TotalControl – an overview
Advanced integrated control of WPPs

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Outline

- Consortium
- Overall objectives and approach
- How? – project structure
  - WP1 + selected high lights
  - WP2 + selected high lights
  - WP3 + selected high lights
  - WP4 + selected high lights
  - Wp5 - dissemination

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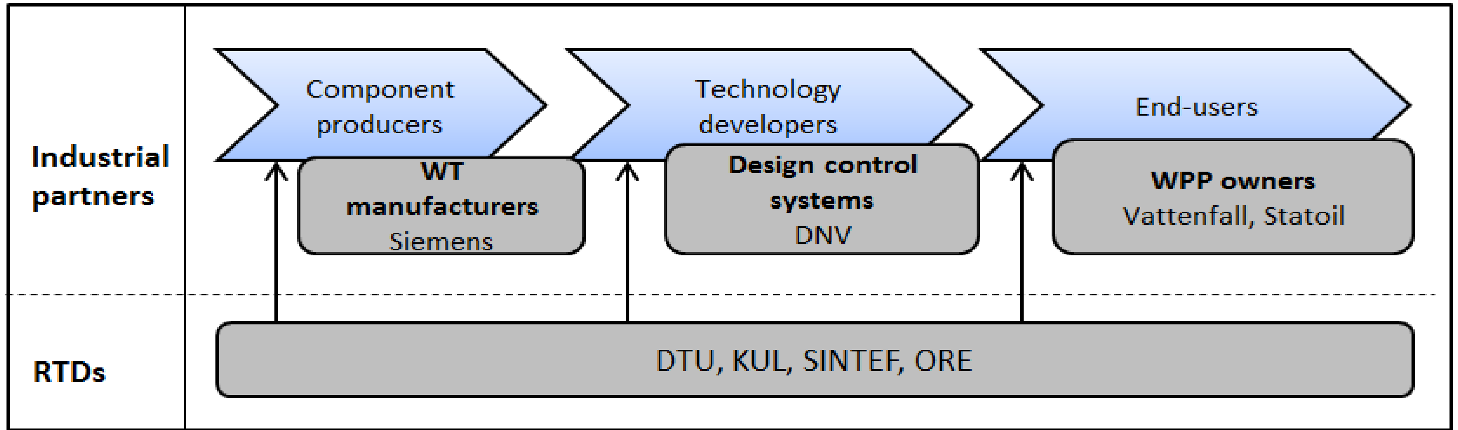
Consortium

Participant no	Participant Organisation Name	Country
1 (Coord.)	Danmarks Tekniske Universitet (DTU)	DK
2	Katholieke Universiteit Leuven (KUL)	BE
3	SINTEF Energi (SINTEF)	NO
4	Garrad Hassan & Partners Ltd (DNV)	UK
5	Vattenfall (VF)	SE
6	ORE Catapult (ORE)	UK
7	Siemens (SWP)	DK
8	Statoil (Statoil)	NO



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Overall objectives

- To develop ***integrated*** WPP/WT control strategies conditioned on grid demands … that ***maximize*** the life-cycle ***profitability*** of a WPP
  - Maximizing ***power*** production balanced against turbine ***loading*** (i.e. fatigue load degradation of WTs and O&M costs) and electricity price
  - Enhancing WPP capability to provide ***ancillary services***
- To validate derived models: All WPs include ***experimental validation*** … WP1, WP2, and WP3 include full-scale experiments; WP4 include lab. scale experiments

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Approach

- The ambition of TotalControl is to move WPP controller design philosophy from ***greedy individual*** optimization of WTs operation to a ***collaborative*** optimization of the overall WPP performance

WP's

WP1: WPP design and control models

Goal
– Development of appropriate control models for other WPs
– Set up of virtual testing environment that can be used in other WPs

To that end:
– Measurement campaign in Lillgrund
– Use of high-fidelity numerical simulation models (SP-Wind, SOWFA, Ellipsys)

WP2: quasi-static open-loop WPP control

Goal
Wind-farm control with **control time steps of 10-20 min**

To:
– Improve power extraction by yawing
– Reduce loads (steered by lifetime and O&M costs/timing) by yawing, or induction control
– Decide on WPP downrating in response to market, tertiary ancillary services
– …

WP3: WT control

Goal
Enhance WT control
control time step: < 1s

To:
– Further load reduction
– Turbulence or market based derating
– Primary ancillary services (FFR, Voltage support)
– Allow other and dynamically changing set-points – widen available operational range for controllers in WP2 and WP4
– LIDAR assisted control
– ….

WP4: feedback WPP control

Goal
Wind-farm control with **control time steps < 1 min**

To:
– Dynamic optimization
– Reduce loads (subject to turbulent gusts)
– Provide primary and/or secondary ancillary services (e.g. power signal tracking)
– Increase energy extraction (subject to turbulence)
– Deep understanding of WPP system dynamics

VERIFICATION/VALIDATION

– Experiments @ Lillgrund
– Use virtual simulation environment

– Experiments on the Samsung 7MW turbine

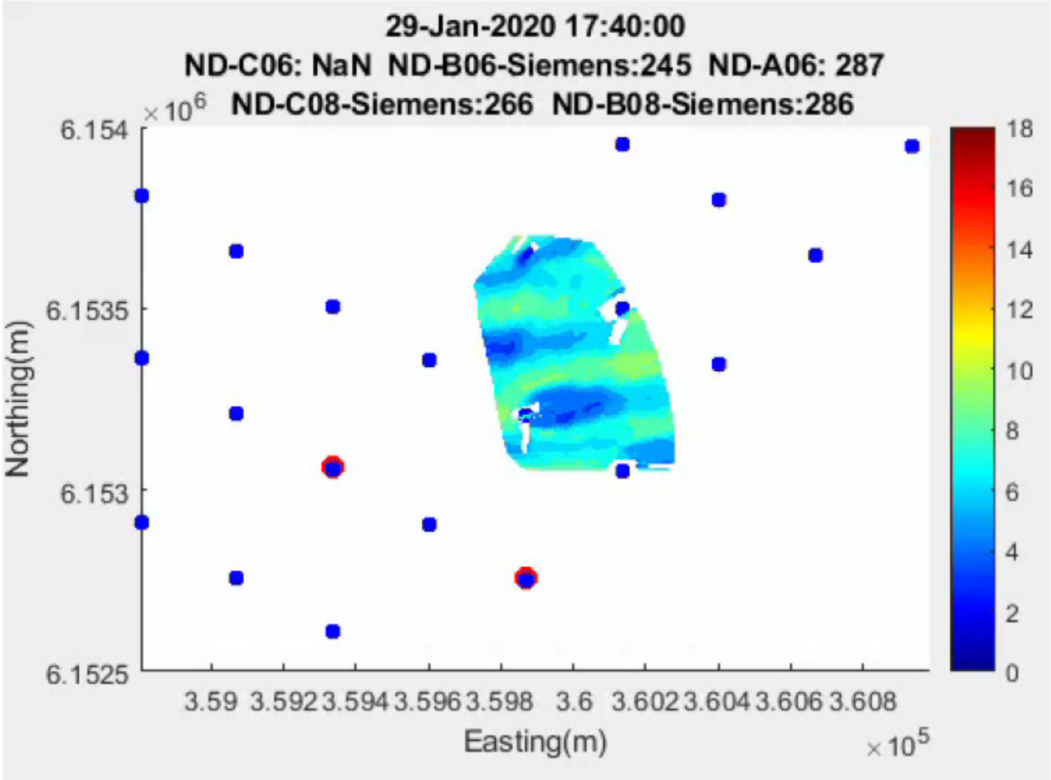
– Laboratory experiments
– Use virtual simulation environment (validated in WP1)

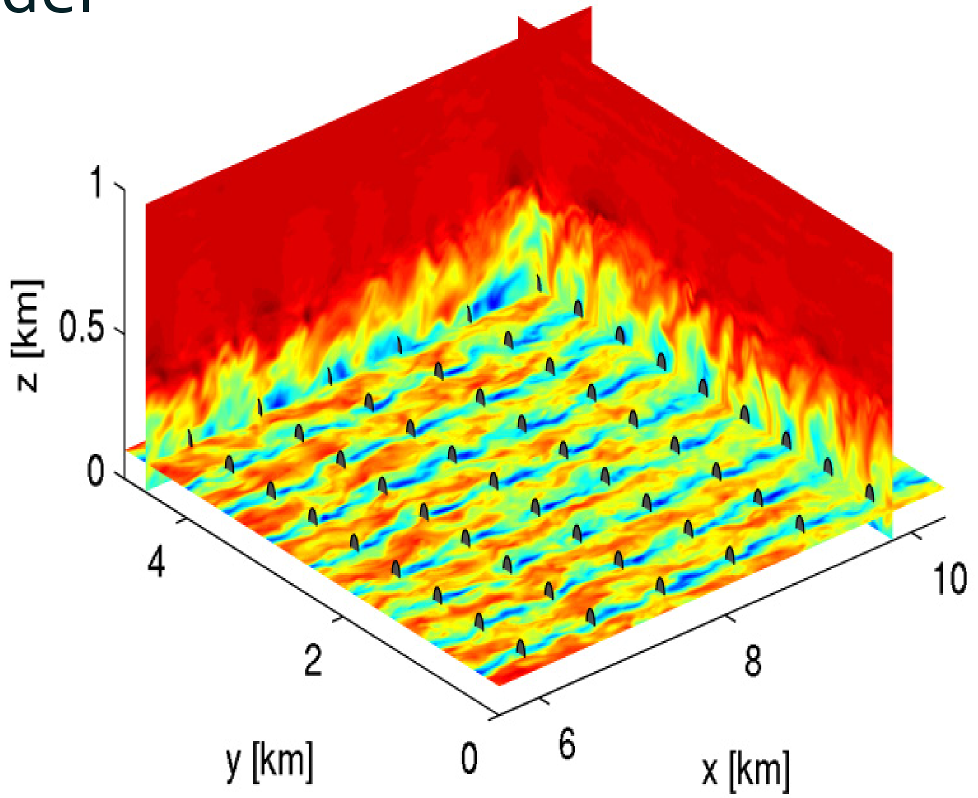
WP5: DISSEMINATION

WP6: MANAGEMENT

WP1 - WPP simulation models (1)

- **Objectives:** *Development* and *validation* of WPP simulation models of various fidelity … covering the *whole chain* from flow model over aero-elastic model to power-grid model





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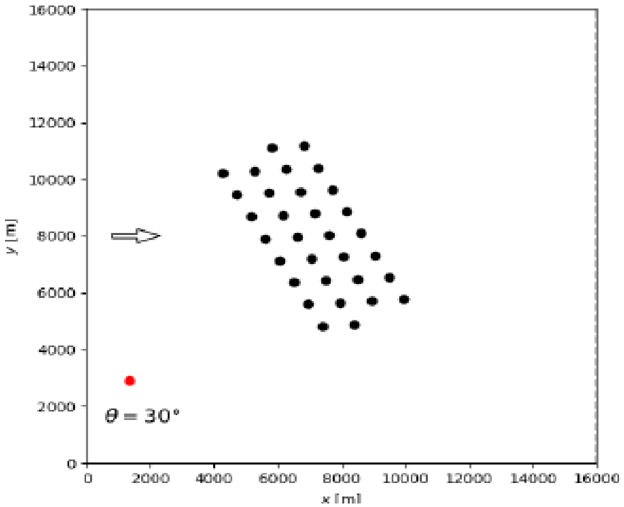
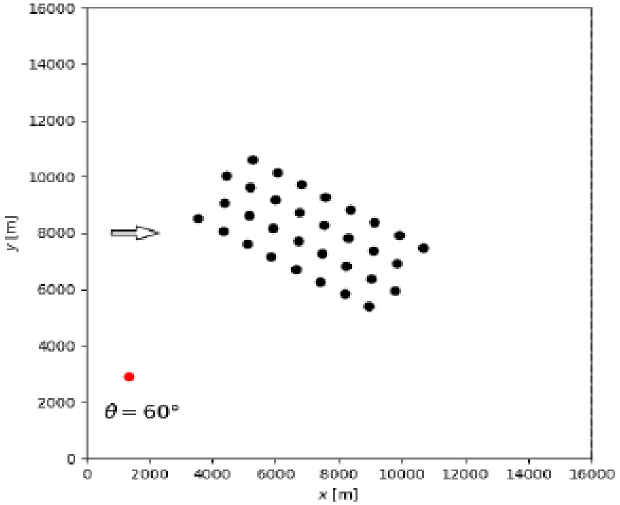
WP1 - WPP simulation models (2)

- **Modeling – High fidelity; medium fidelity; engineering:**
  - CFD LES simulations; **dynamic**
  - DWM … generalized to account for yawed WTs; **dynamic**
  - Linearized CFD RANS (Fuga - super fast) … generalized to account for yawed actuator disc WTs; **static**
  - Simple dynamic wind farm model (LongSim; eng. wake model embedded in dynamic flow field); **dynamic**
  - Coupling of Gaussian wake model to background ABL model; **static**

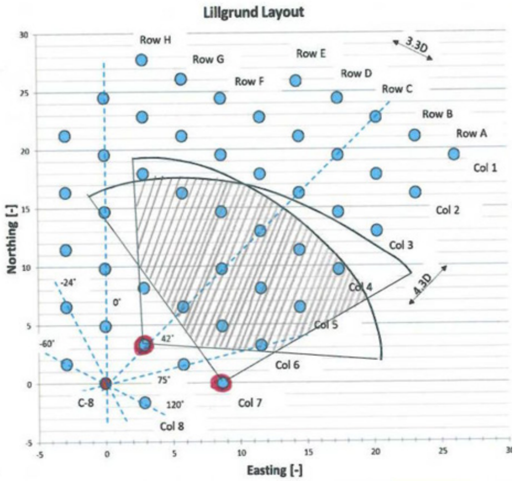
WP1 - WPP simulation models (3)

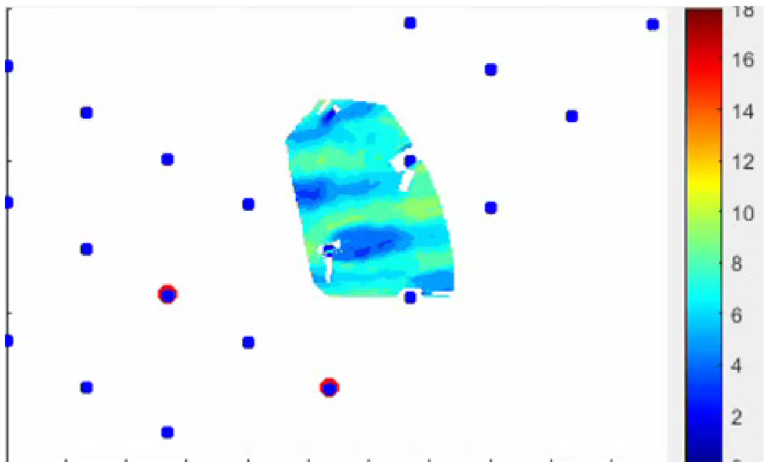
- **Show cases – demonstration, validation:**
  - Reference wind farm including power grid





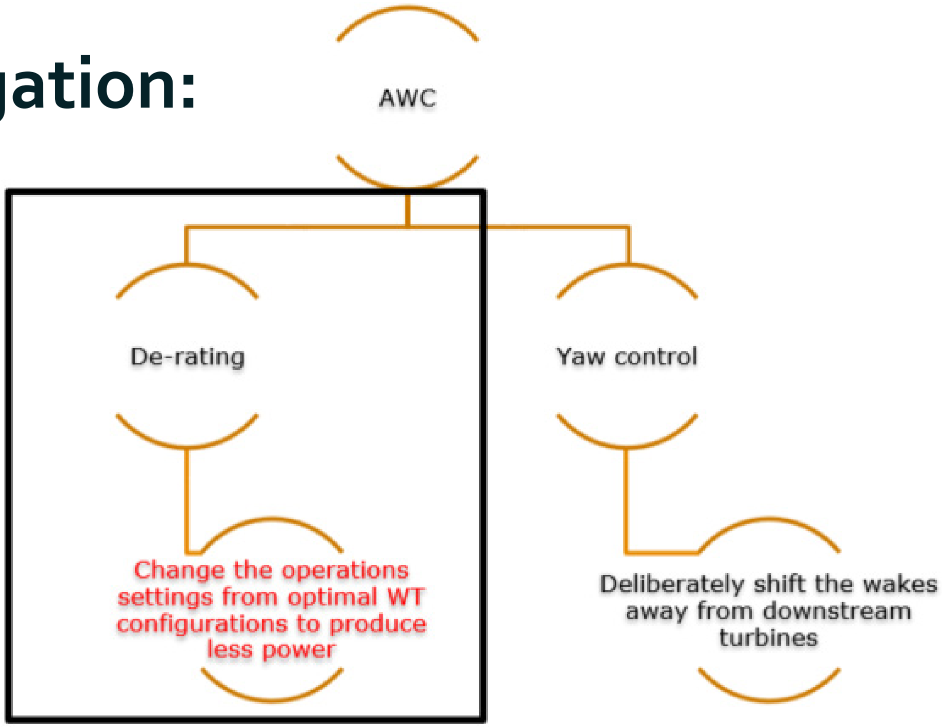
  - Lillgrunden





WP2 – Open loop control schemes (1)

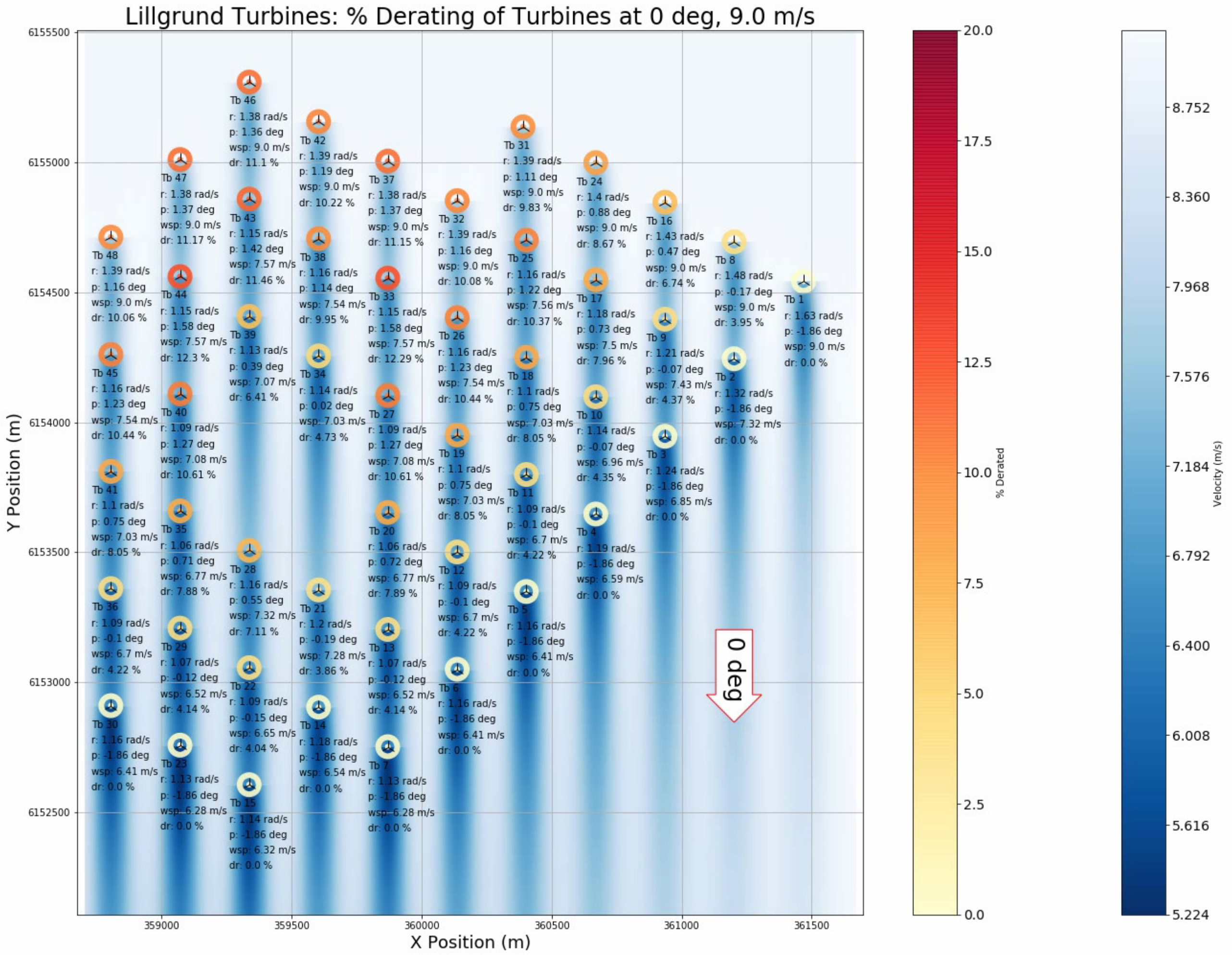
- **Objectives:** Develop and validate *optimized WPP control schemes* ... optimal economic WPP performance (power, load and electrical aspects) is pursued over the WPP life time ... on *time scales of the order of 10 minutes*
- **Approach ... wake mitigation:**



WP2 – Open loop control schemes (2)

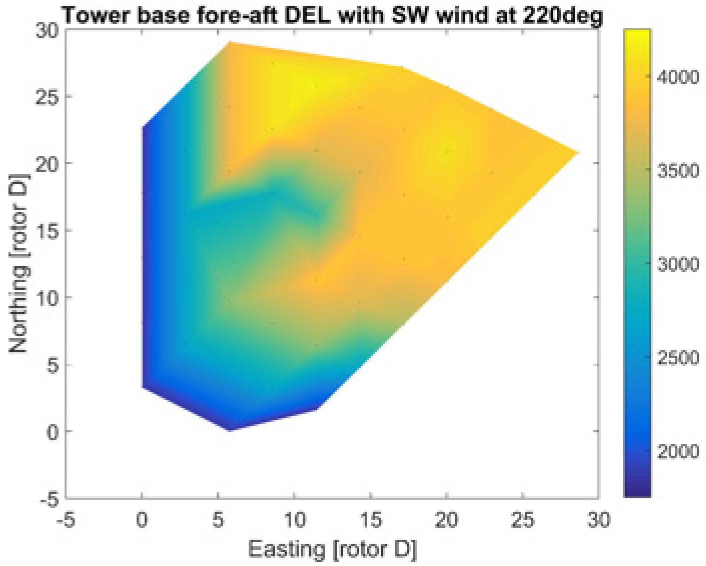
- **Optimal WPP control schedules – static approach**
  - Objective function: WPP power production | (U,Θ)
  - De-rating using 2 design variables pr. WT … Ω and α_p
  - WTs modeled as actuator discs in Fuga (linearized CFD code)
  - Lillgrund show case

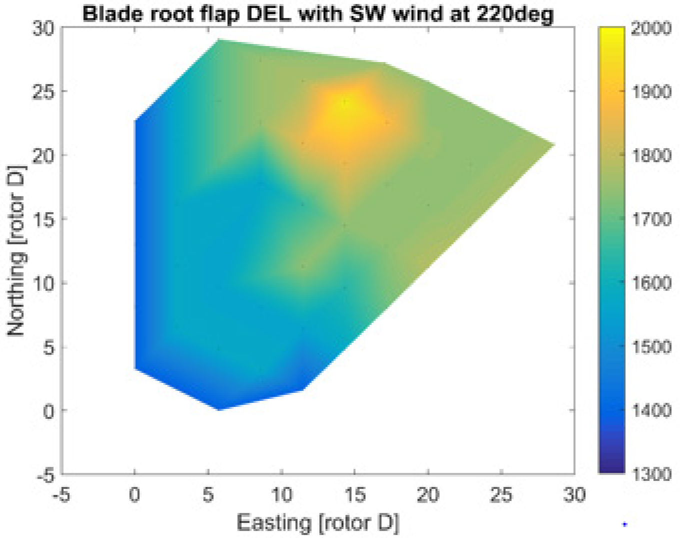
WP2 – Open loop control schemes (3)



WP2 – Open loop control schemes (4)

- **Optimal WPP control schedules – dynamic approach**
  - Keyword: surrogate models … due to CPU issues
  - Lillgrund show case





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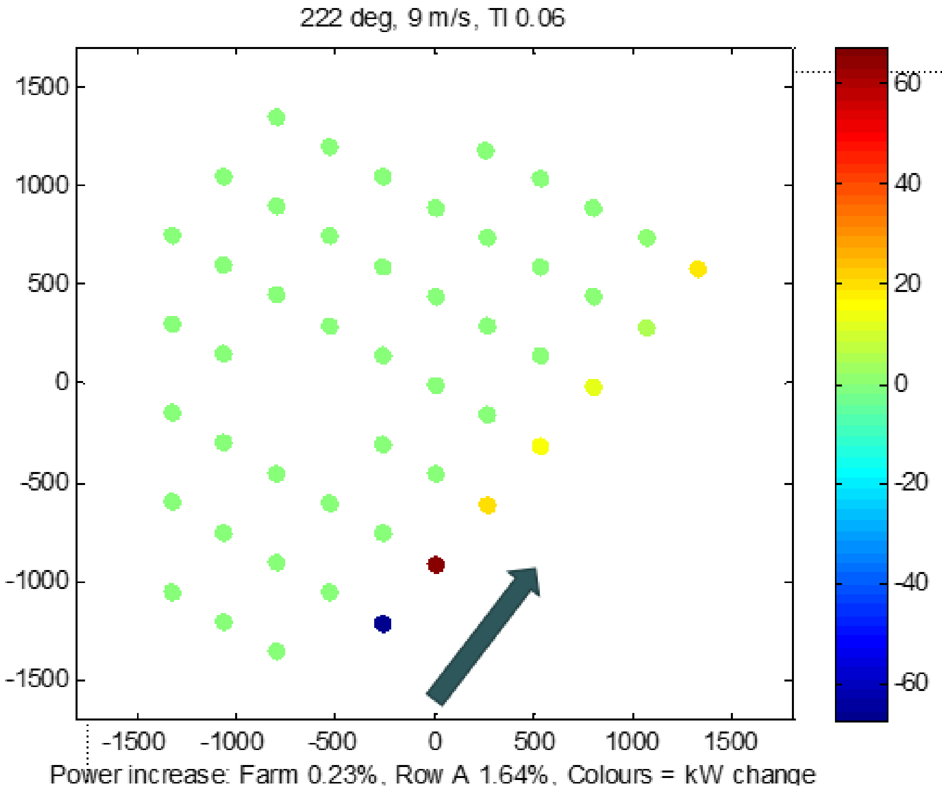
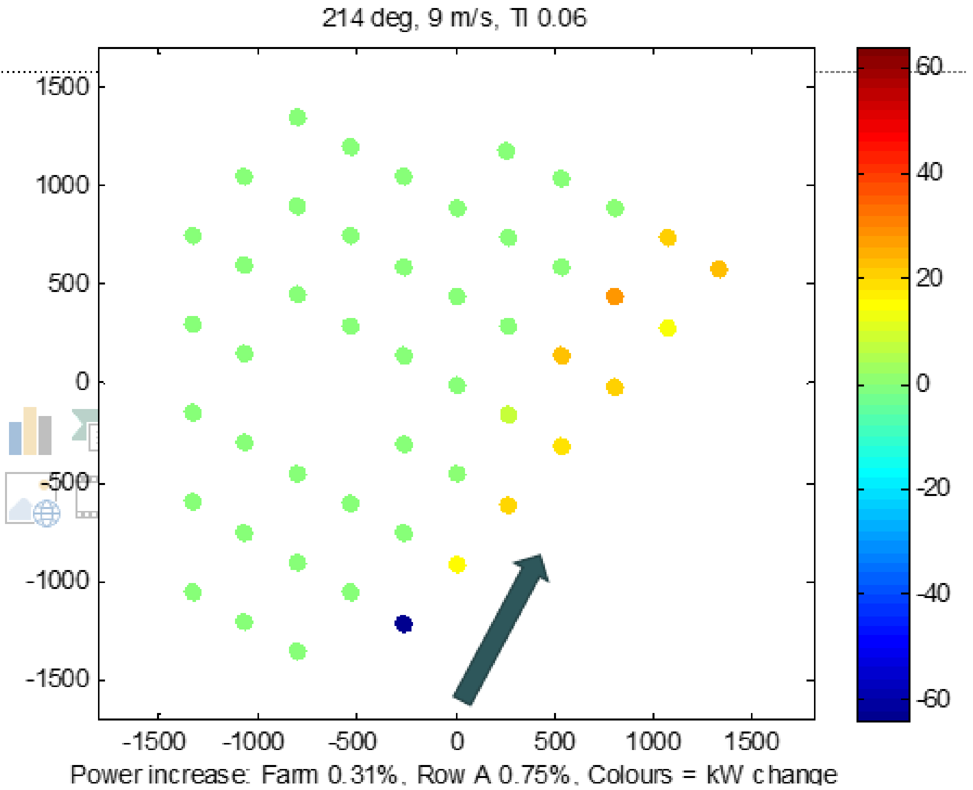
WP2 – Open loop control schemes (5)

- **Full scale de-rating validation case – power capture; Lillgrunden**





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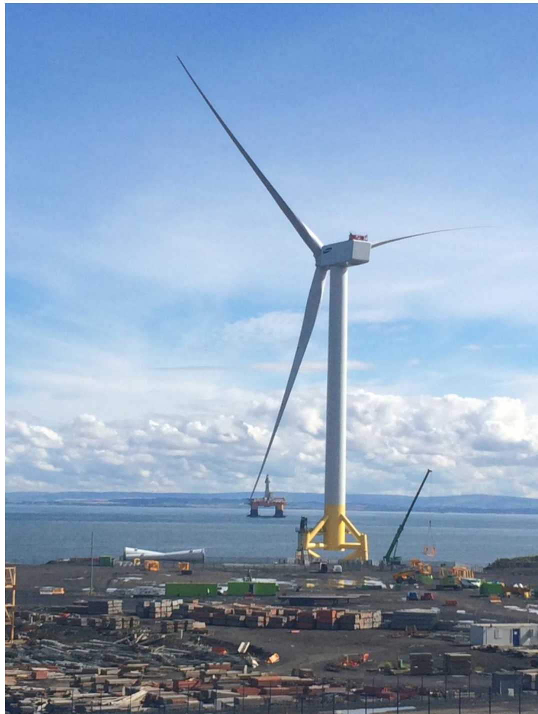
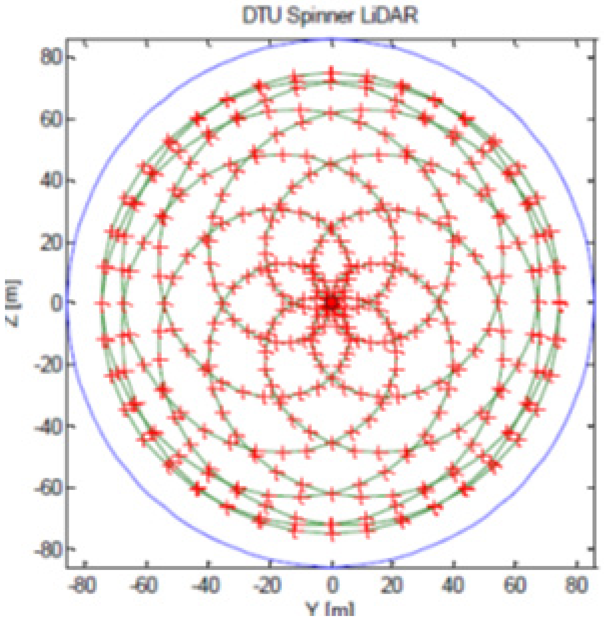
WP3 - Enhanced WT control schemes (1)

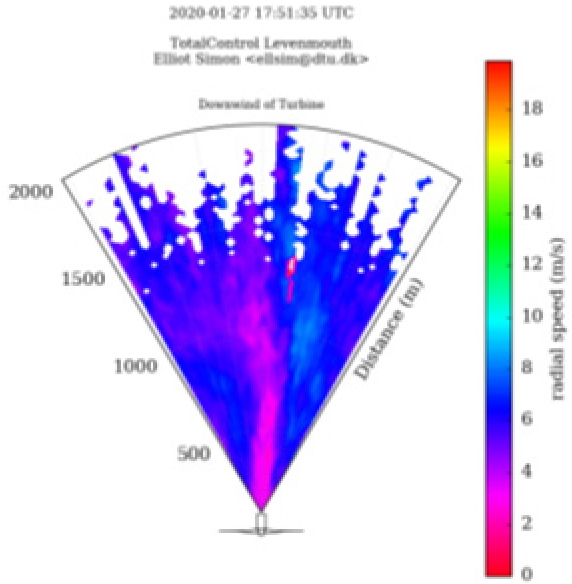
- **Objectives:** Development of new **WT** controller functionalities for facilitating *optimization* of wind plant operation over the WPP lifetime
- **Approach:**
  - Develop *new innovative WT control* features … and use numerical simulations to test and evaluate these
    - Samsung 7MW WT is the test case
    - Power set-point reduction algorithms
    - Active yaw control
    - Model predictive controller
    - Individual pitch control using tower-top sensors
    - Lidar assisted control for load reduction



WP3 - Enhanced WT control schemes (2)

- Full-scale *validation* and *testing* using the Samsung 7MW WT
  - Forward-facing scanning LiDAR on the nacelle (inflow)
  - Rear-facing LiDAR resolving the effect of control actions on the wake





WP4 - Closed loop control schemes (1)

- **Objectives:** *Unification of the results* from other WPs into a suite of practical wind power plant controllers + develop guidelines and *standards* for the design of wind power plants with advanced control functions
- **Approach:**
  - "Closes the loop" on the open-loop wake control strategies developed in WP2, by
    - Accounting for *model uncertainty*
    - Accounting for *stochastic (short term) variability* of external conditions ... based on on-line input from e.g. electrical sensors, wind speed sensors, and condition monitoring equipment

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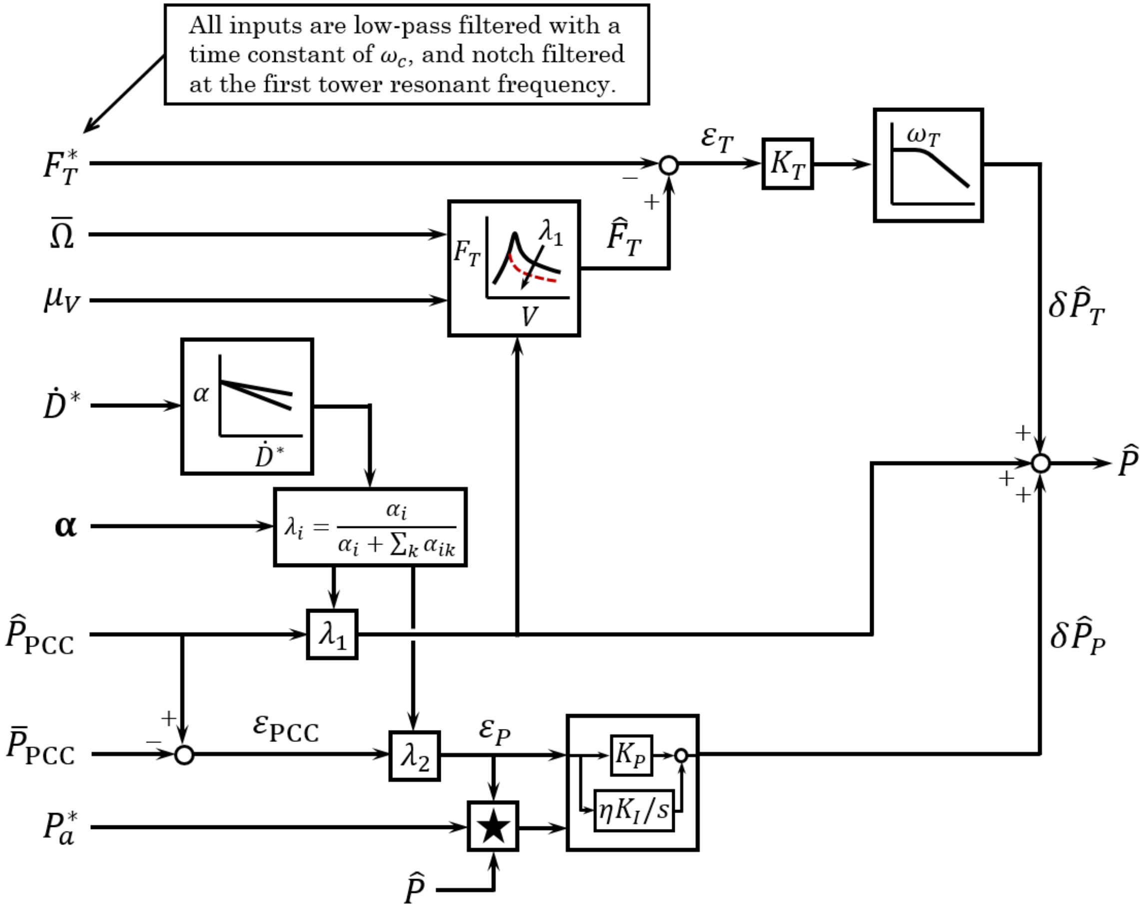
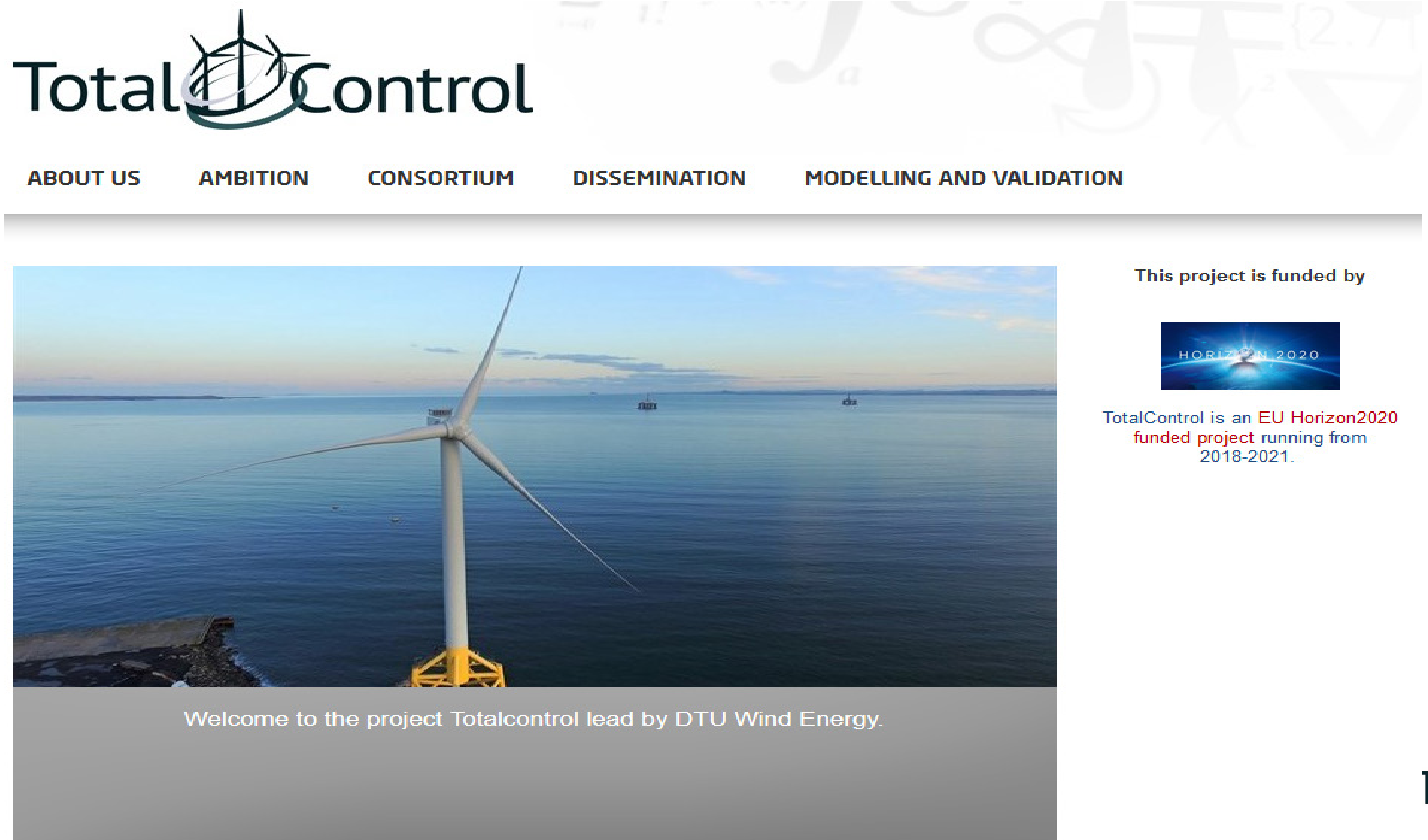
WP4 - Closed loop control schemes (2)

- Hierarchical wind power plant supervisory controller … a complex linear approach



WP5 Dissemination

Website: totalcontrolproject.eu



Thank You!

Questions?