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

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ICONIC Project partners







Key Ambition of ICONIC





Main Objectives of ICONIC



• O1: Develop new wind farm control tools to improve wind farm operations leveraging Al innovations.

• O2: Investigate turbine control solutions with load-reduction abilities to deliver farm-wide objectives.

• O3: Develop digital twins and physical tools for awareness and control enhancement considering RUL assessment of wind turbine key components.

• O4: Validate and exploit the integrated control system and DTs via wind tunnel tests, historical operational data, dedicated test rigs, and field tests, and bring ICONIC's key innovations to TRL5



Control-Oriented Wind Farm Modelling via CFD and Machine learning

- CFD models accurate but slow
- Analytical wake models fast but inaccurate



Low fidelity model FLORIS



High fidelity LES by SOWFA





Al-Based Farm-Level Control and Decision-Making to Improve Operating Efficiency of Wind Farms





Offline RL-based wind farm control



Y. Huang and X. Zhao, Wind Farm Control via Offline Reinforcement Learning with Adversarial Training, IEEE Transactions on Automation Science and Engineering, under revision, 2024.

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Grid

Random

Wind farm layouts

C-Power

2

4

6

8

Offline RL-based wind farm control



2

4

6

8





Advanced Turbine-Level Control with Load-Reduction Abilities

- A novel stochastic MPC for pitch and torque control to reduce conservativeness and enhance performance.
- A novel tube MPC method for yaw control to ensure strict safety requirements
- Time-critical justification for MPC methods to achieve complexity reduction and computational time boundedness
- Control performance enhancement with LIDAR measurements





Wind Farm Digital Twin via Physics-Informed Deep Learning





Data (Lidar) + Physics (NS equations) + ML

Digital Twins and Lifetime/RUL Estimations of Critical Components



Historical data

Multi-physical wind turbine drivetrain **Digital Twins** (coupled via signal processing & state/input observers)

Current Status, Outlook, Impact & Ways for future 20MW Wind Turbines

	OFFSHORE WIND TURBINES						
		2020 - BAU		2030		2050	
	Unit	Avg*	Max**	Avg*	Max**	Avg *	Max**
Worldwide: installed capacity	GW	29	.1 ^(a)	22 175	28 ^(b) -210 ^(e)	1000 ^(b)	
Europe: Installed capacity	GW	22 ^(c)		78 ^(b) 77-127 ^(d)		215 ^(b)	
Wind turbine unitary nominal power	MW	7,2 ^(k)	12 (7)	10-12	15-20 ⁽ⁿ⁾	20(0)	>20
Capacity factor Wind farm size	% GW	38 ^(k)	63(1)	36-58 ^(b)		43-60 ^(b)	
		621 ^(e)	1,210	1-1.5	3		
Number of turbines per wind farm	0	87 ^(e)	1740	83-125	125	****	
Hub height	m	100	150(1)	-	160.2 ^(g) 276 ^(g) 135 ^(g)	mized values respect the 20 MW in 2020	***
Rotor diameter	m	154	220(1)	Spe			
Blade length	m	75	107(1)	202			***
Blade weight	Tn	***	***	mised values the 12 MW in	259(9)		
Blade root diameter	m	4 ^(s)	6 ^(s)		5.5-7(9)		8-10 ^(q)
Power train nominal torque (LSS)	kNm				26.711 ^(g)		
Power train nominal speed	rpm		****	Option	7.15 ^(g)	Option	Gr-

Wind turbine size forecast (inc. 20MW) from Innteresting.



Layout and virtual location of CS3 wind farm.

Comprehensive Validations of Controls and Digital Twins

- Wind tunnel tests
- Numerical Simulations various fidelities
- Field tests



- Case study #1: C-power (offshore)
- Case study #2: BP (onshore)
- Case study #3: Virtual farm design (20MW)





Thanks for your attention

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