IEA Wind TCP Task 37: Wind Energy Systems Engineering

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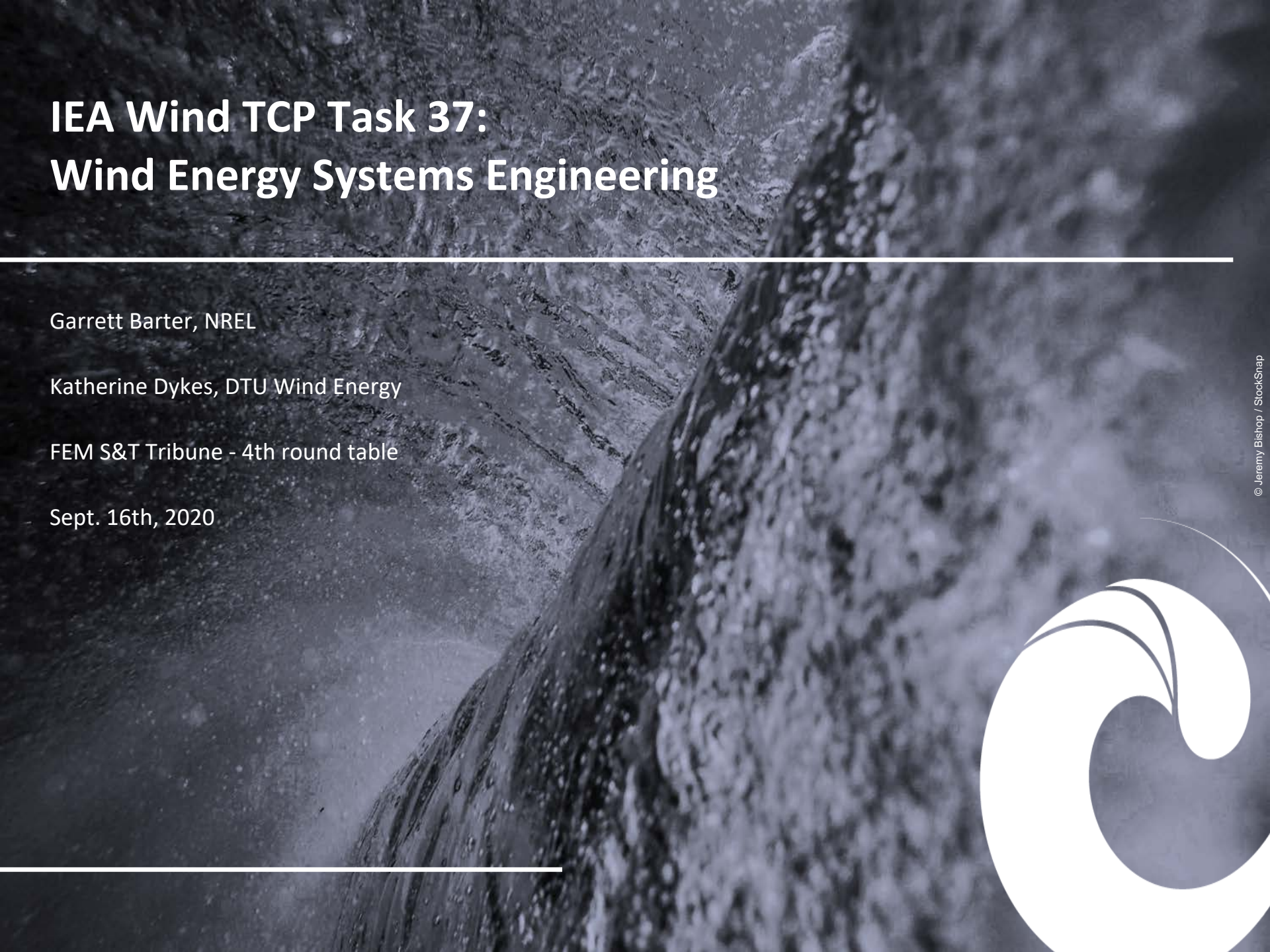
FEM S&T Tribune - 4th round table

Sept. 16th, 2020



Task Objectives & Expected Results

Project Objectives and Outcomes

- Improve quality of systems engineering by practitioners through development of best practices and benchmarking exercises
- Promote general knowledge and value demonstrations of systems engineering tools and methods applied to wind energy RD&D

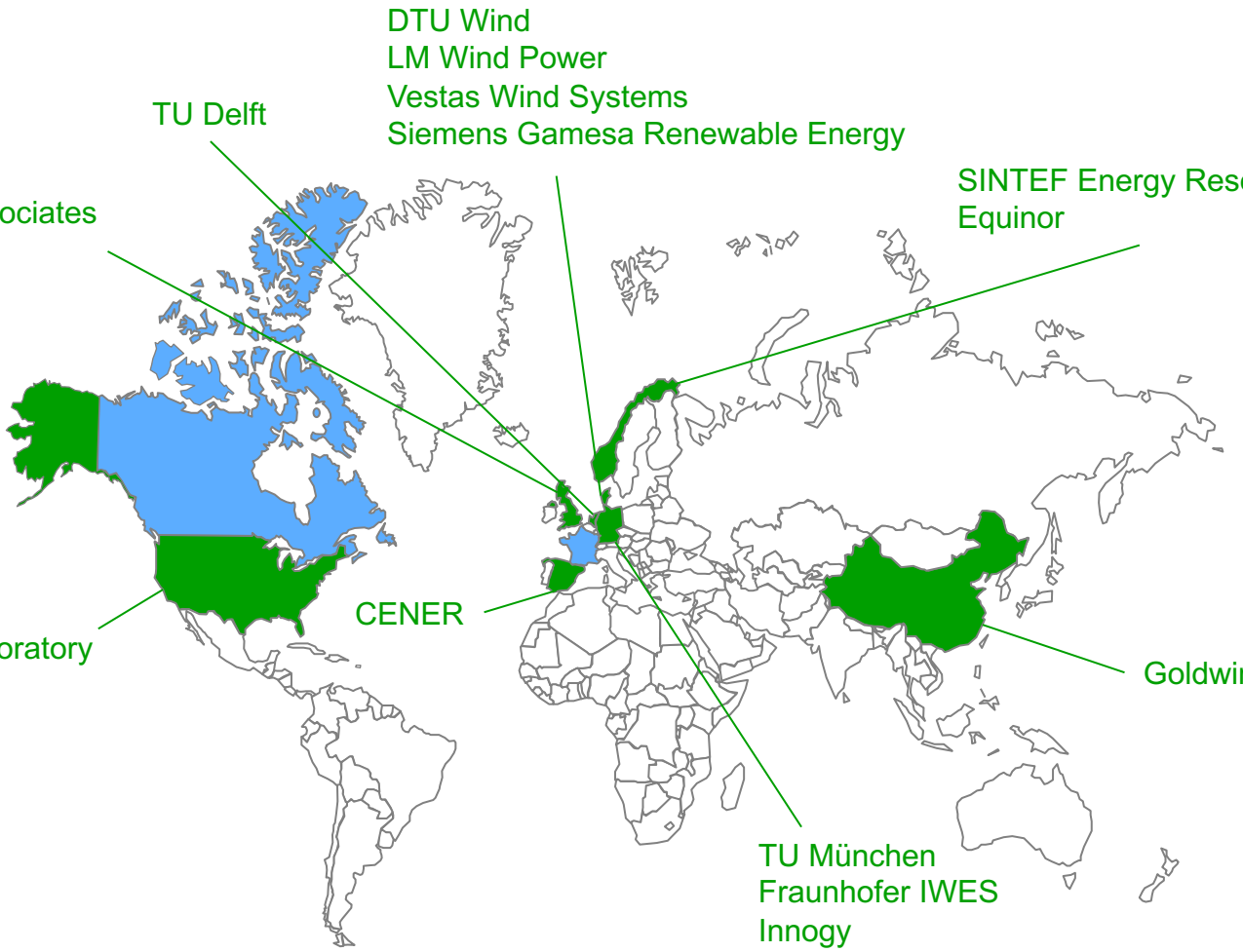
Target audience

- Wind turbine OEMs
- Wind plant developers

Terms

- Phase I: 2016 – 2019
- Phase II: 2020 – 2022

Country Participation



- Eight countries participating: six universities, six national labs, eight companies
- Canada expressed interest, France (IFPEN, France Energies Marines) in process of officially joining task

Work Package Overview

WP1

Guidelines for integrated wind turbine and plant software frameworks

WP2

Series of reference turbine and plant designs for supporting integrated analysis activities

WP3

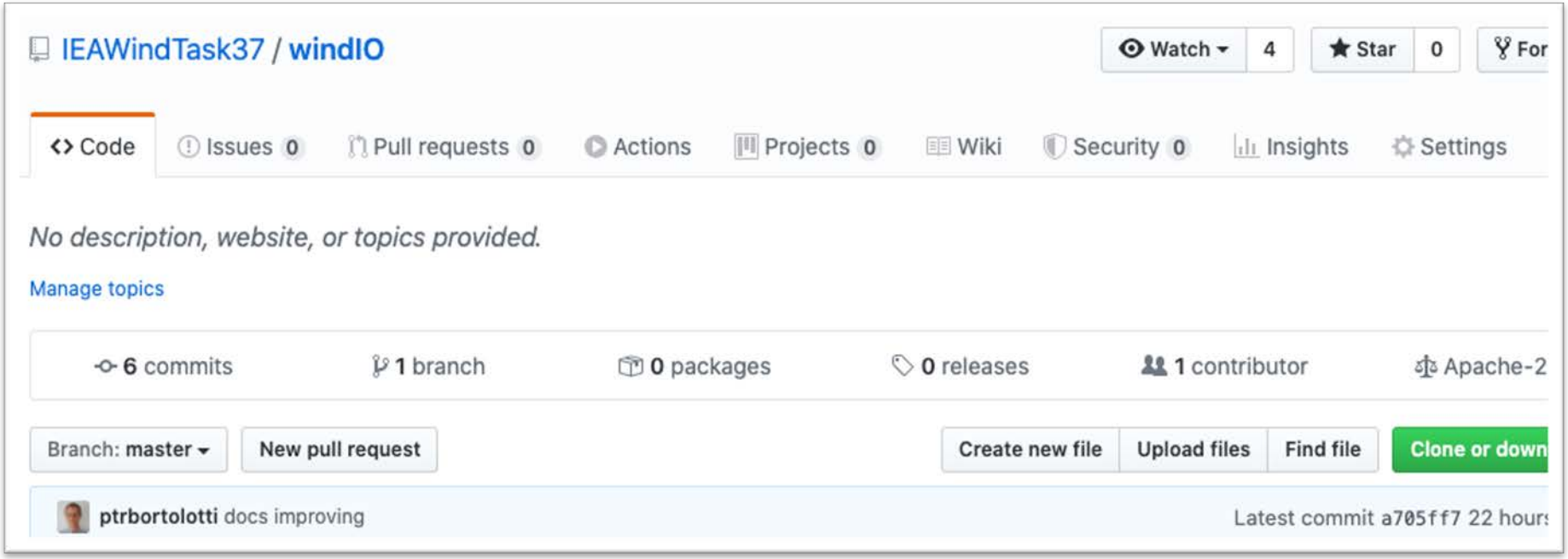
Work towards best practice recommendations on Multi-disciplinary Design, Analysis and Optimization (MDAO) applied to wind systems

WP4

Workshops with other IEA Wind Tasks on state-of-the-art in MDAO

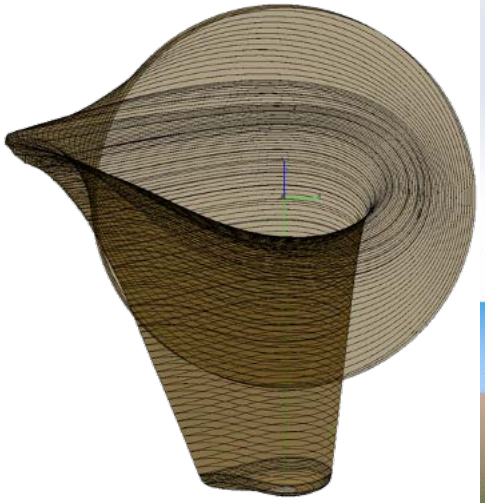
Technical Results: WP1 (Frameworks)

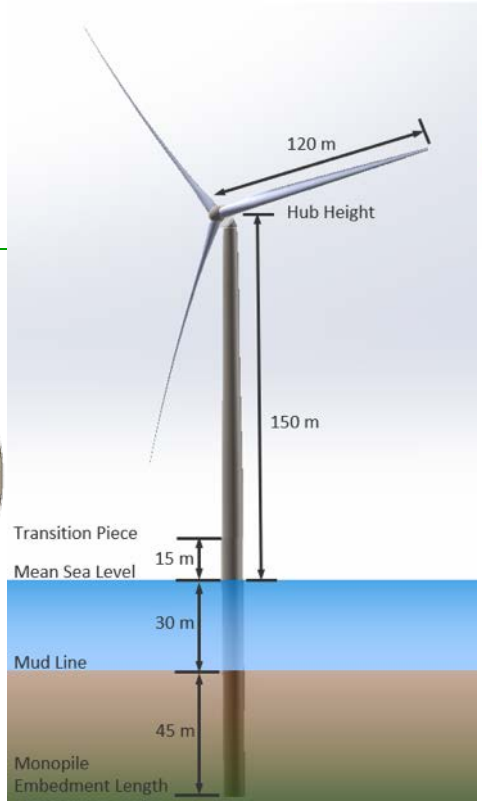
- **Formalization of the common software framework as the WindIO project**
  - https://github.com/IEAWindTask37/windIO
- **Significant progress on developing an "ontology" suitable for wind plant wake flow analysis and layout optimization**
- **Collaboration to extend the framework to cover all remaining turbine components (drivetrain, towers, monopiles, floating platforms, moorings, etc)**



Technical Results: WP2 (Reference Systems)

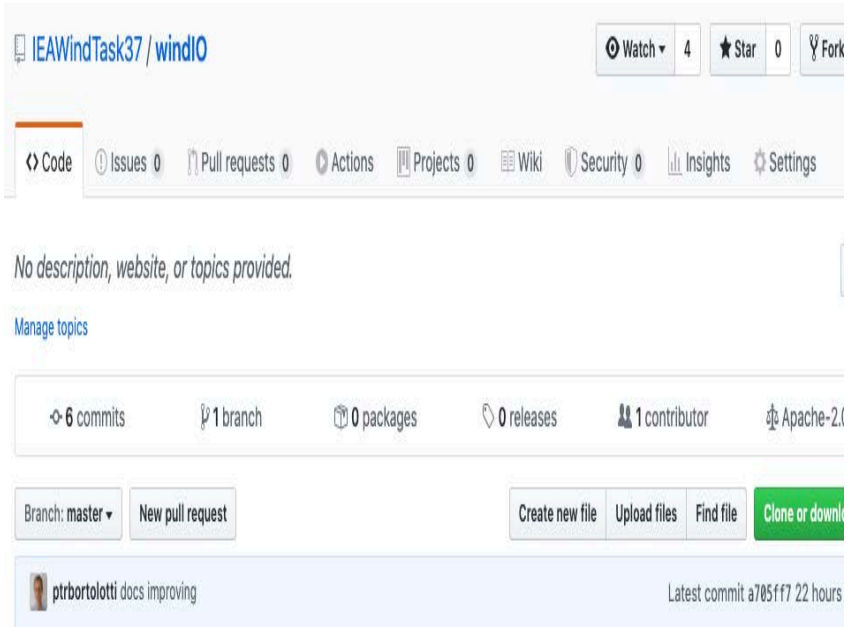
- **IEA Wind 15MW Reference Wind Turbine completed through tight NREL-DTU collaboration:**
  - All Task 37 RWTs: https://github.com/IEAWindTask37/
  - Fixed bottom report: https://www.nrel.gov/docs/fy20osti/75698.pdf
  - Floating platform report: (forthcoming)





- **Significant media attention:**
  - https://www.nrel.gov/news/program/2020/reference-turbine-gives-offshore-wind-updraft.html
  - https://www.offshorewind.biz/2020/02/14/nrel-unveils-15mw-reference-offshore-wind-turbine/
  - https://www.rechargenews.com/wind/us-unveils-15mw-open-source-wind-turbine-after-global-project/2-1-756058
  - https://www.windpowermonthly.com/article/1682050/windtech-digital-15mw-turbine-offers-help-scaling

- **IEA Wind 10 MW / 3.4 MW turbines also released:**
  - https://www.nrel.gov/docs/fy19osti/73492.pdf



Technical Results WP2 (Reference Sys)

WP2.2 Reference wind plants

- Completed layout design for offshore wind plant in the Borssele wind energy area (TU Delft) including detailed design of monopile foundations (NREL/DTU), electrical infrastructure (Sintef) and IO&M strategy (NREL) and LCOE analysis (ORE Catapult)
- Draft report developed and will begin NREL communications process

Onshore wind park (DTU & NREL)

- Under development, delayed

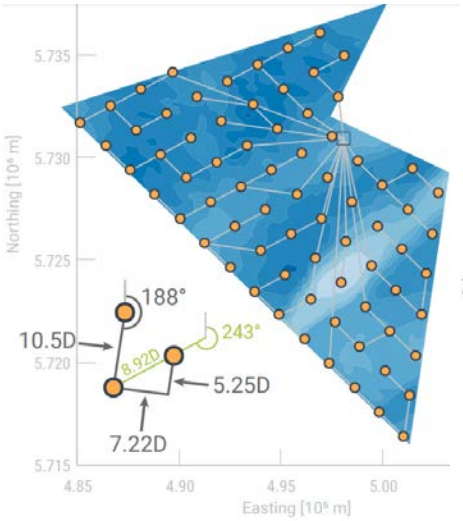


Fig. 3 Final result of the wind farm layout optimisation problem.

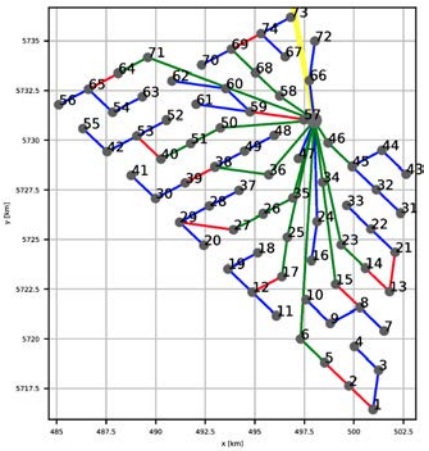


Fig. 4 Topology of the electrical collection cabling.

Offshore wind park (SINTEF & TU Delft)

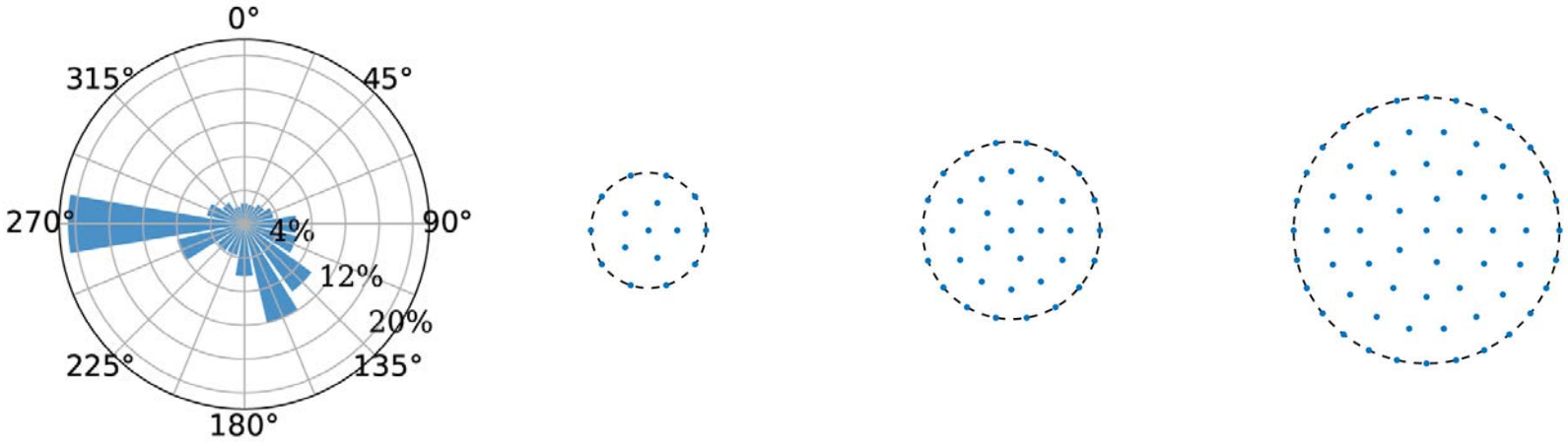
- 74 IEA10MW – 740 MW
- 30-40 meter water depth
- One transformer station 66 kV
- Transmission 220 kV – 40 km to shore

Fig. 1 Borssele wind energy areas III and IV are the site of the RWP.

Technical Results WP3 (Case Studies)

WP3.2 Plant MDAO case study (BYU)

- Applying “lessons learned” from first rotor-aero case study
- **Phase 1**: participants provided with the same software workflow and asked to execute optimization for 3 different problems
- **Phase 2**: participants use their own software on high-simplified optimization problem and results compared to high-fidelity code
- Paper presented at AIAA SciTech 2019

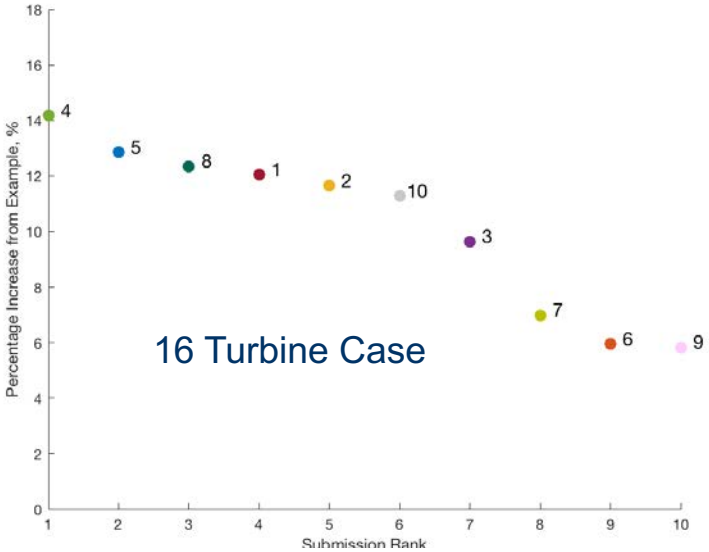


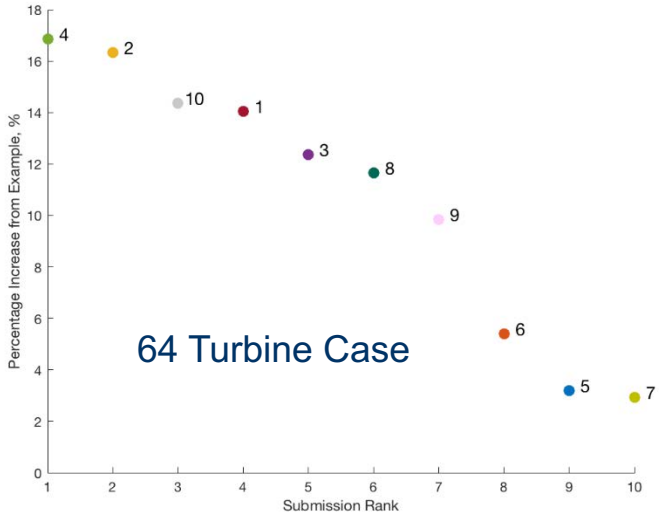
Technical Results WP3 (Case Studies)

WP3.2 Plant MDAO case study (BYU)

- Main findings:
  - Despite use of same exact model, part 1 of the case study still had a significant spread in results (which increased with increasing turbine number)

sub#	Algorithm	Grad.
1	SNOPT	G
2	Preconditioned Sequential Quadratic Programming	G
3	Full Pseudo-Gradient Approach	GF
4	SNOPT+WEC	G
5	fmincon	G
6	Simple Particle Swarm Optimization	GF
7	Basic Genetic Algorithm	GF
8	SNOPT	G
9	Simple Pseudo-Gradient Approach	GF
10	Multistart Interior-Point	G

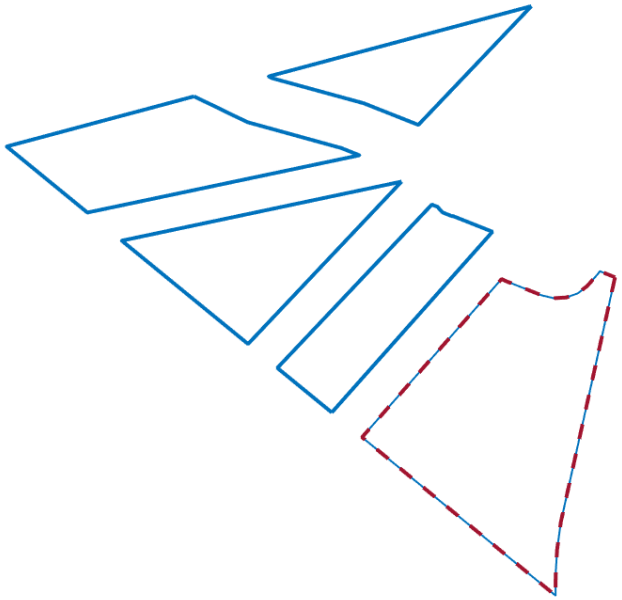




Technical Results WP3 (Case Studies)

WP3 Case Studies in MDAO (Plant)

- Realistic boundaries that gradient-based methods struggle with
- Second round of optimization underway with ongoing discussion of methods and results (collaborative journal article planned)
- Participants: BYU (lead), NREL, DTU, TU Delft, Innogy, UL AWS Truepower, Qubit Engineering, and IFPEN (pending))



Case Study 3:

- Single region
- Non-uniform
- Concavities

Case Study 4:

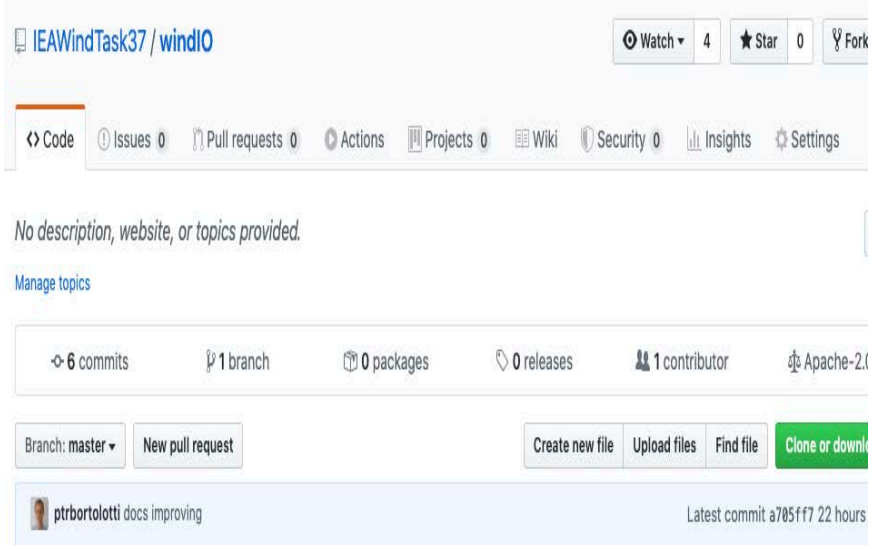
- Multiple regions
- Discontinuities

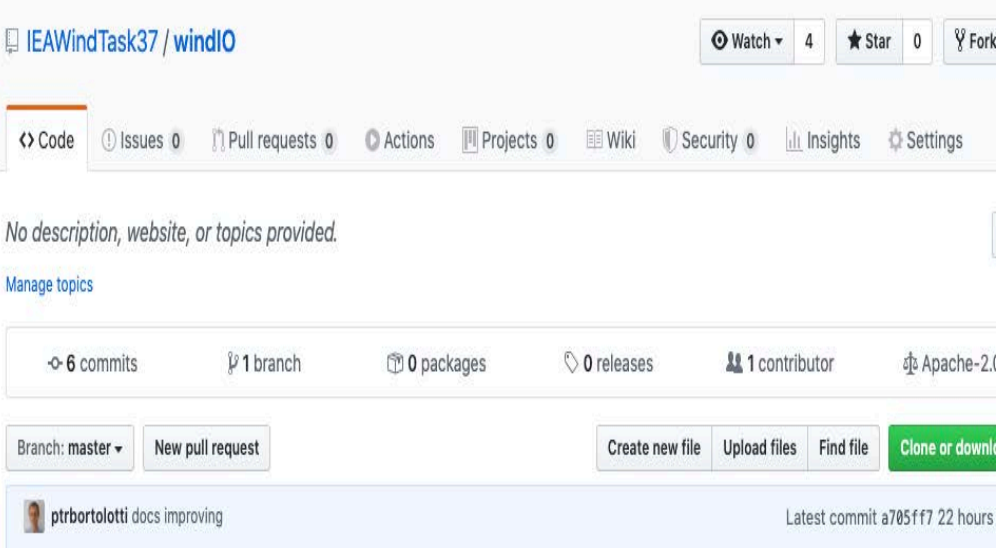
Technical Results WP4 (Workshops on MDAO state-of-the-art)

IEA Wind Task 32/37 Workshop on System Design for LIDAR-Based Control

- Held October 2019 following the NAWEA conference
- Identified 4 promising applications of Lidar-assisted control:
  1. Increasing annual energy production
  2. Decreasing capital expenditure costs by reducing design loads
  3. Extending turbine lifetime by reducing operating loads
  4. Enabling wind turbine class upgrades

Torque paper written & accepted based on workshop findings





Outreach & Dissemination

Participation

- Industry participates during annual meetings, provides technical review of all WP results and fill surveys to help scope task activities; All project deliverables are publicly available to participants

Workshops and Meetings

- Phase II official kick-off and **annual meeting** held Sept. 30th – Oct. 1st in Pamplona, Spain
- 5th Wind Energy Systems Engineering Workshop held Oct 2-3 in Pamplona, Spain.
  - Hosted by CENER in collaboration with NREL and DTU Wind Energy
  - Online proceedings: https://www.nrel.gov/wind/systems-engineering-workshop-2019.html
- IEA Wind Task 32/37 on Lidar-assisted control and design Oct. 17th – 18th
- Annual Meeting ahead of TORQUE postponed- held virtually Sept. 9th and 11th
- Future meetings TBD due to COVID

Plans for Next Term

WP1: Description Framework ("Ontology")

- Completion of first draft of plant ontology and floating platform ontology

WP2: Reference Systems

- Development of offshore floating reference wind power plant

WP3: Case Studies in Best Practices

- 3.1: New rotor aero, structure and aero-structural optimization
- 3.2: New wind plant optimization case studies with additional disciplines

WP4: Workshops on MDAO State-of-the-art

- 4.2: Reference energy systems joint workshop with Tasks 25/26/37

Thank You!!

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Cover Photo: October 1, 2016 - Heavy seas engulf the Block Island Wind Farm—the first U.S. offshore wind farm. A project of Deepwater Wind, the 30-MW wind farm located 3.8 miles (6.1 km) from Block Island, Rhode Island in the Atlantic Ocean, came online in December 2016. (Photo by Dennis Schroeder / NREL)