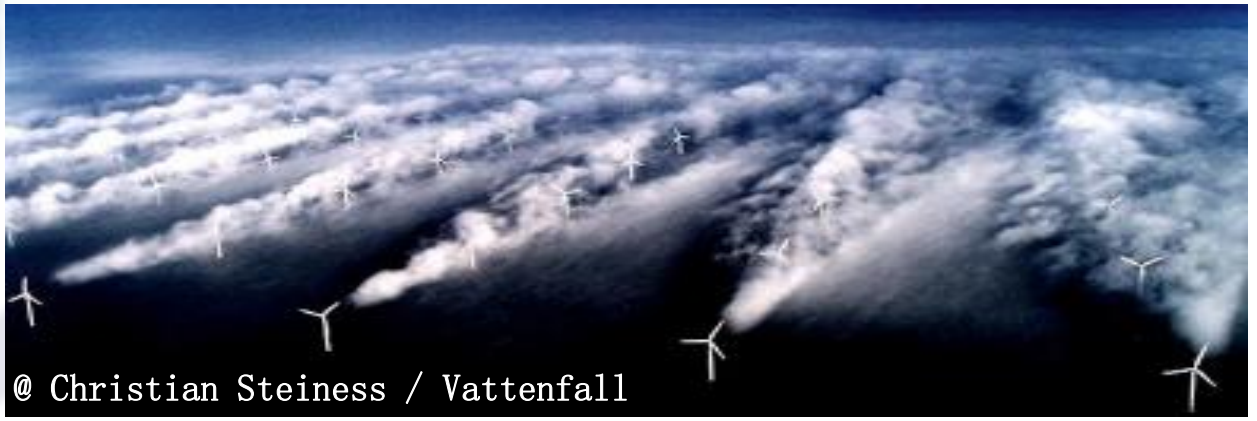
Dong, H., Zhang, J., & Zhao, X. (2021). Intelligent wind farm control via deep reinforcement learning and high-fidelity simulations. *Applied Energy*, *292*, 116928.

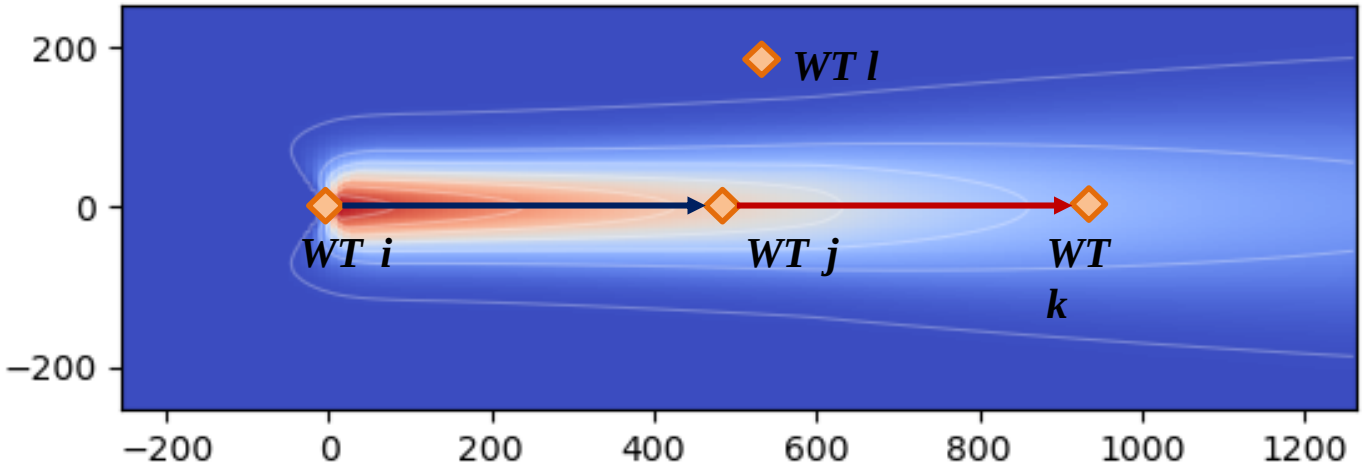
AI-based modelling, digital twin and control of wind farms

Control

Automatic Grouping + Deep Reinforcement Learning

- Dividing a large wind farm into small turbine groups.
- Defining turbines' influence factors by evaluating the weighted wind speed deficit induced by the turbine's operation.
- Setting a threshold for the influence factor leads to the influence field, as illustrated by the envelops.





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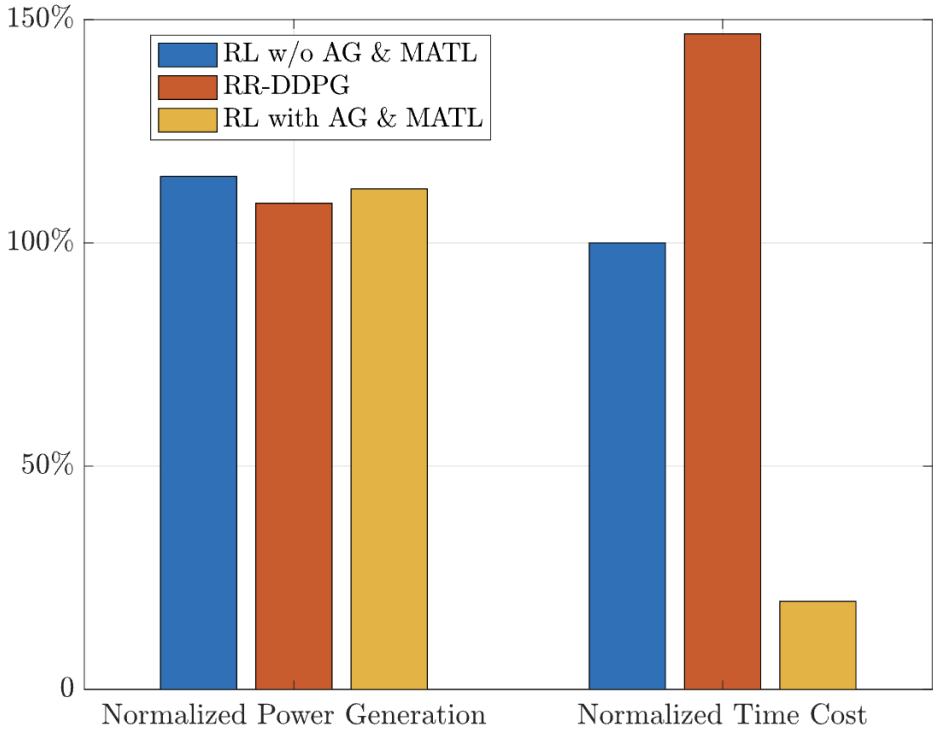
Control

Automatic Grouping + Deep Reinforcement Learning

Reduce computational cost by ~80%, while maintaining control performance



Lays a foundation for applications in large wind farms

Dong, H., & Zhao, X. (2023). Reinforcement Learning-Based Wind Farm Control: Towards Large Farm Applications via Automatic Grouping and Transfer Learning. *IEEE Transactions on Industrial Informatics*.

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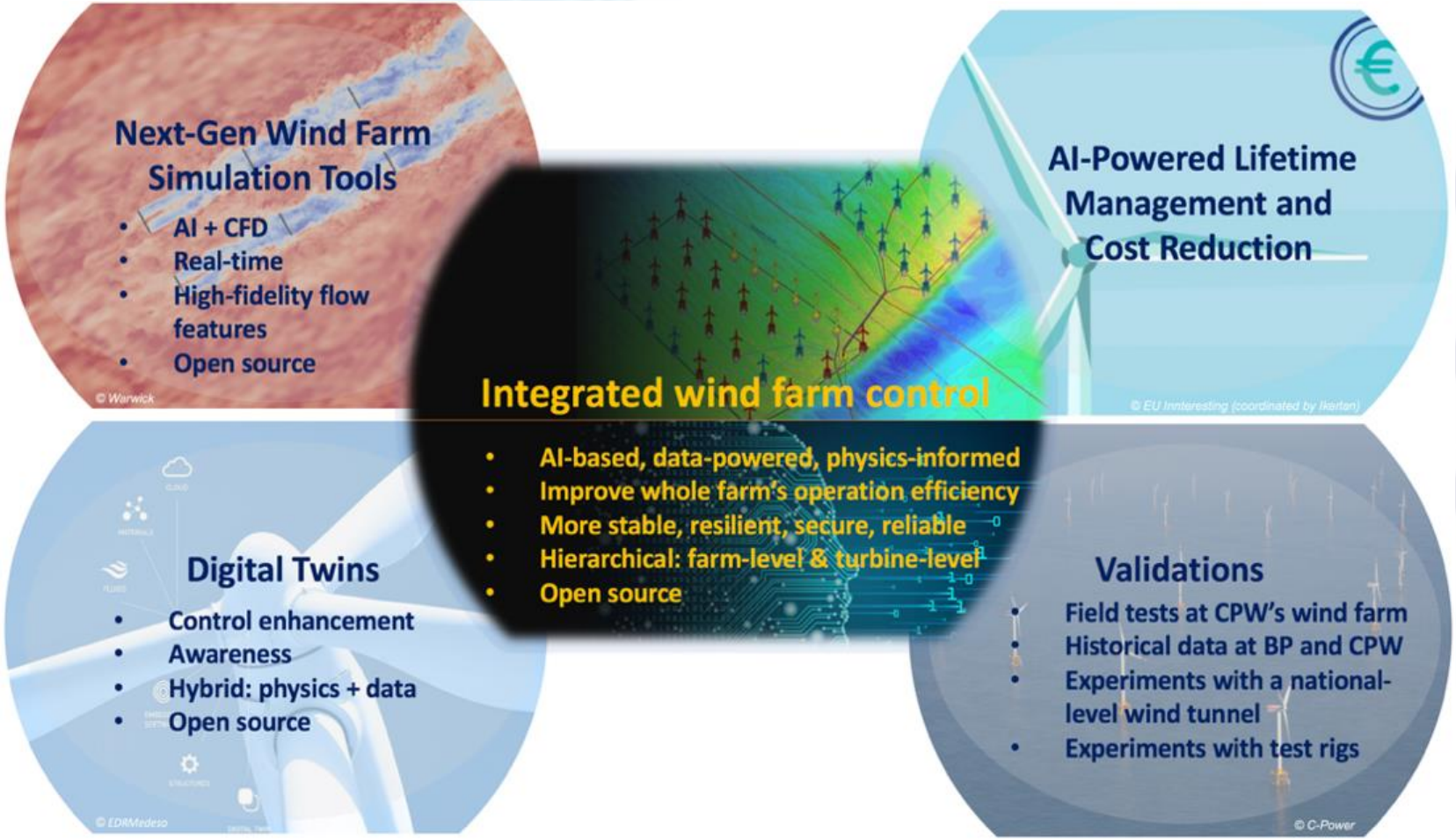
Ongoing work: ICONIC

Smart, Aware, Integrated Wind Farm Control Interacting with Digital Twins (ICONIC)



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Ongoing work: ICONIC

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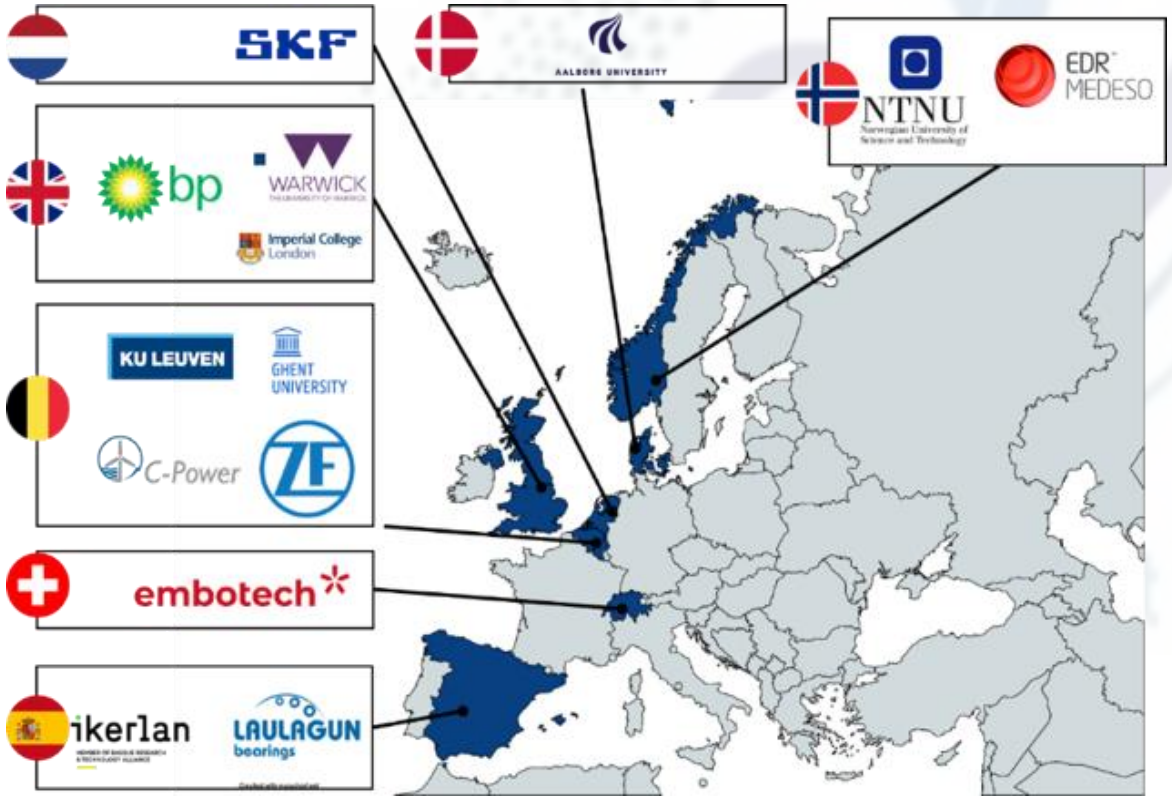

MANCHESTER PRIZE

The **Manchester Prize**, an initiative of **the UK Department for Science, Innovation and Technology**, will award £1 million every year to a team of innovators with the most cutting-edge AI solution for public good.

The first Manchester Prize is seeking innovation from UK-led teams with breakthrough ideas for overcoming challenges in the fields of energy, environment and infrastructure.

Slide from Manchester Prize

MANCHESTER PRIZE

Congratulations!

We received over 275 entries to the Manchester Prize and rigorously evaluated these through a panel of 30 assessors and 8 distinguished judges.

Your entry becoming a finalists is a testament to the boldness and brilliance of your innovation, and we are confident that they hold immense potential to shape the future of the UK.

Slide from Manchester Prize

ABOUT Supergen Network+ in AI for Renewable Energy (SuperAIRE)

EPSRC Supergen programme was set up in 2001 to deliver sustained and coordinated research on Sustainable PowER GENeration and supply, focusing on several key research areas.

SuperAIRE's Ambition

- To establish a world-leading network connecting academia, industries, and policymakers across the spectrum of AI for renewable energy (RE).
- This includes generation, storage, transmission/distribution, and demand side management.
- To create the conditions in which AI for RE can be promoted much more rapidly than at present to boost the development and deployment of RE.

ABOUT Supergen Network+ in AI for Renewable Energy (SuperAIRE)

SuperAIRE Investigators

Prof Xiaowei Zhao (PI),
University of Warwick

Main expertise: Control theory and machine learning with applications in ORE, smart grids, and autonomous systems.

Prof Sara Walker (CoI),
University of Birmingham

Main expertise: Whole energy systems and systems transformation, energy efficiency, and renewable energy.

Prof Yulong Ding (CoI),
University of Birmingham

Main expertise: Energy storage, including liquid air energy storage technology, thermal energy storage, passively cooled container technology, etc.

Prof Philip Torr (CoI),
University of Oxford

Main expertise: Machine learning, computer vision, and robotics.

ABOUT Supergen Network+ in AI for Renewable Energy (SuperAIRE)

SuperAIRE's Research Themes (RTs)

- RT1: Prediction and forecasting across scales
- RT2: AI-powered digital twins
- RT3: Intelligent control and management
- RT4: Smart integration
- RT5: Intelligent robotics and autonomous systems in resource assessments, operations, and maintenance
- RT6: Robust and trustworthy AI

Thank you