Coordinated control of single-point moored floating multi-wind turbines under fault events and shutdowns

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INDUSTRIAL CONTEXT

- **Floating multi-wind turbine assets**
  - Two or more full wind turbines placed on the same floating platform
  - Novel system concept aiming at LCOE reduction in floating wind energy
  - Capability to scale up the unit power of the asset with existing commercial wind turbines
  - Single-point distribution of mooring lines commonly used to avoid wake interaction among WTs in misaligned conditions $\Rightarrow$ aiming at elimination of active yaw control system (weathervaning)
  - Several industrial designs at various stages of development

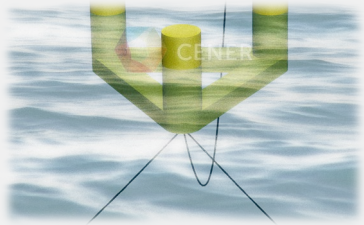
W2Power by EnerOcean


Nezzy2 by Aerodyn


TwinWind by Hexicon

CHALLENGES

- **Highly coupled and complex dynamic system** [1]
  - Multiple system interactions:
    - Among the wind turbines: structural, aerodynamic / wakes, dynamic, control
    - With the floating platform
  - Dependence on system configuration



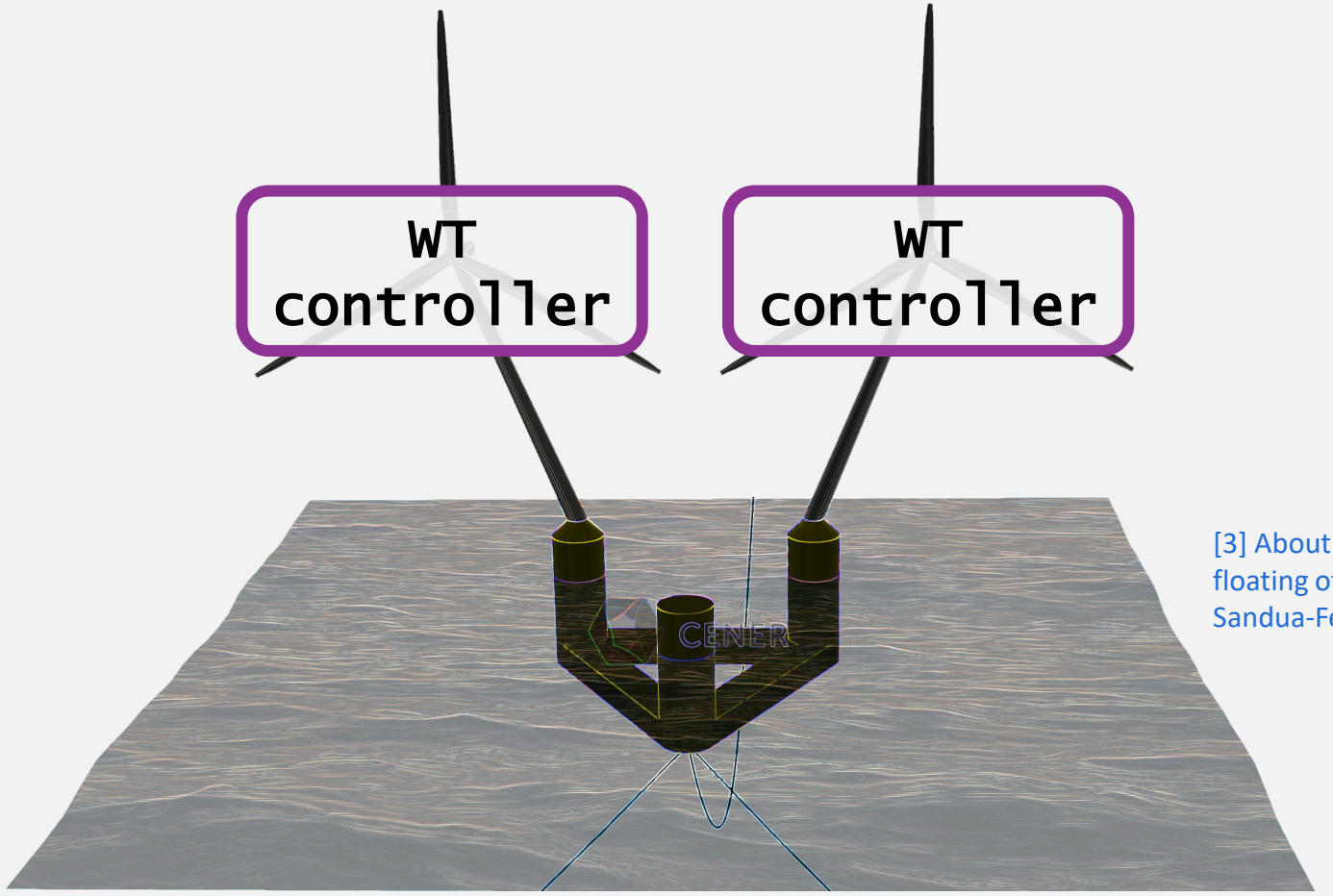
- **Single-point mooring configurations**
  - Vertical moment produced by the rotor
  - Free yaw rotation

- **Higher combination of failures, challenging dynamic interaction under fault events**
  - Shown for blade faults in simulations without considering aerodynamic interaction [2]
  - Differential thrust may provoke large uncontrolled platform rotation
  - May put system integrity at risk

[1] Assessment of the power obtained by a multi wind turbine floating platform, Martín-San-Román *et al* (2022)
[2] The dynamic coupling effects of a MUFOWT (Multiple Unit Floating Offshore Wind Turbine) with partially broken blade, Bae & Kim (2015)

>How to address platform drift in production mode?_

WT control strategies [3]

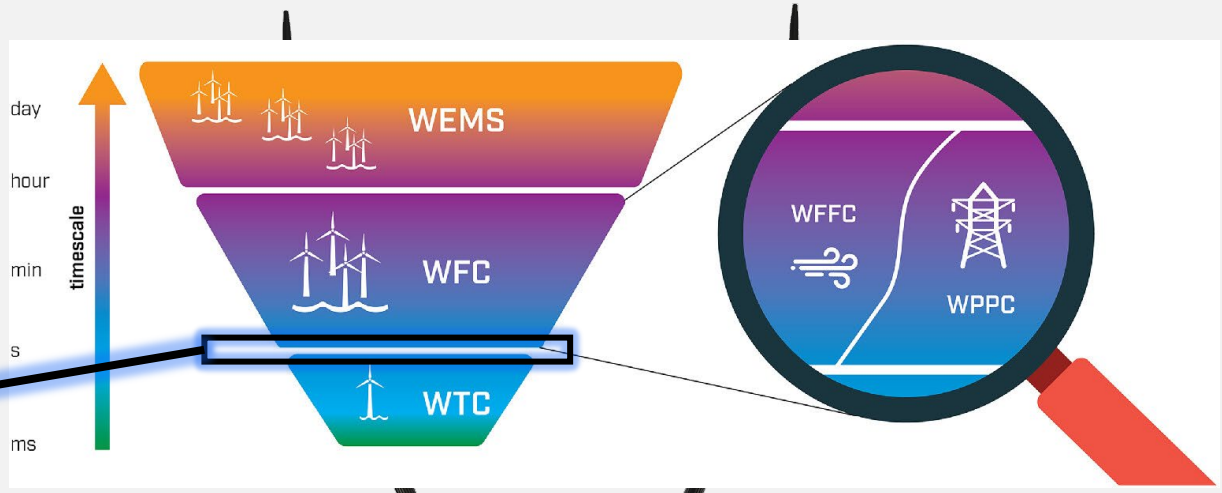


[3] About bi-wind turbine single-point-mooring floating offshore wind turbines dynamics and control, Sandua-Fernández *et al* (submitted to Torque2024)

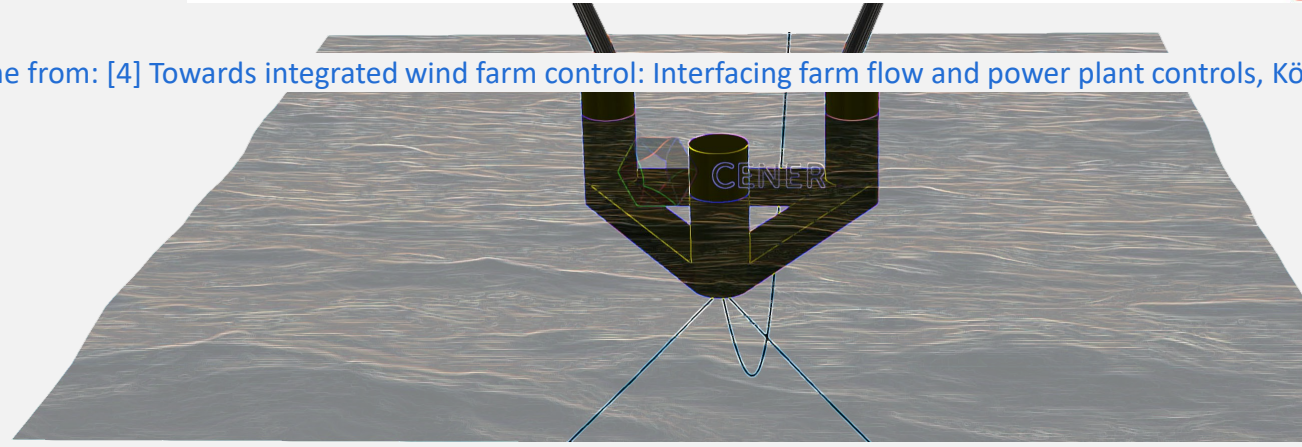
>How to solve fault events and shutdowns?_

COORDINATED CONTROL

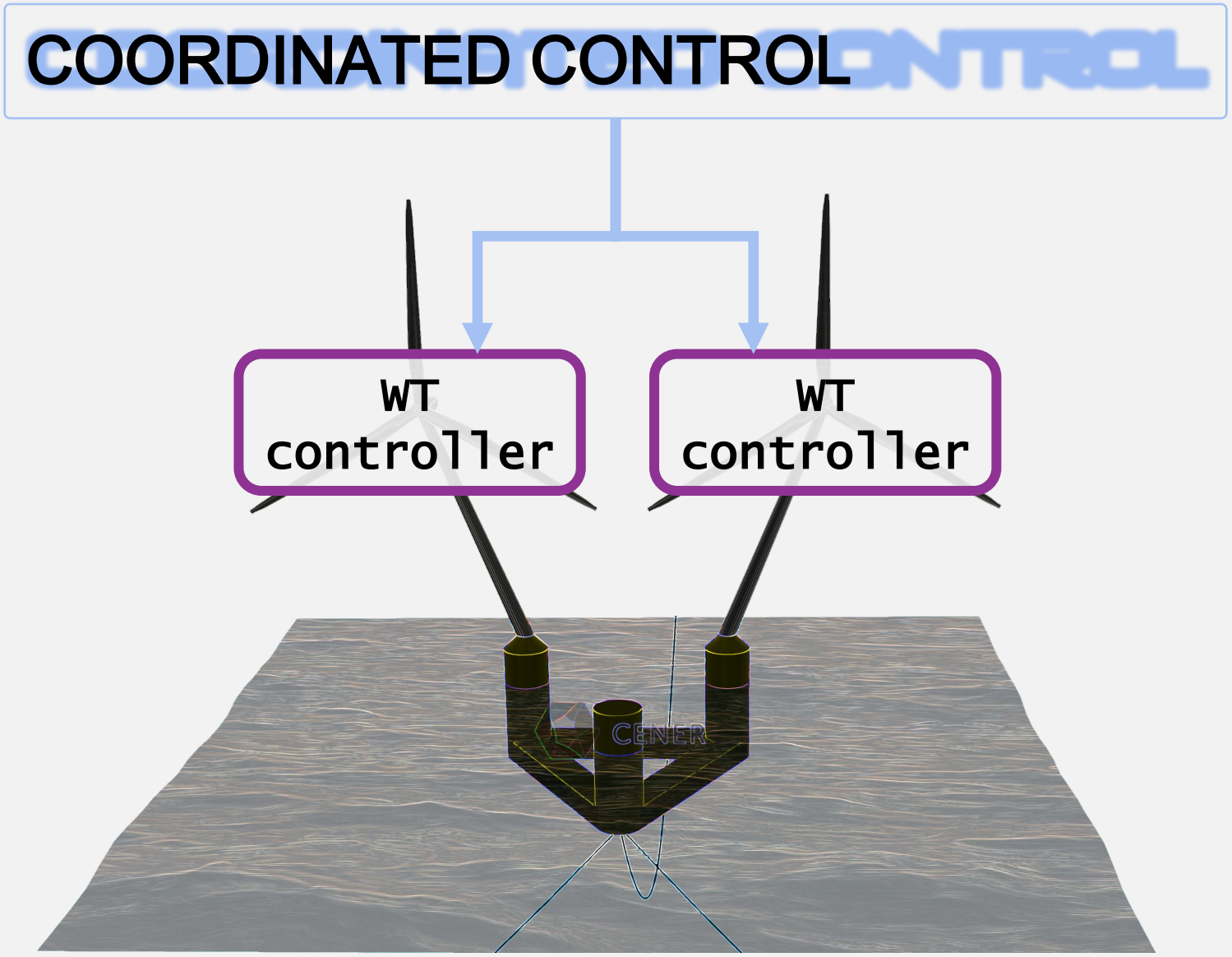
Multi-wind turbine asset control



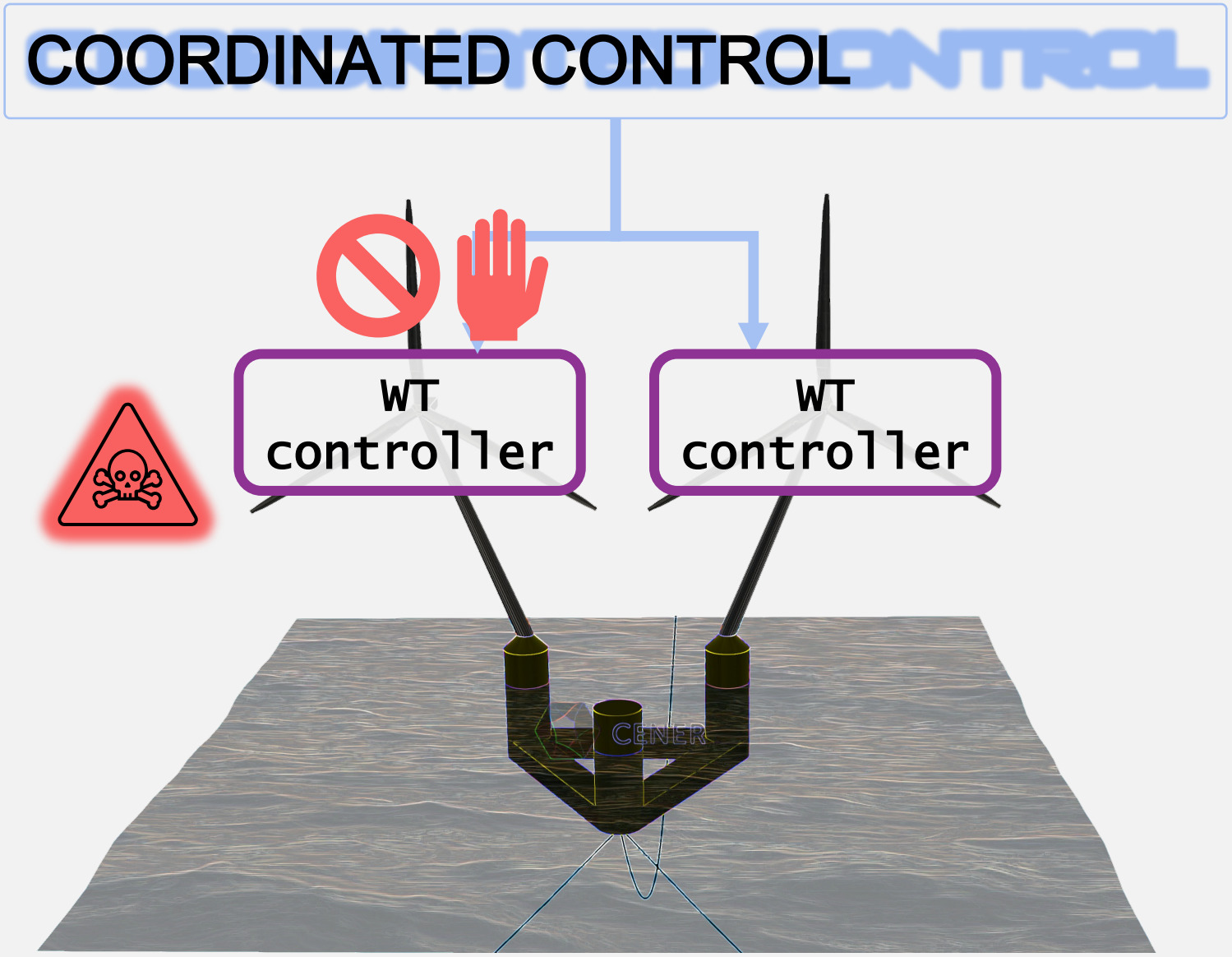
Scheme from: [4] Towards integrated wind farm control: Interfacing farm flow and power plant controls, Kölle *et al* (2022)



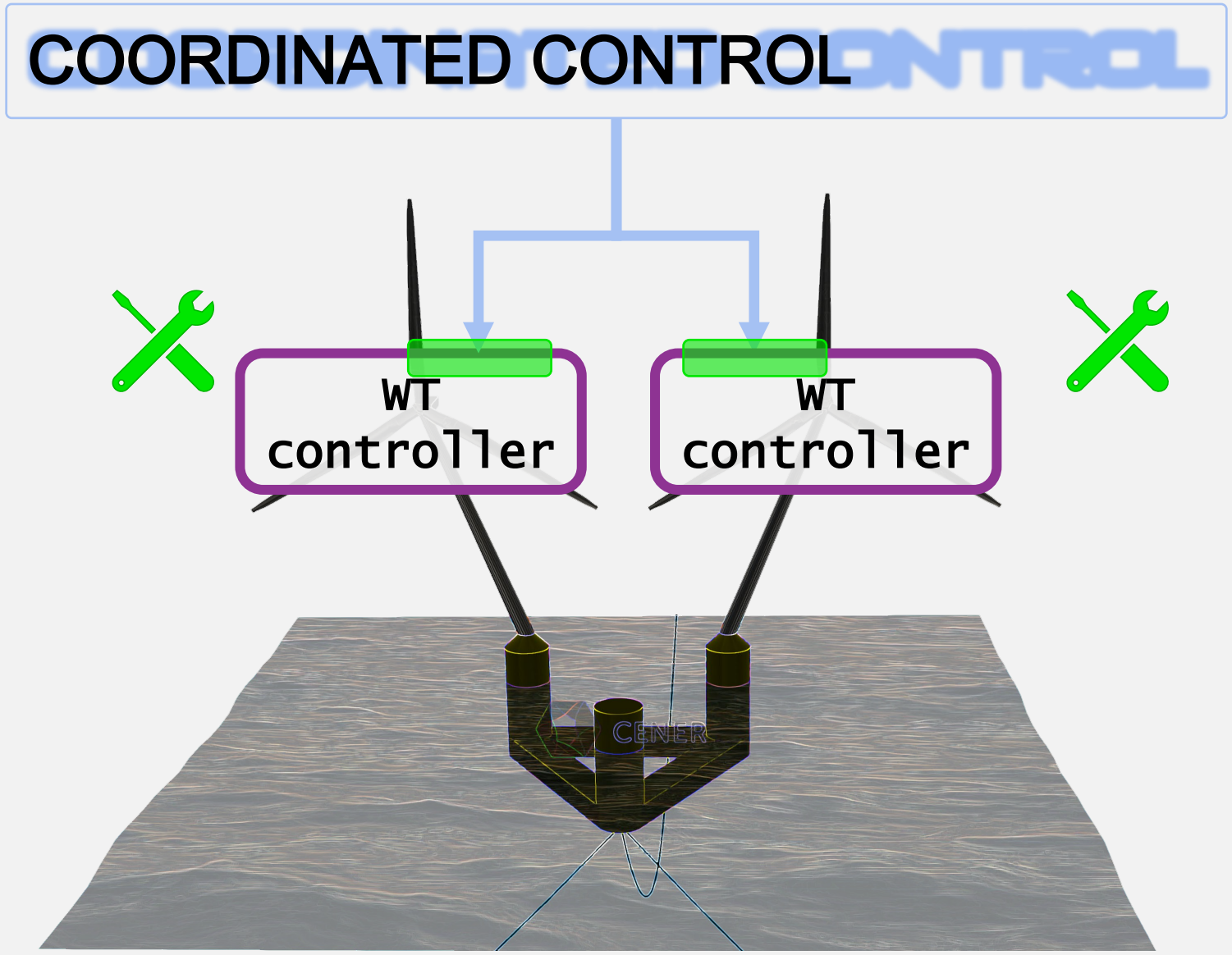
>Upper hierarchical control level_



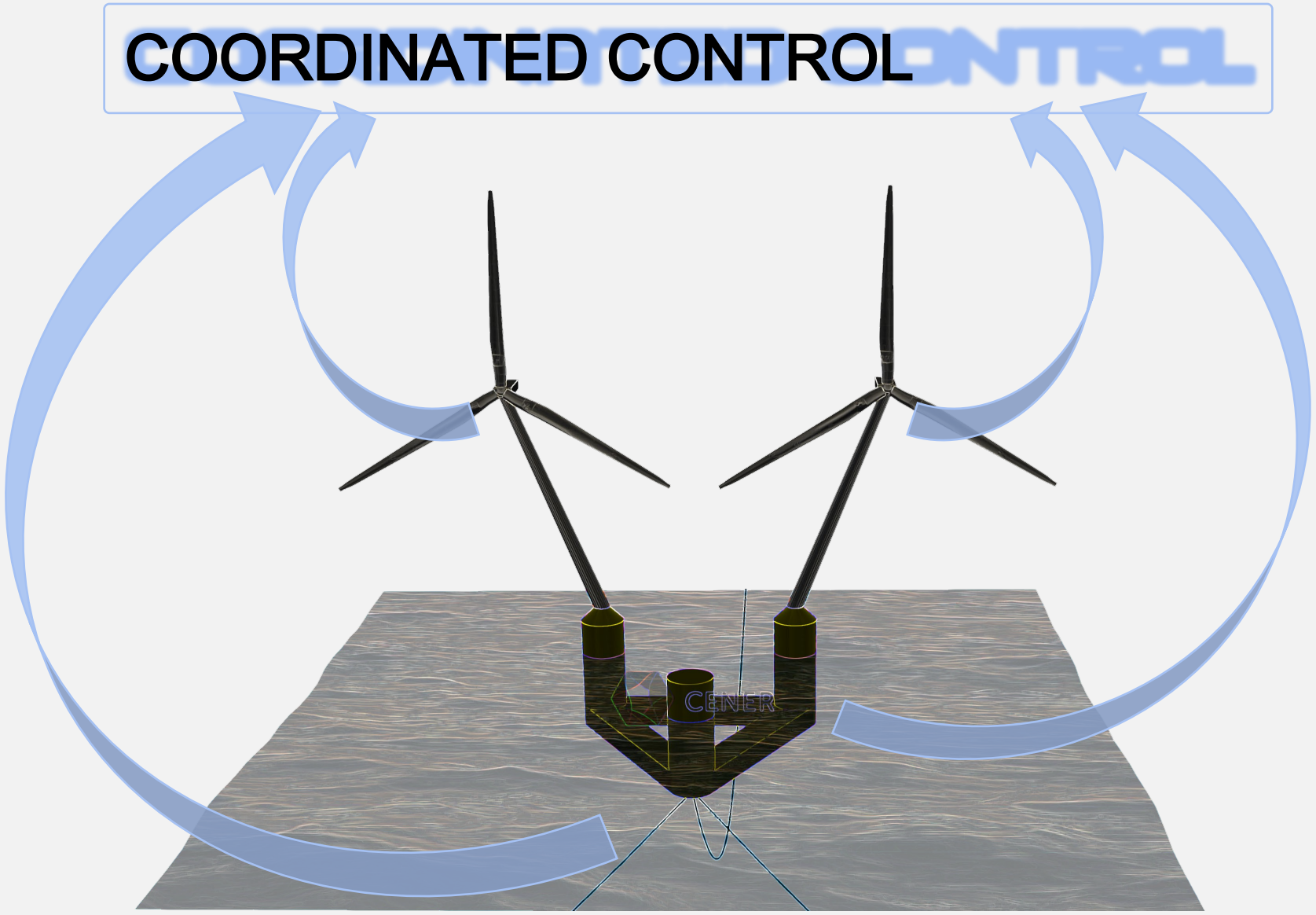
>Control override by WTC for safety reasons_



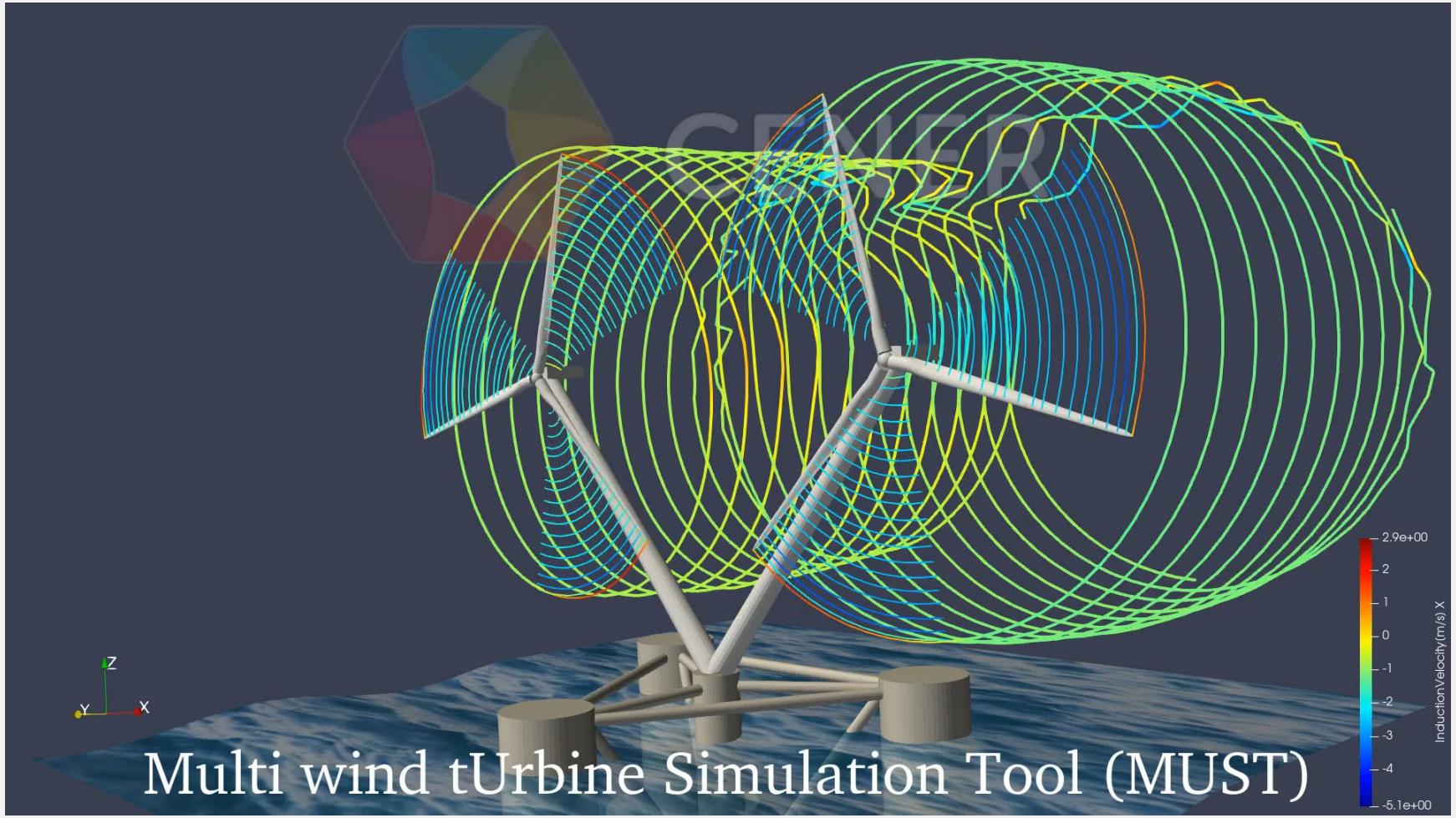
>Minor adaptation of existing WT controllers_



>Aware of all asset subcomponents_



>Multi-Wind Turbine Simulation Tool (MUST)_



Multi-wind turbine simulation

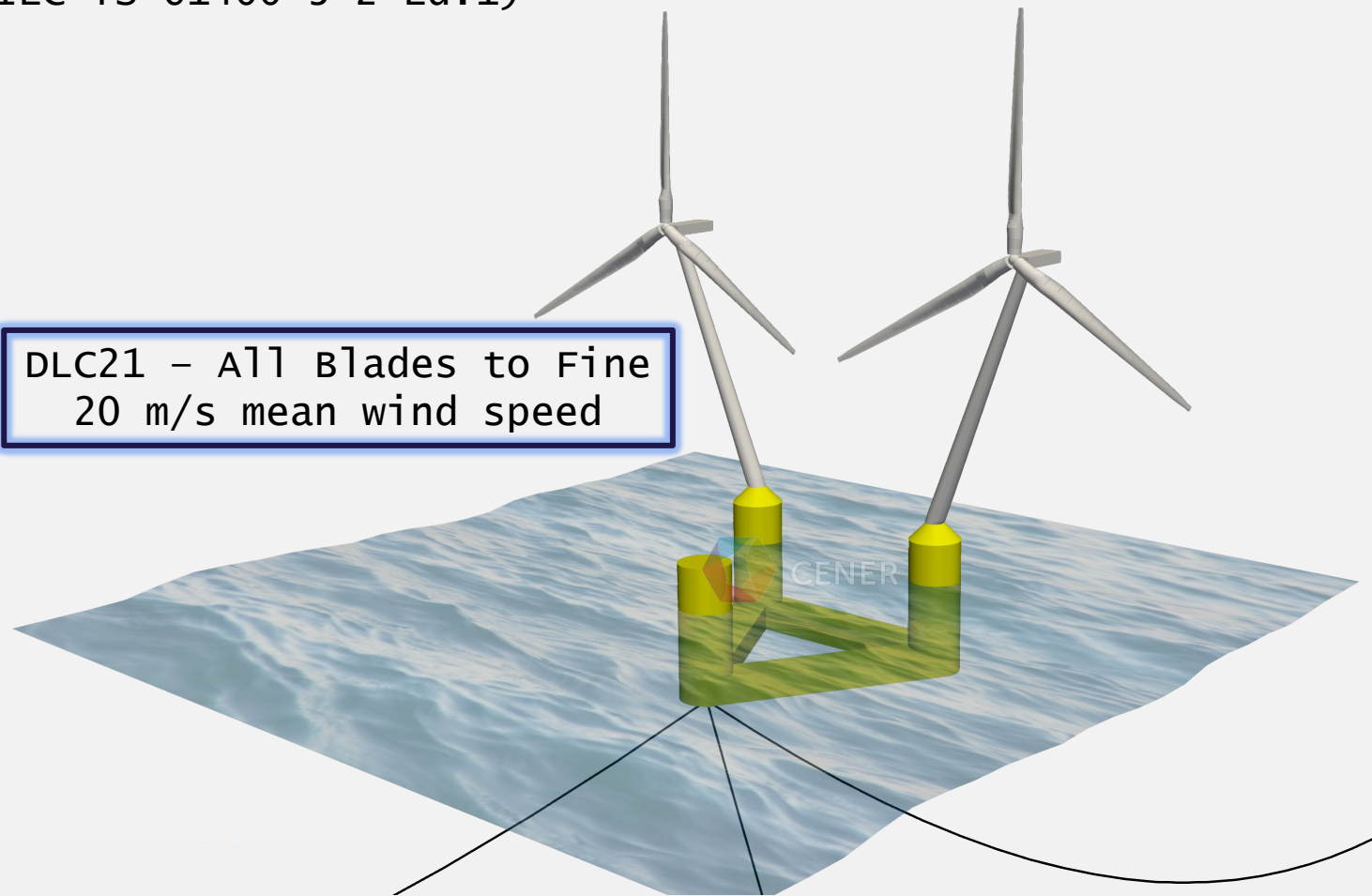
Aerodynamic, hydrodynamic & structural coupling

Coordinated Control module (CoCoDyn)

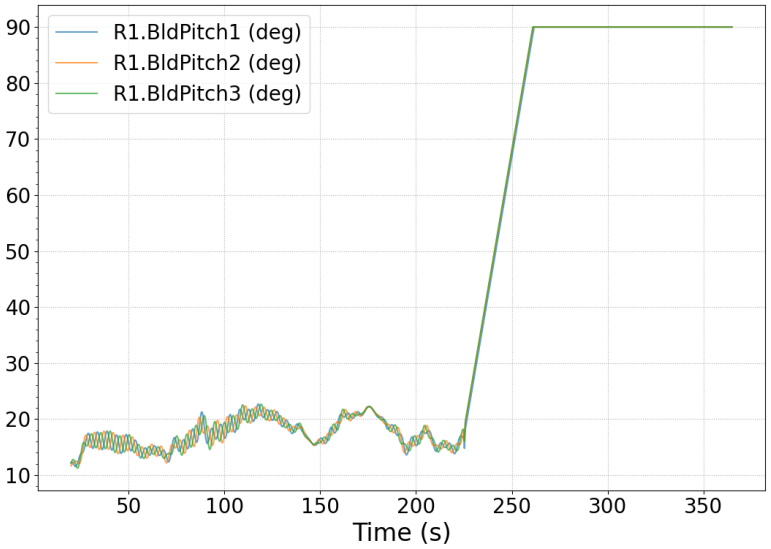
>Demonstration Study_

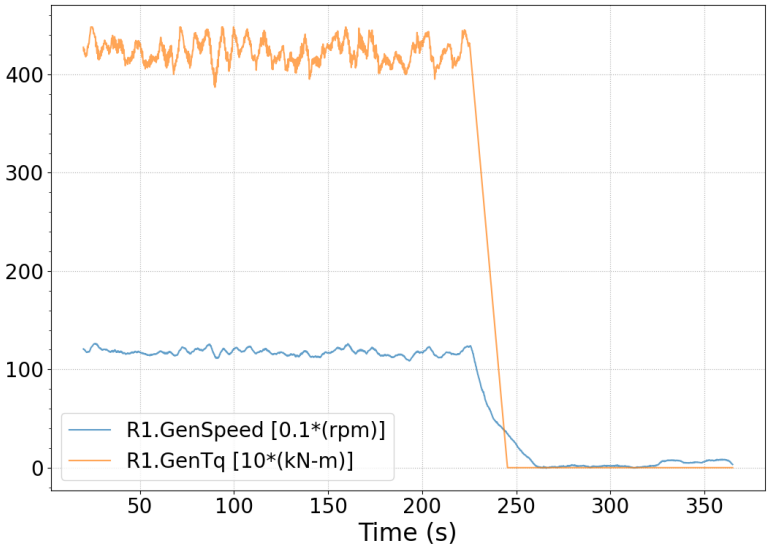
- **DeltaWind2WT** platform designed by CENER
- 2 wind turbines: 5-MW NREL reference wind turbines
- Reduced set of extreme load cases (IEC TS 61400-3-2 Ed.1)

Design Load Cases (DLC)	
1.3	Power Production with ETM (Extreme Turbulence Model)
1.6	Power Production with SSS (Severe Sea State)
2.1	Blade1 to feather, Blade1 to fine, All blades to fine, Overspeed n4
2.2	Seized blade1, Overspeed nA
5.1	Emergency stop
9.1	Power production + fault occurrence (mooring fault)

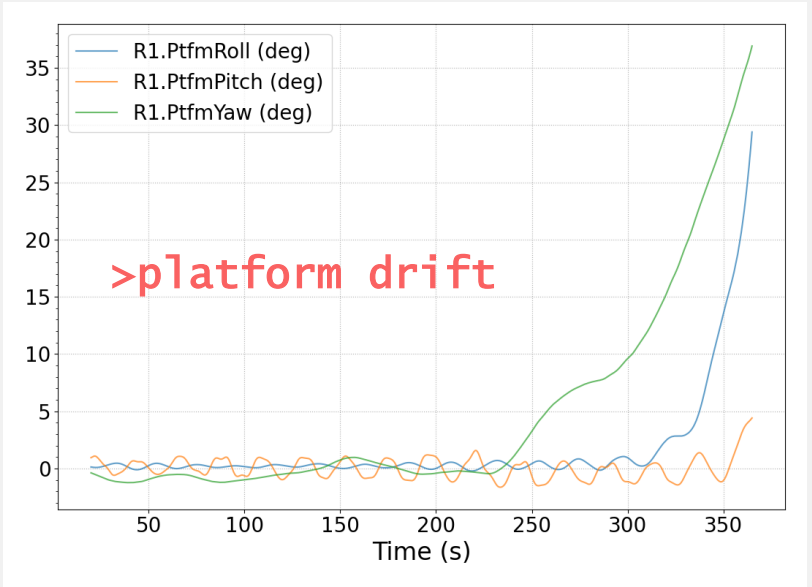


>Results/DLC21_All Blades to Fine/NO Coordinated Control_

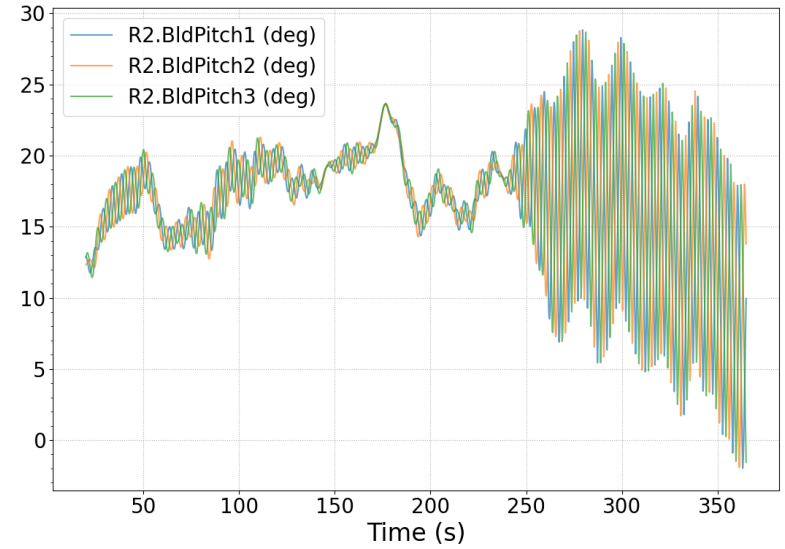


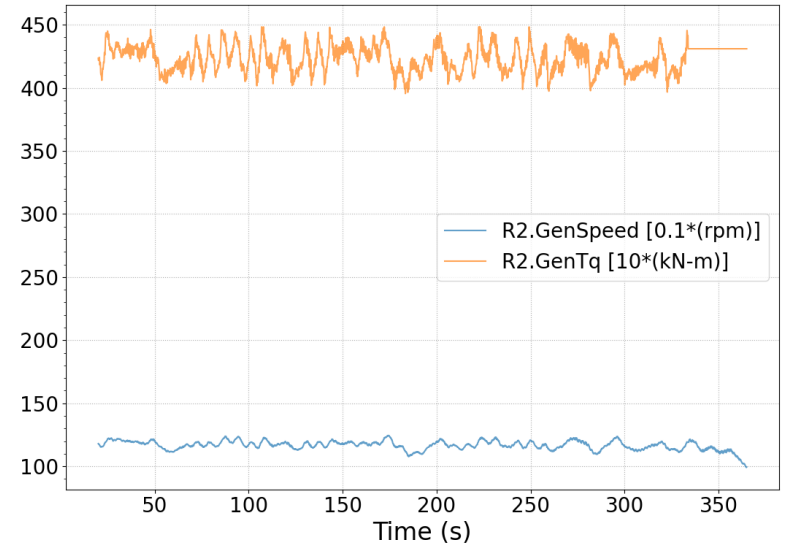


@WT1> blade fault > stop



@WT2> ignores WT1 fault





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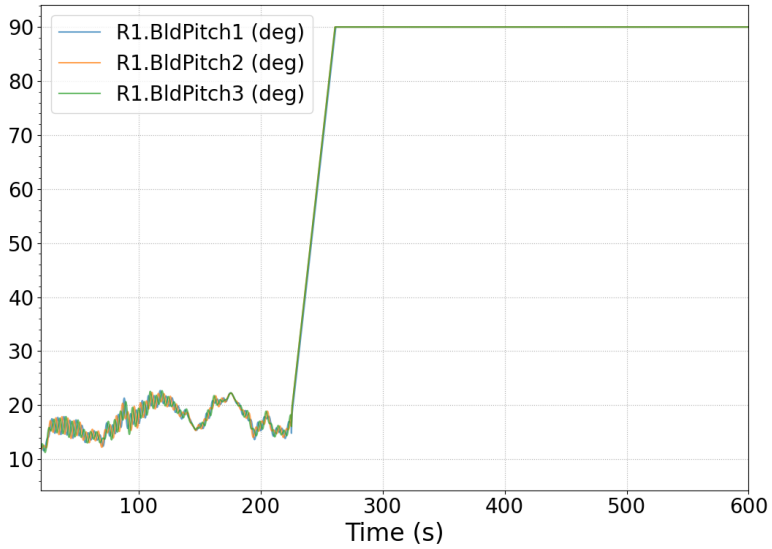
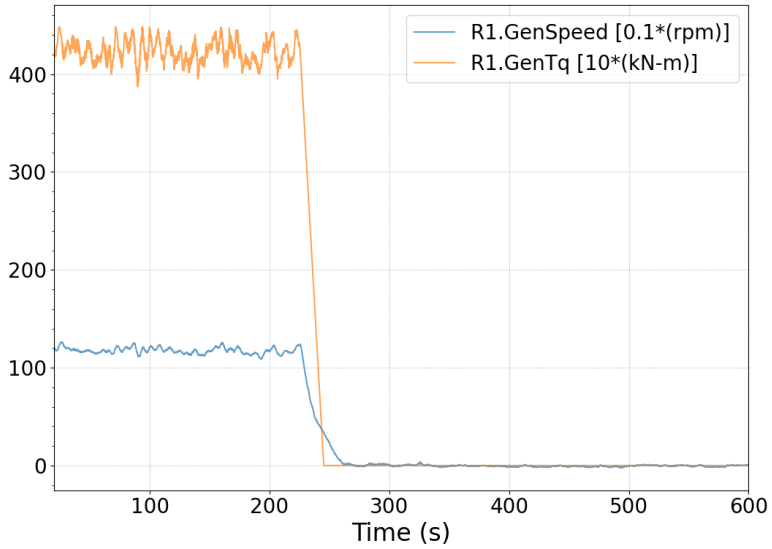
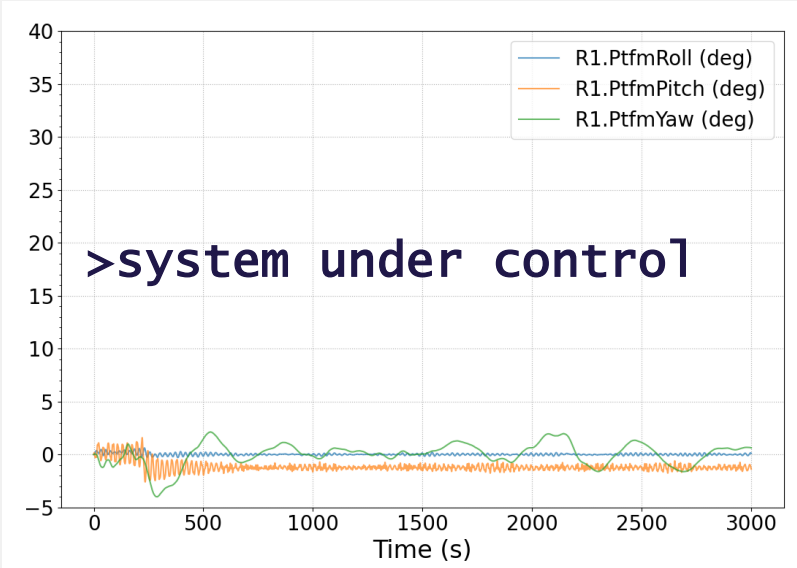
>Results/DLC21_All Blades to Fine/Coordinated Control_

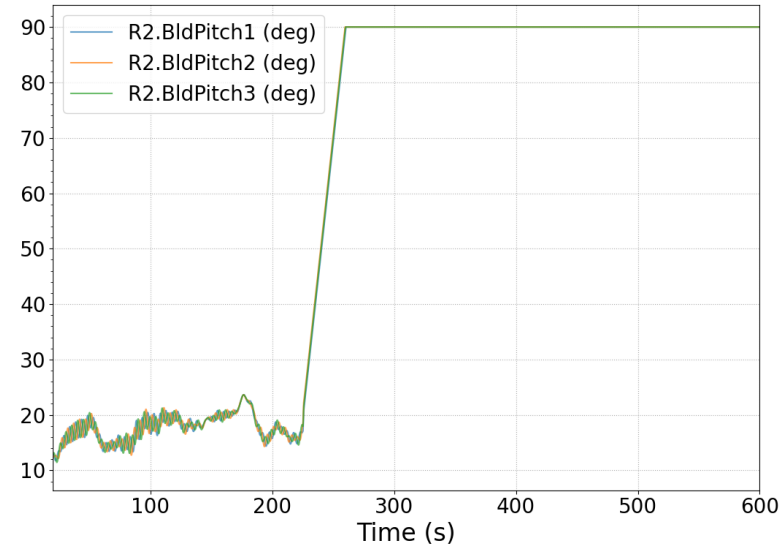


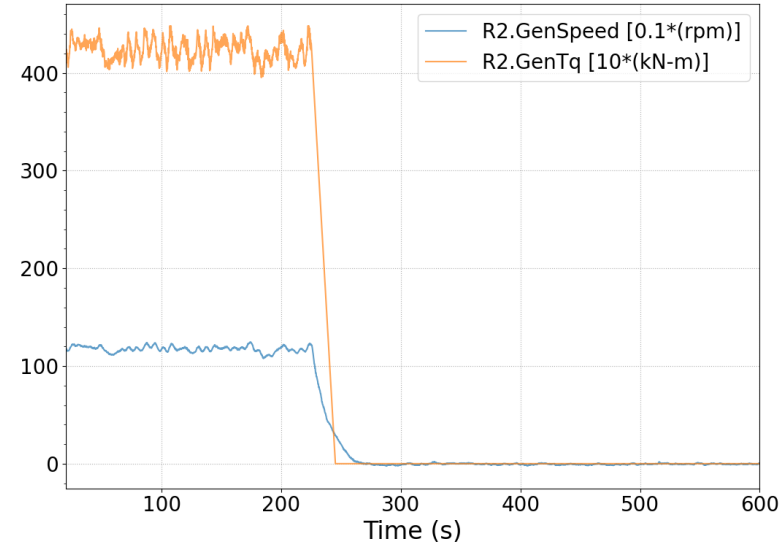


@WT1> blade fault > stop



@WT2> stop triggered by Coordinated Control





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>Impact of Coordinated Control of multi-WT assets_

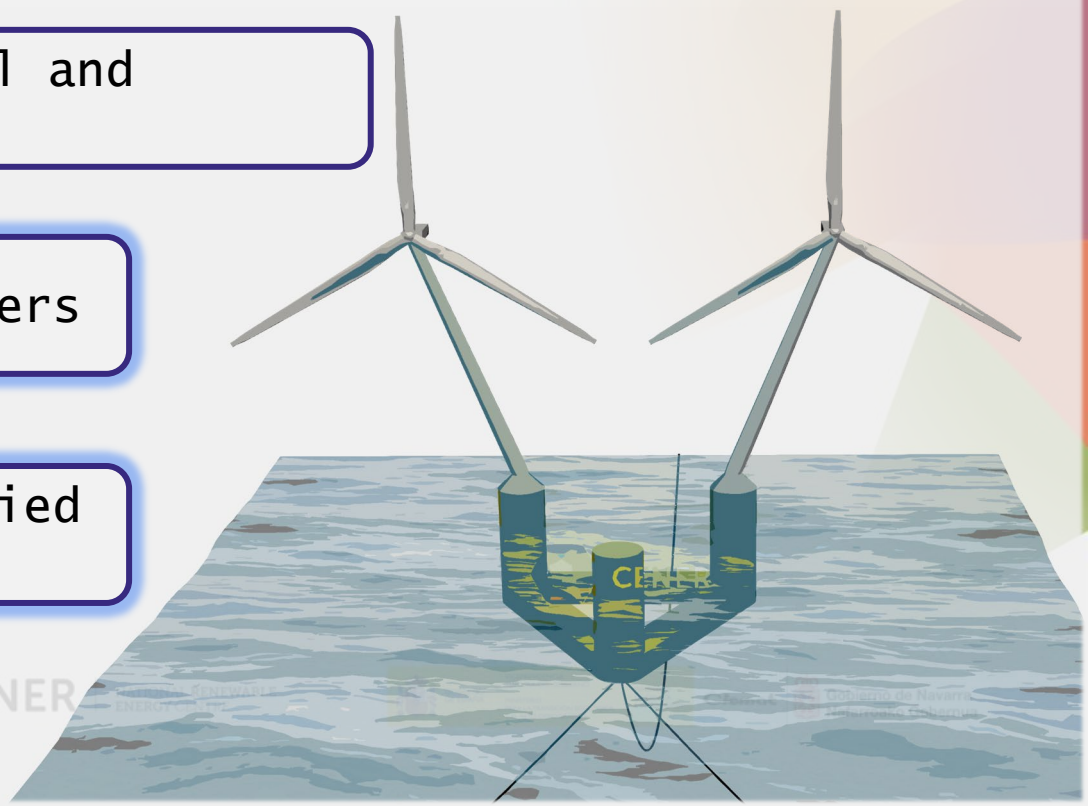
Effectively command the whole system under fault events and shutdowns

Avoid excessive platform drift and blade pitch activity

Ensure safety and system integrity; optimal and reliable performance

Smooth integration with individual WT controllers

Simulation tool & control library already applied to certification of an industrial design



THANKS A LOT.

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