Optimization of FOWT Designs: QBlade in the WEIS Framework

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the European Union

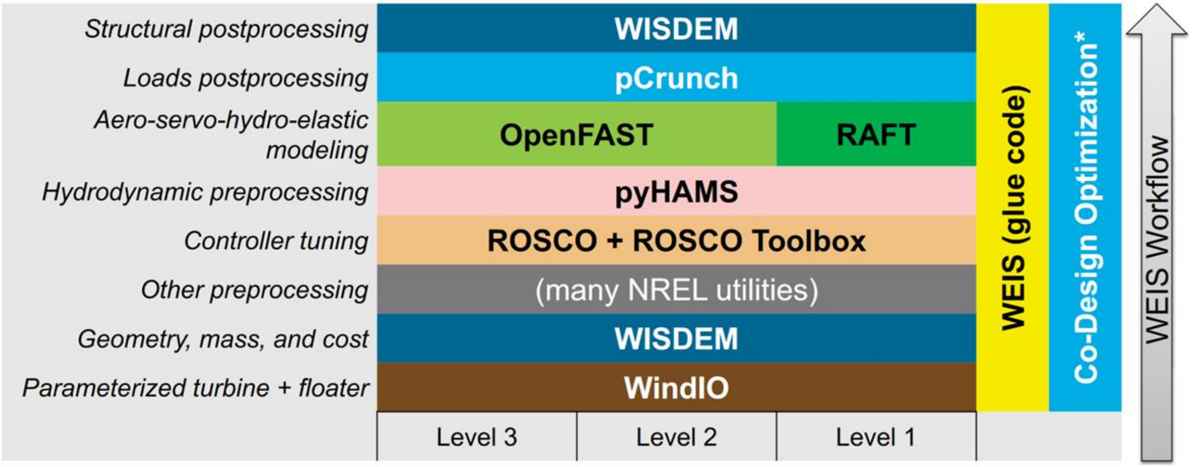
Outline

1. Introduction
2. Integration of QBlade in WEIS Framework
3. Testing & Validation
4. Going Forward

Introduction

WEIS – Wind Energy and Integrated Servo-Controls

WEIS is a framework that combines multiple (mostly) NREL-developed tools to enable design optimization of floating offshore wind turbines and perform multifidelity co-design tasks.

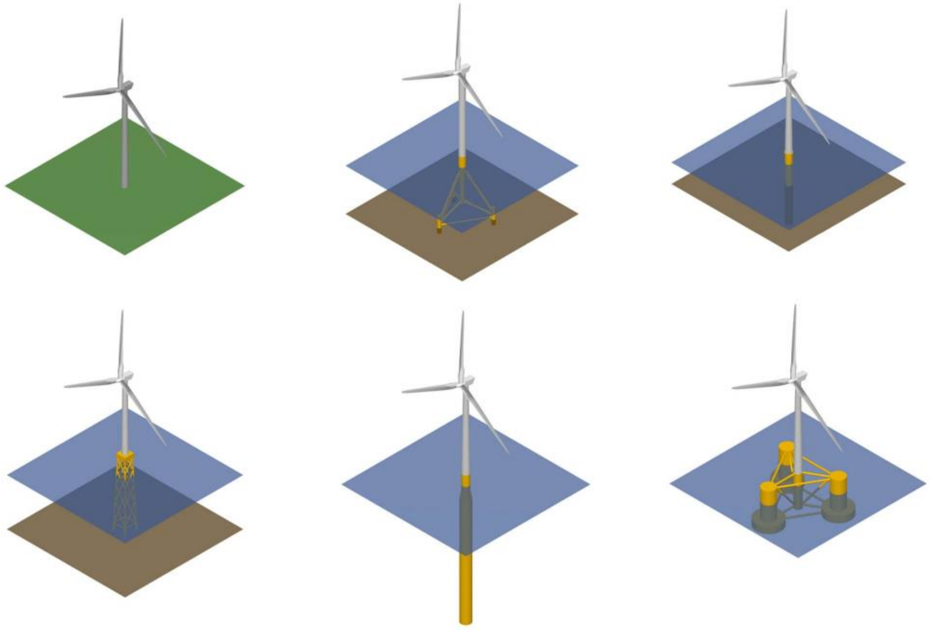


Daniel Zalkind and Pietro Bortolotti 2024 J.Phys.:Conf.Ser. 2767 082020

Introduction

QBlade

QBlade is a multi-physics code covering the complete range of aspects required for the aero-servo-hydro-elastic simulation of horizontal or vertical axis floating offshore wind turbines.

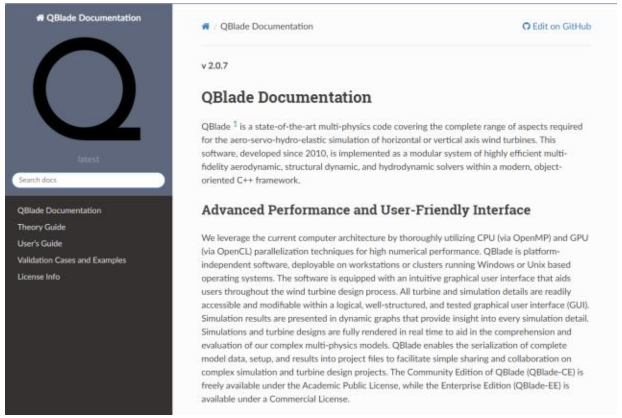


https://docs.qblade.org/

Introduction

QBlade

- Optimized Lifting-Line Free Vortex Wake method
- Non-linear structural model with Project-CHRONO (Euler-Bernoulli, Timoshenko & Timoshenko-FPM)



QBlade Documentation

latest

Search docs

QBlade Documentation
Theory Guide
User's Guide
Validation Cases and Examples
License Info

QBlade Documentation / Edit on GitHub

v 2.0.7

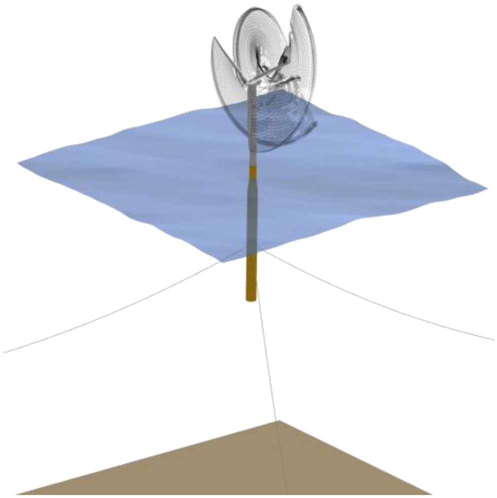
QBlade Documentation

QBlade [1] is a state-of-the-art multi-physics code covering the complete range of aspects required for the aero-servo-hydro-elastic simulation of horizontal or vertical axis wind turbines. This software, developed since 2010, is implemented as a modular system of highly efficient multi-fidelity aerodynamic, structural dynamic, and hydrodynamic solvers within a modern, object-oriented C++ framework.

Advanced Performance and User-Friendly Interface

We leverage the current computer architecture by thoroughly utilizing CPU (via OpenMP) and GPU (via OpenCL) parallelization techniques for high numerical performance. QBlade is platform-independent software, deployable on workstations or clusters running Windows or Unix based operating systems. The software is equipped with an intuitive graphical user interface that aids users throughout the wind turbine design process. All turbine and simulation details are readily accessible and modifiable within a logical, well-structured, and tested graphical user interface (GUI). Simulation results are presented in dynamic graphs that provide insight into every simulation detail. Simulations and turbine designs are fully rendered in real time to aid in the comprehension and evaluation of our complex multi-physics models. QBlade enables the serialization of complete model data, setup, and results into project files to facilitate simple sharing and collaboration on complex simulation and turbine design projects. The Community Edition of QBlade (QBlade-CE) is freely available under the Academic Public License, while the Enterprise Edition (QBlade-EE) is available under a Commercial License.

https://qblade.org/



https://docs.qblade.org/src/theory/structure/chrono/chrono.html

Introduction

FLOATFARM and Development in WEIS

FLOATFARM Project Goals

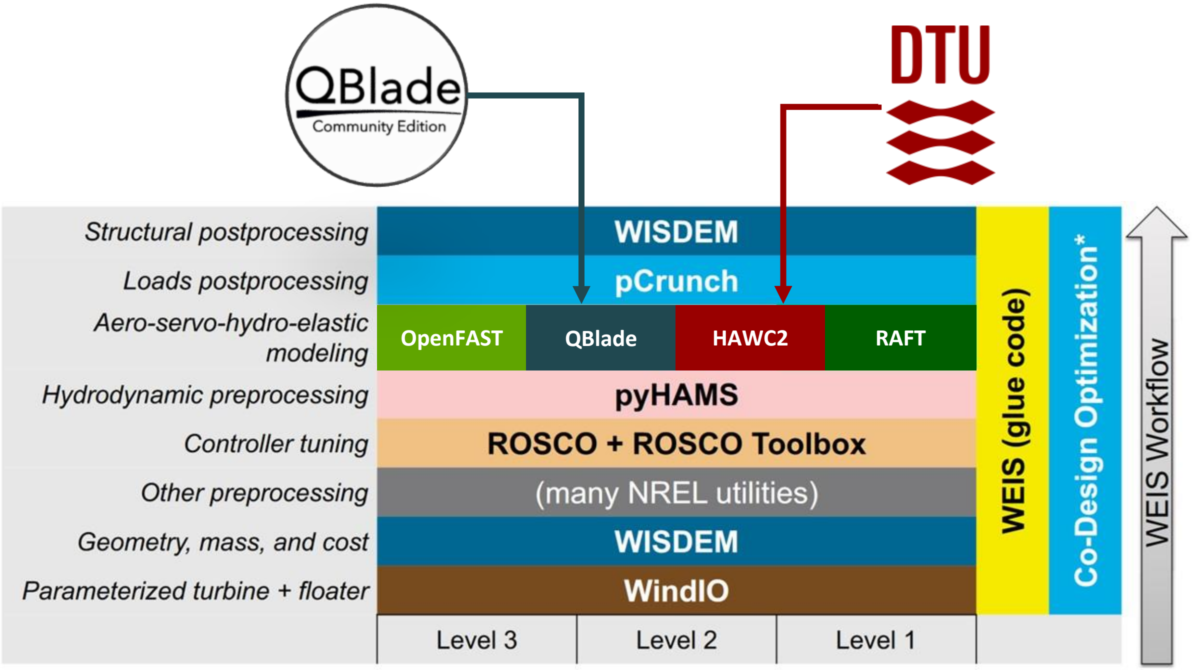
- Development of an open-source, low-specific-power 15MW turbine.
- Advancement of TRL for key technologies to enhance the value of FOWTs

Key Tools and Approach

- WEIS selected as the ideal tool for optimization, design, and analysis tasks.
- Consortium expertise in QBlade and HAWC2 allows integration of these tools for specific optimization tasks.

Integrated Workflow

- QBlade and HAWC2 incorporated into the WEIS toolchain for seamless design and analysis.



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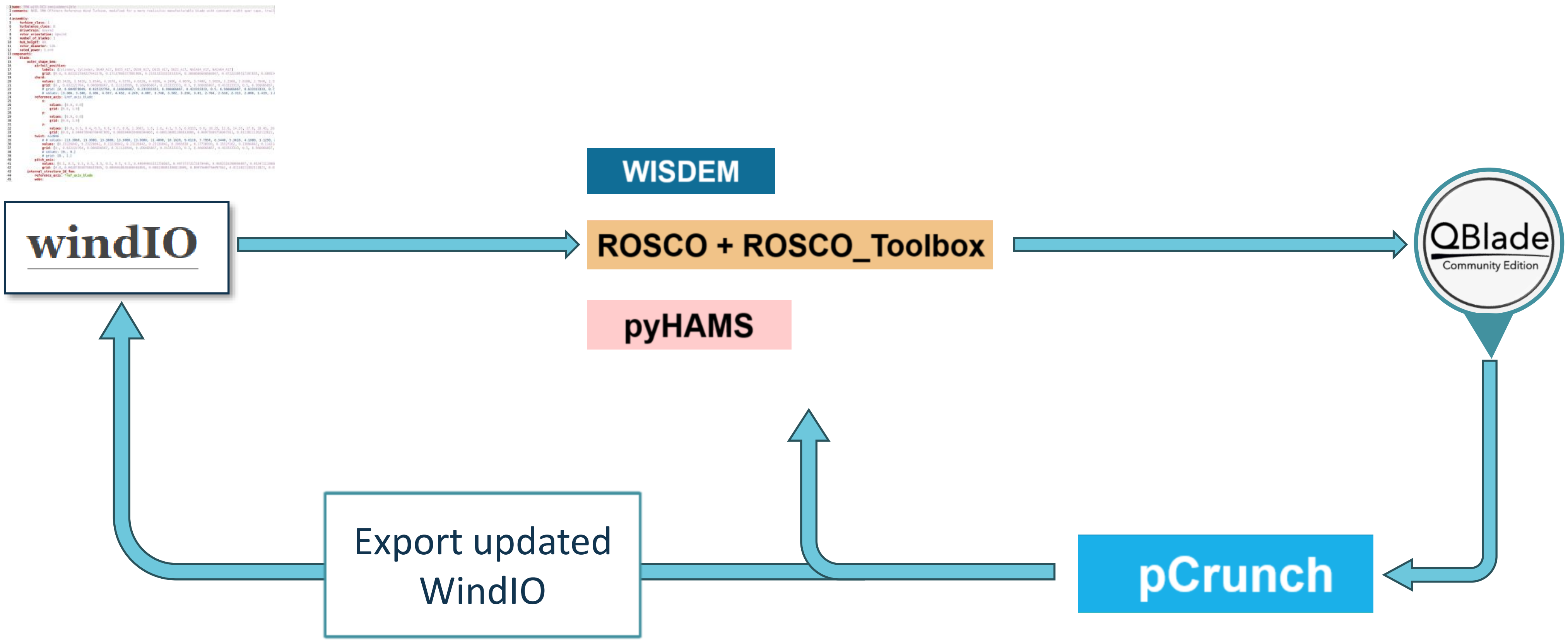
Integration of QBlade in WEIS Framework

Visualization Workflow



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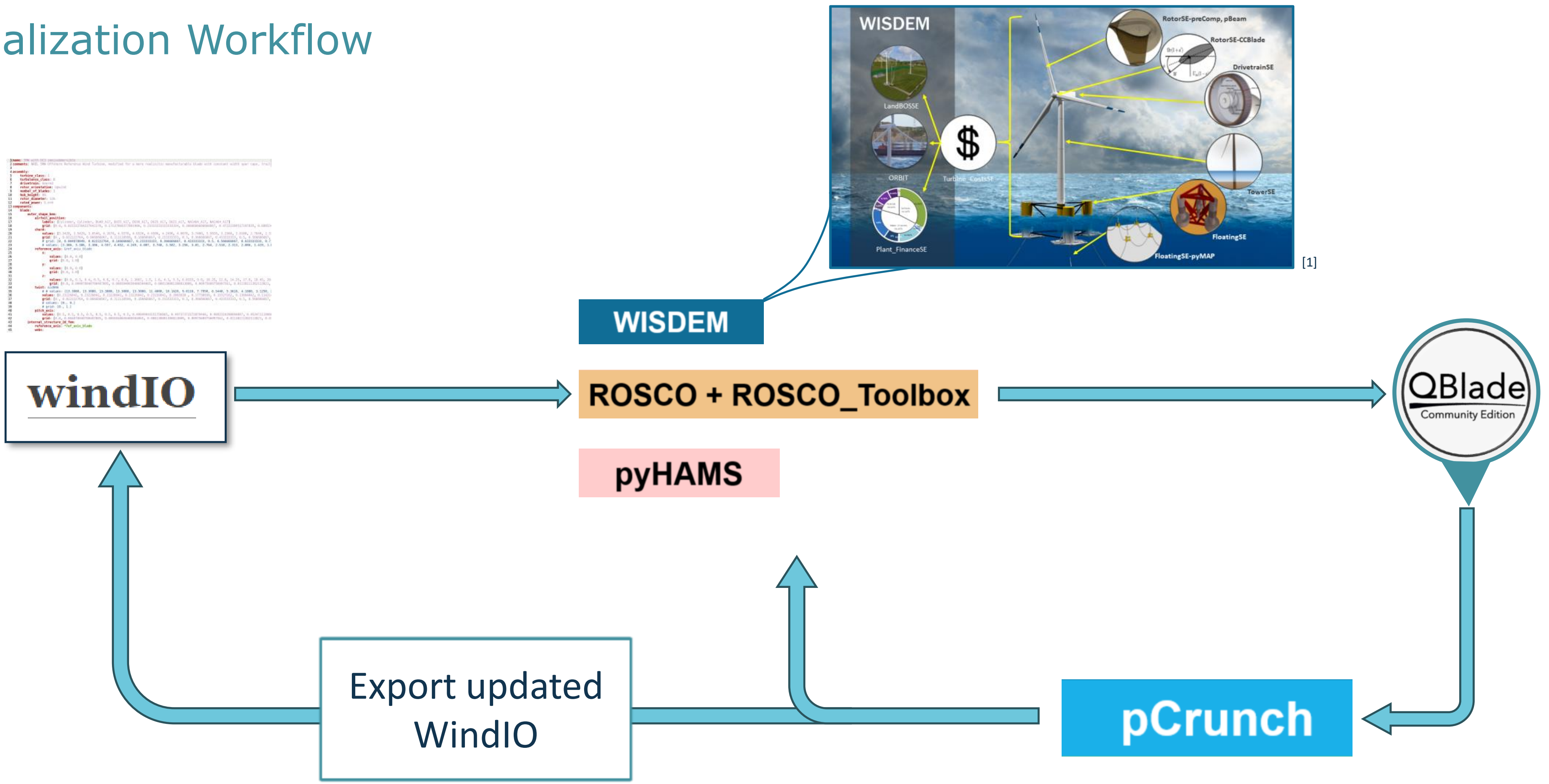

[1]: https://wisdem.readthedocs.io/en/master/

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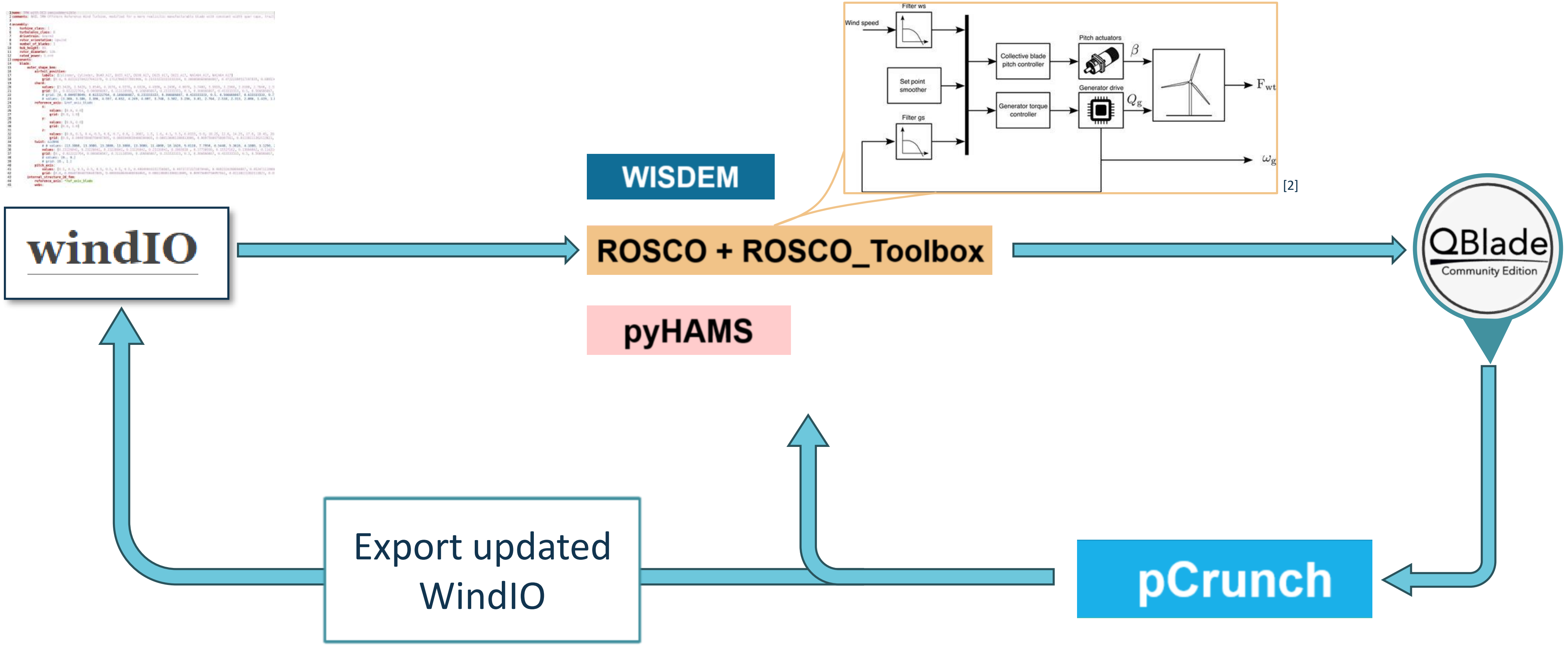

[2]: Fontanella, Alessandro et al. (2023). WES. 8. 1351-1368. 10.5194/wes-8-1351-2023.

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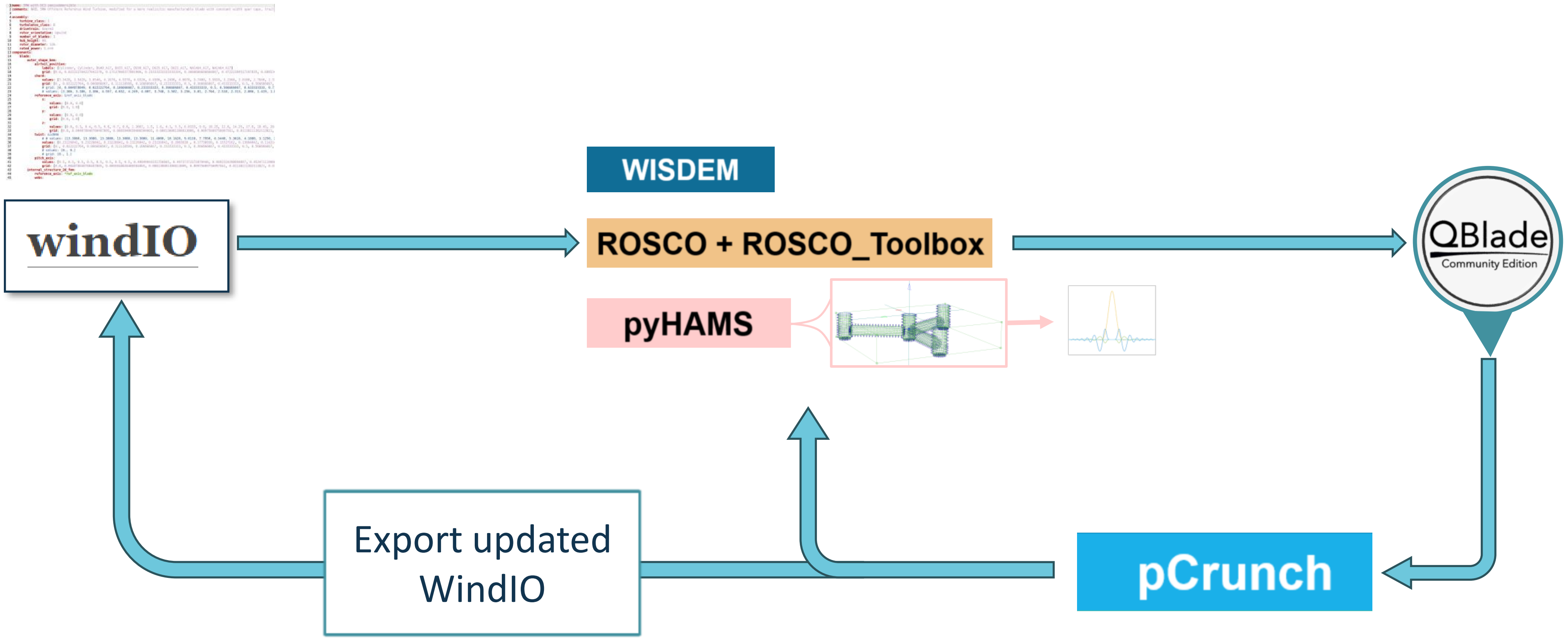

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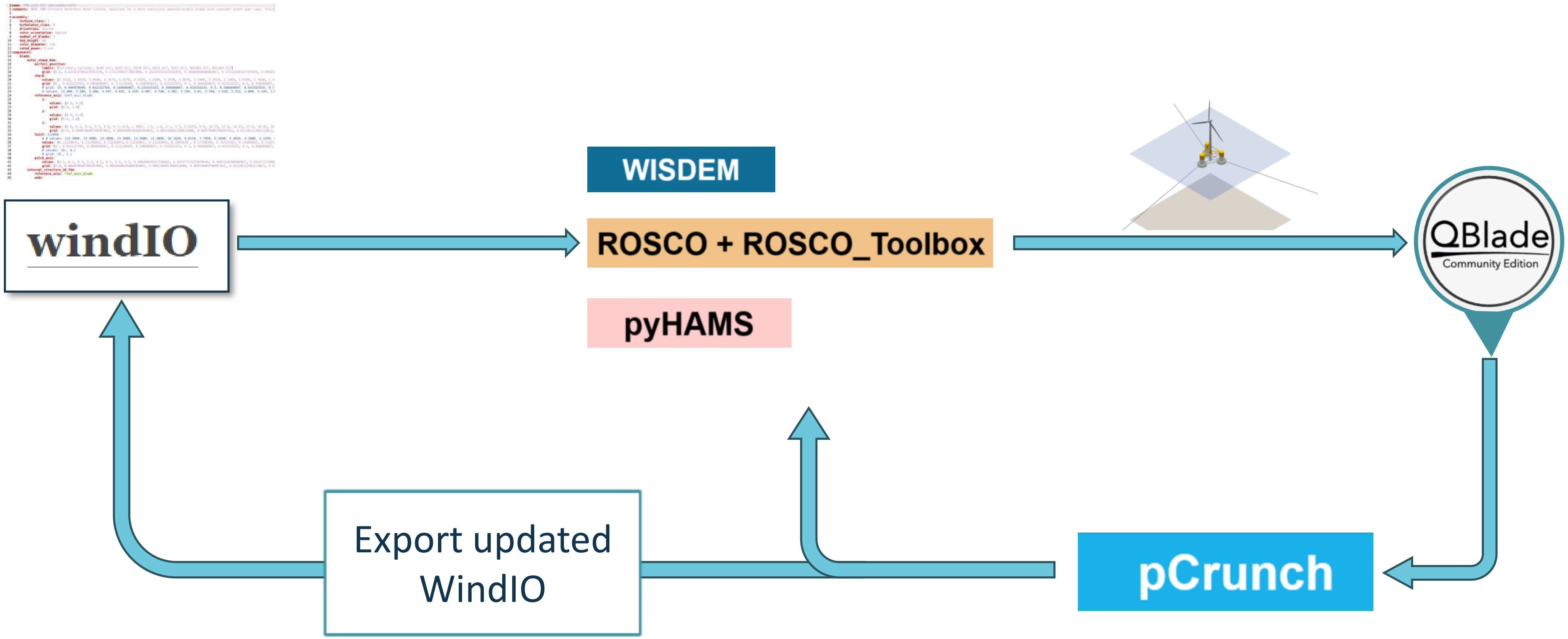

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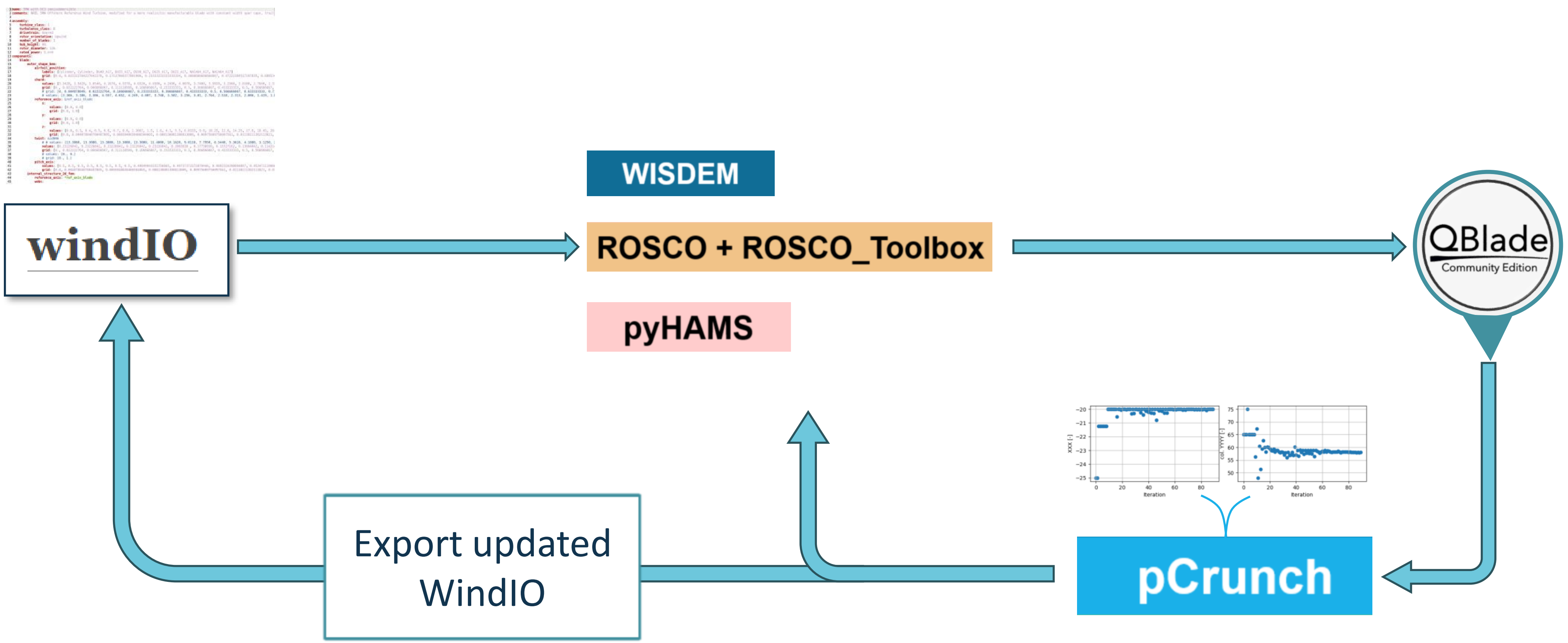

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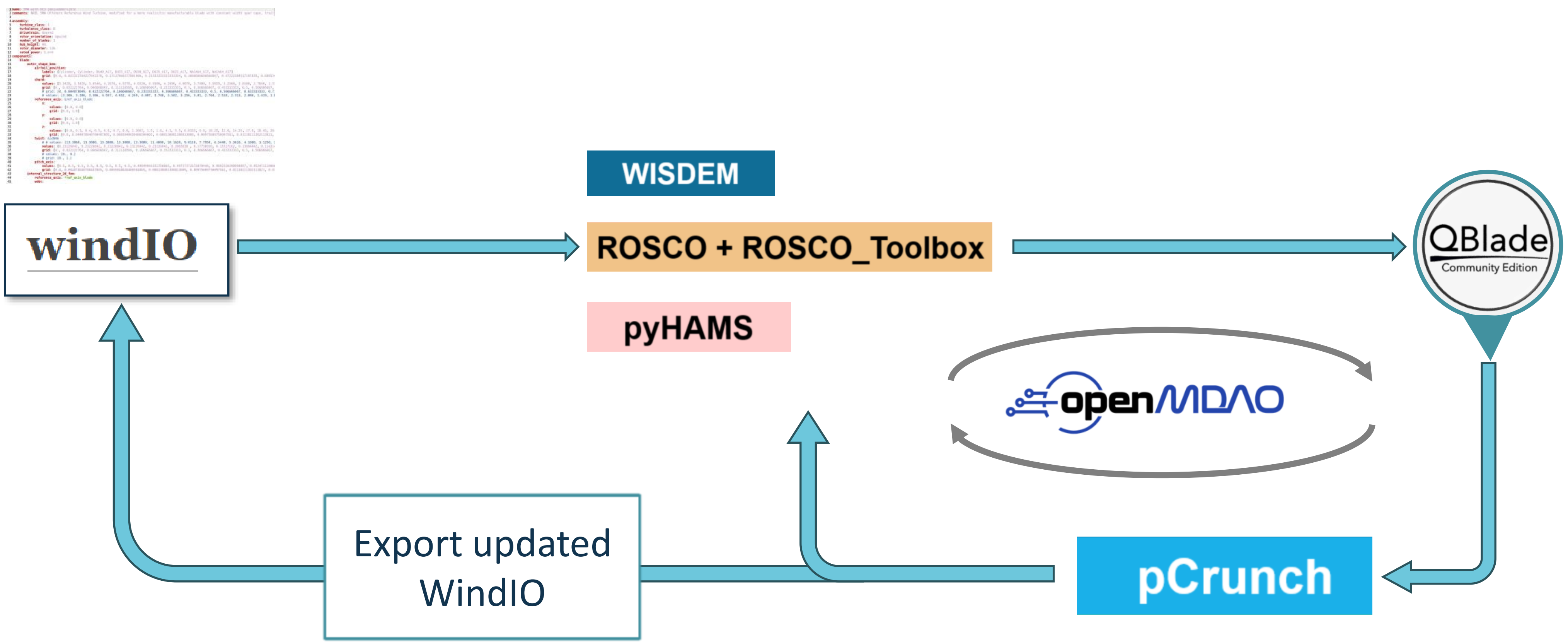


Integration of QBlade in WEIS Framework

Key Highlights

Code Availability

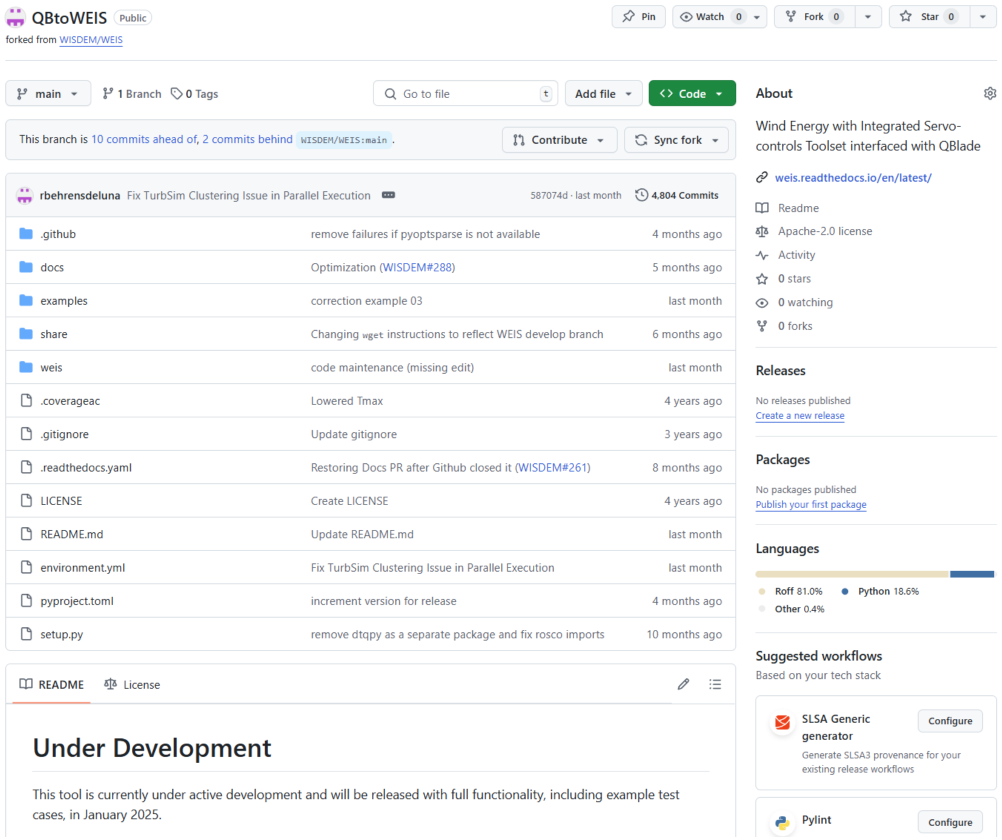
- Released as a fork of the WEIS GitHub Repository (January 2025).
- Actively maintained within the WEIS repository.

Compatibility & Workflow

- Compatible with both QBladeCE and EE editions.
- Mirrors OpenFAST workflow, including identical merit figures, design variables and constraints.

Usage & Documentation

- Comprehensive documentation hosted on the QBlade ReadTheDocs page.
- Includes hands-on examples accessible directly from the repository.



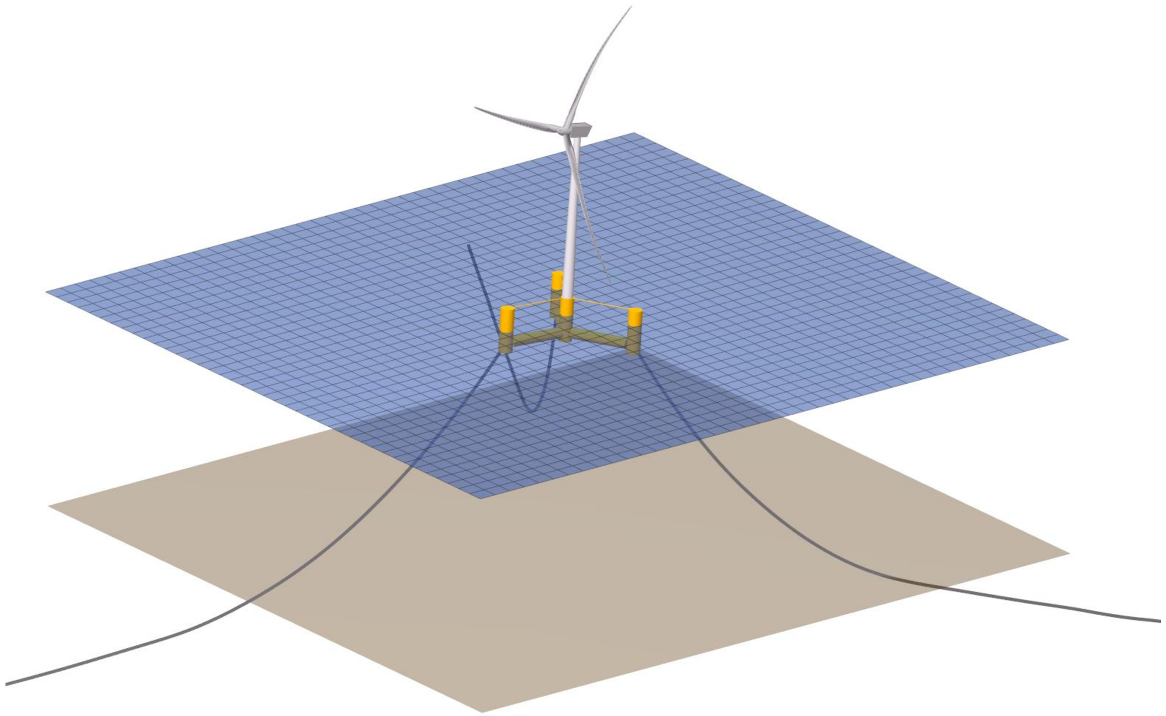
Demonstration on Test Cases

Minimize Platform Mass – IEA22MW UMaine VolturnUS-S

Minimize:
- platform mass

By Varying:
- platform draft
- column spacing
- column diameter
- pc natural frequency
- pc daming ratio
- ...

Subject to:
- pitch period
- heave period
- max. platform pitch



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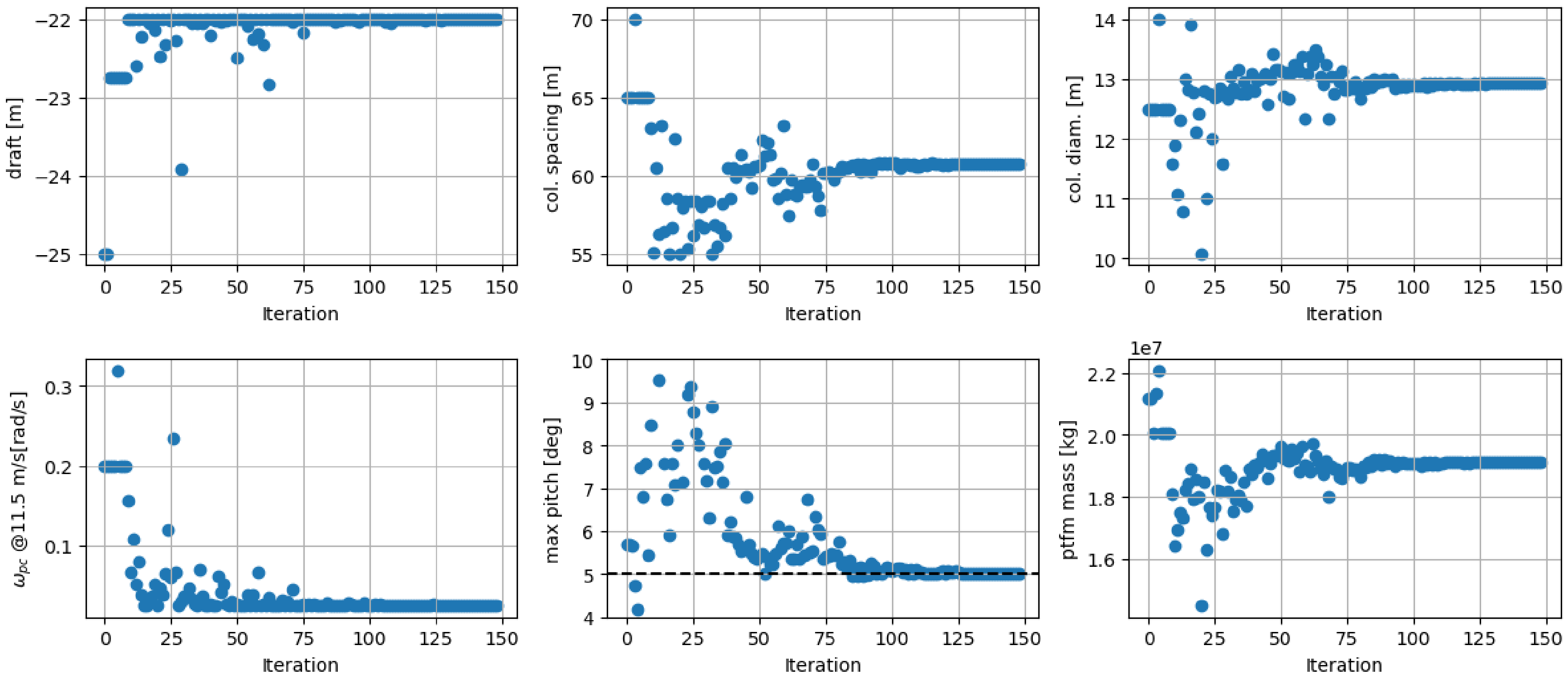

Validation

Steady State, Normal Operation Conditions - IEA22MW Monopile

- **IEA 22MW RWT Validation**
  Utilizing the IEA 22MW Reference Wind Turbine with publicly available results on GitHub for benchmarking.

The Science of Making Torque from Wind (TORQUE 2024) IOP Publishing
Journal of Physics: Conference Series **2767** (2024) 052042 doi:10.1088/1742-6596/2767/5/052042

Aeroelastic code comparison using the IEA 22MW reference turbine

W Collier[1], D Ors[1], T Barlas[2], F Zahle[2], P Bortolotti[3], D Marten[4], C S L Jensen[1], E Branlard[3], D Zalkind[3], K Lønbæk[2]

[1] DNV Services UK Limited, United Kingdom
[2] Department of Wind and Energy Systems, Technical University of Denmark
[3] National Renewable Energy Laboratory, Golden CO, USA
[4] Technical University of Berlin, Chair of Fluid Dynamics, Mueller-Breslau Strasse 8, 10623 Berlin, Germany

email: william.collier@dnv.com

Abstract. Reference wind turbine designs and the associated aeroelastic models are widely used in both research and industry. Reference models representing future concepts are of particular interest. Current state of the art aeroelastic tools are relied upon to design the next generation of large wind turbines. However, modelling assumptions may be invalidated by upcoming very large turbines, and different aeroelastic tools may give inconsistent results. A 22MW turbine model has been defined as part of International Energy Agency (IEA) Wind Task 55 on Reference Wind Turbines and Farms to represent future turbines to be deployed in the 2030s. In this study, an aeroelastic model of this turbine has been created in four tools; Bladed, HAWC2, OpenFAST, and QBlade. Code comparisons are presented for steady state operation, linear stability analysis, and time domain power production simulations in steady and turbulent wind. Generally, the codes show a good agreement, but with some differences present in the linear stability analysis, periodic azimuthal variation, and time domain simulations. The models are a good basis for further study with the IEA 22MW turbine, and further code comparison exercises.

W Collier et al 2024 J. Phys.: Conf. Ser. 2767 052042

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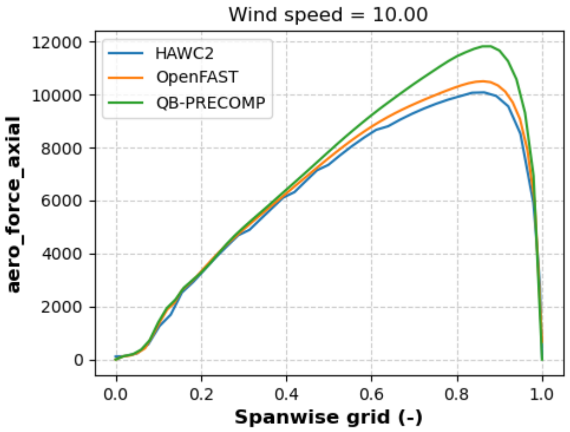
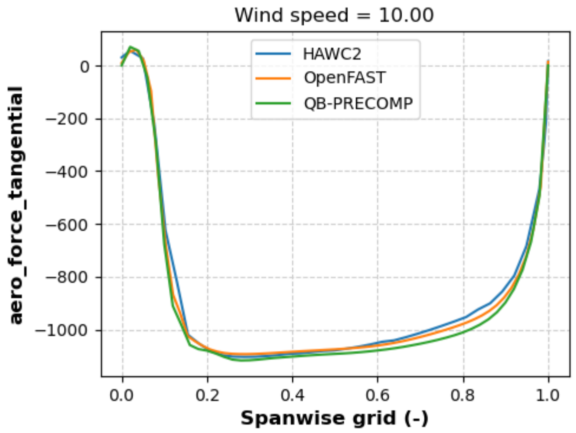
  WISDEM's PreComp showed limitations for such a flexible blade design.





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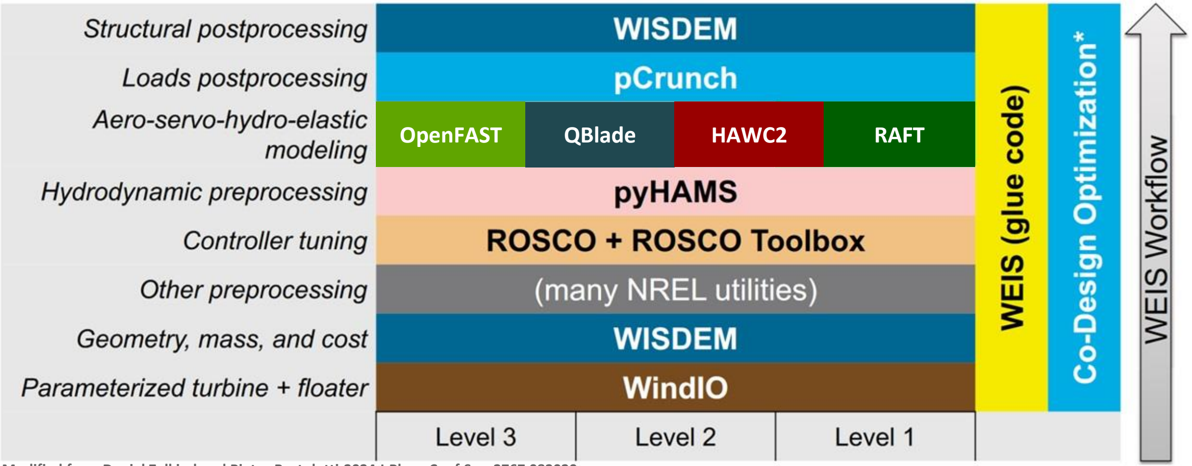
  SONATA provides higher-fidelity cross-sectional analysis. Outputs include 6x6 stiffness and inertia matrices



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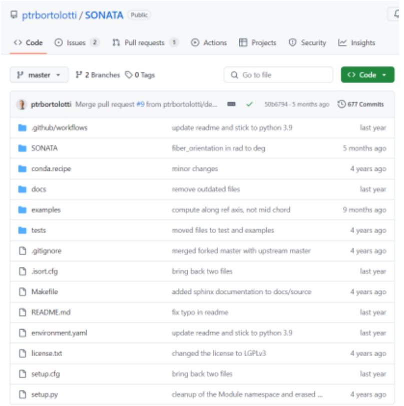
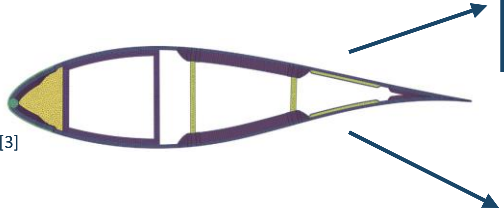


https://github.com/ptrbortolotti/SONATA



[3]

$$\begin{bmatrix} s_{11} & \cdots & s_{16} \\ \vdots & \ddots & \vdots \\ s_{61} & \cdots & s_{66} \end{bmatrix}$$

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[3]: **A Cross-Sectional Aeroelastic Analysis and Structural Optimization Tool for Slender Composite Structures.** / Feil, Roland; Pflumm, Tobias; Bortolotti, Pietro et al. In: Composite Structures, Vol. 253, 112755, 2020.

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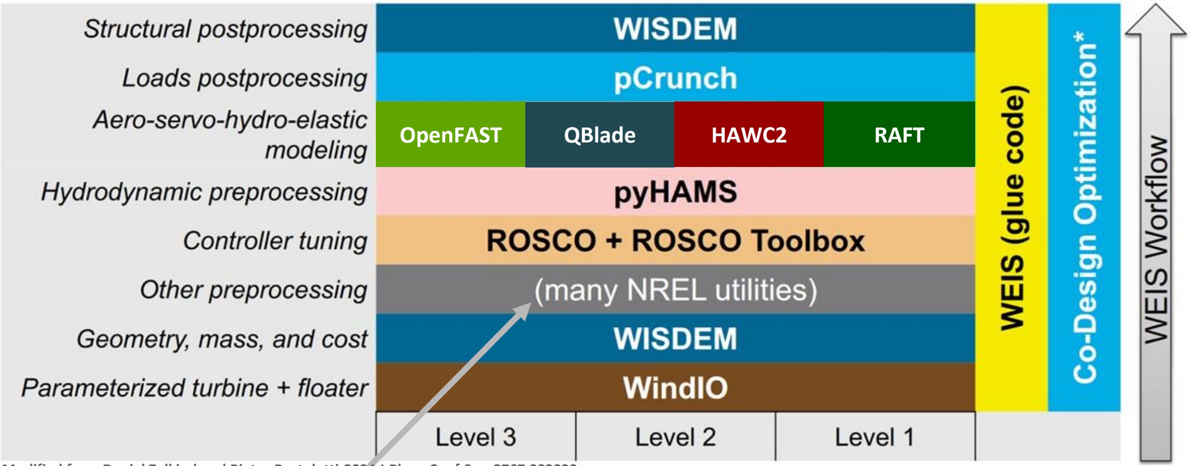
- **SONATA Integration in WEIS**
  Integration as openMDAO component to enable closed-loop optimization



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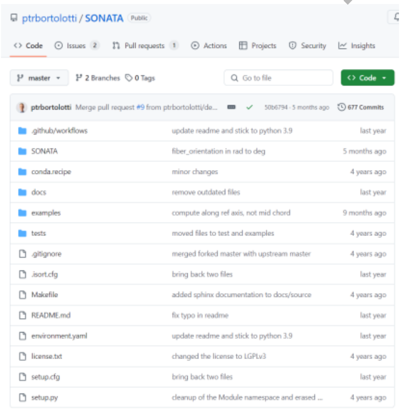

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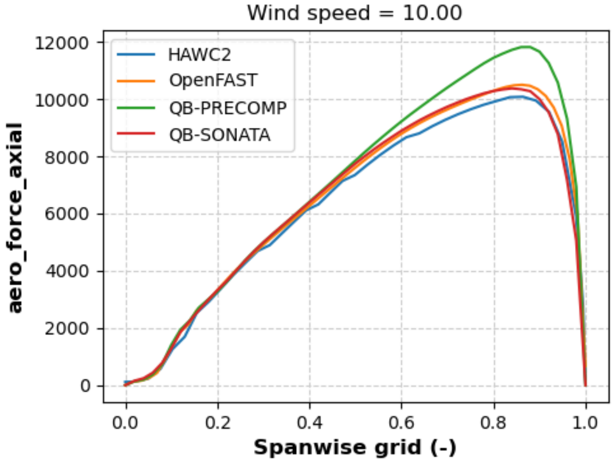

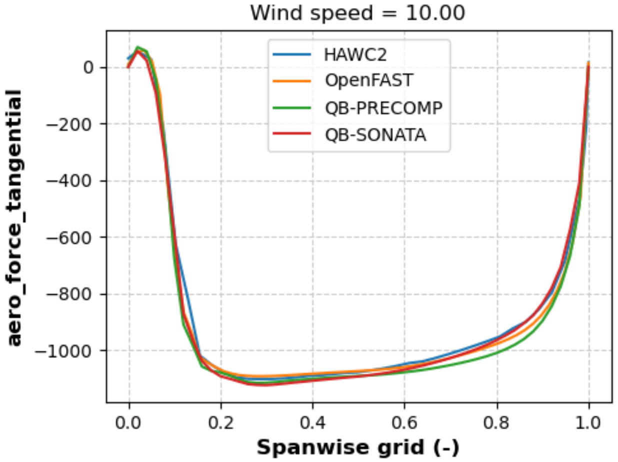

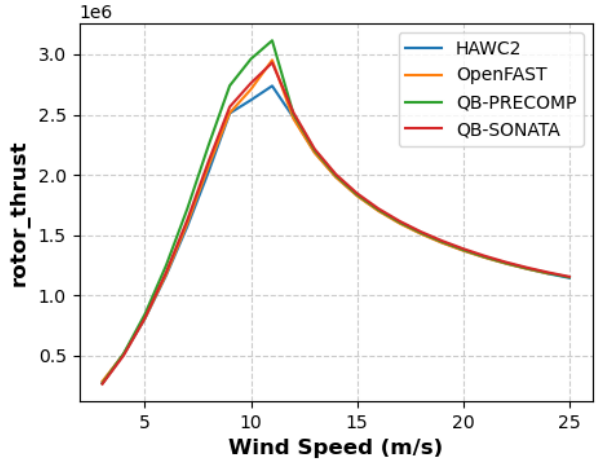

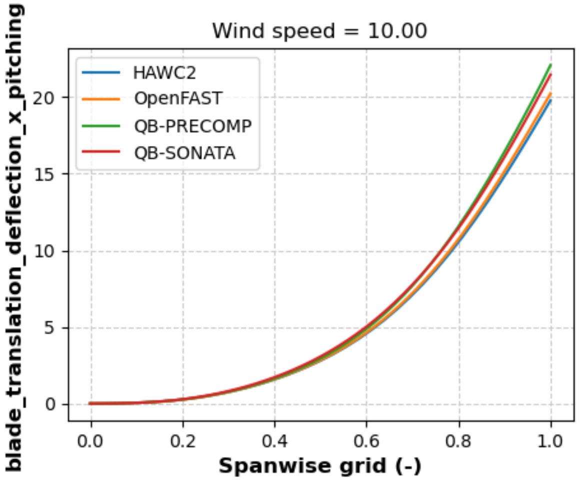

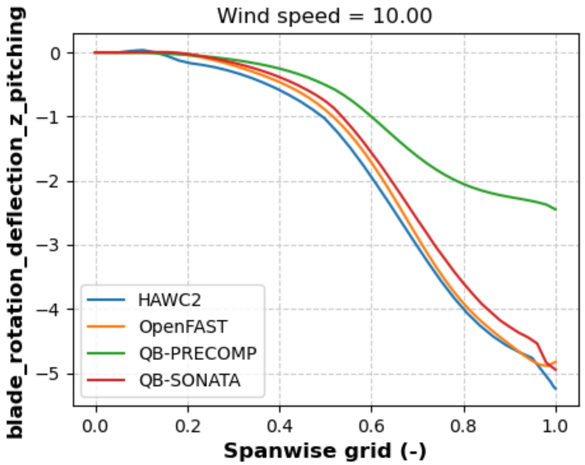

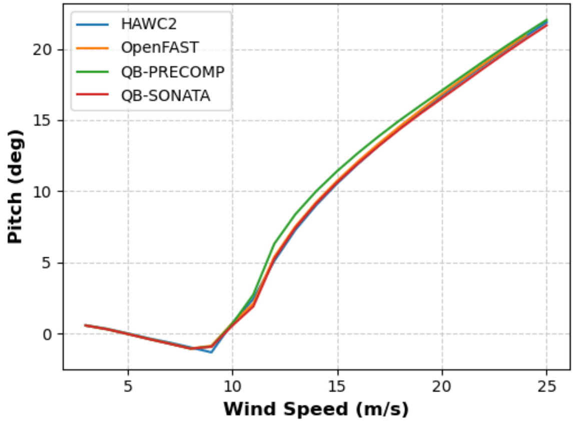

Going Forward

1 2 3 4

Validation and Comparison with HAWC2-WEIS

Investigate the impact of simulation fidelity on optimization outcomes.

Design Applications in FLOATFARM

Leverage tool for designing a low-specific-power 15 MW rotor

Collaboration with Saipem on optimization potential on Hexafloat substructure

Challenges

Finding a balance between complexity and feasibility when setting DVs and constraints

Feedback

Adapting Optimization to Real-World Scenarios

What are the most significant (design driving) real-world constraints or challenges in your work?

Are there industry standards or best practices you follow?

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Thank you

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