FBsowento Next for next-generation control of floating offshore wind turbines

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Abstract

This paper presents *FBsowento Next*, sowento's innovative multi-variable feedback controller for Floating Offshore Wind Turbines (FOWTs). FOWTs make it possible to capture wind energy in deep-water areas, opening access to a significant renewable energy resource. The turbine requires a controller for its operation. To significantly improve fatigue loads and platform stability, the FBsowento Next presents a multi-variable feedback controller. By integrating floater dynamics into its control strategy, the Next achieves unparalleled reductions in mooring line fatigue (up to 30%), tower fatigue reduction and improves platform stability. Utilizing sowento's SLOW model for state-space representation and featuring automated tuning, the controller seamlessly aligns with iterative design processes, advancing the state of FOWT control technology. The controller is intended to be used in pre-Front-End Engineering Design (FEED) and FEED stages of FOWT projects, before a wind turbine designer is selected. FBsowento Next will be shared with turbine designers without royalties.

Introduction

Floating offshore wind turbines (FOWTs) enable energy generation in deep-water environments, where stronger and more consistent wind resources are accessible. Despite their potential to advance renewable energy goals, the dynamic interactions between the turbine, platform, and environmental forces present significant challenges for stable and efficient operation.

Controllers play a critical role in operating the turbine, by regulating generator torque and blade pitch angles to optimize energy capture and protect structural integrity. For FOWTs, the controller must also mitigate platform motions caused by wind, waves, and currents. Poorly tuned controllers intensify these issues. Moreover, most controllers have a simple design without capabilities to stabilize the floater dynamics or reduce structural loads significantly.

FBsowento Next addresses these challenges with a multi-variable design that incorporates floater dynamics into its control strategy. By reducing loads and enhancing stability, the controller represents a significant advancement in FOWT control methodologies. This paper describes its design, performance, and application to a reference turbine, demonstrating its potential to improve the design and reliability of floating wind projects.

Method

The multivariable controller employs both the blade pitch angle and generator torque collaboratively, for above-rated wind speeds. It is designed using the control-oriented SLOW model (Lemmer et al., 2018), which provides an accurate linear state-space representation of the FOWT at each operating condition. A cost function is defined to determine optimal performance, putting weight on key parameters such as variations in rotor speed, power, platform pitch speed and platform surge speed. An optimal state feedback matrix is computed from solving the Riccati differential equation (Franklin et al., 2002), based on the linear SLOW model and the cost function. Since the tuning is solely dependent on the cost function and the model, the procedure enables automated tuning based on model changes.

The remaining architecture of the FBsowento Next controller is based on the FBsowento One (Al et al., 2025). The set-point of the controller is determined by the original collective blade pitch controller, which is extended with a low-pass filter. For below-rated wind speeds, the controller employs a standard optimal quadratic strategy to regulate generator torque. The transition between below-rated and above-rated control is managed through set-point-fading (Schlipf, 2019).

A FBsowento Next controller has been developed for the IEA15MW UMaine VolturnUS-S reference turbine (Allen et al., 2020) using an automated tuning procedure. The performance is compared against the reference ROSCO controller by using Design Load Case (DLC) 1.2 simulations in the non-linear SLOW model, for the environmental conditions with aligned wind and waves, given in Table 1 in the appendix. The Damage Equivalent Load (DELS) are computed using rainflow counting with a Woehler exponent of $m = 3$ and reference number of cycles $n_{ref} = 5 \cdot 10^7$. The rotor speed overshoot is computed with respect to the rated value. The statistics are life-time weighted based on the probability of occurrence.

Results

The FBsowento Next controller effectively reduces both turbine loads and blade pitch action. Figure 1 demonstrates the life-time weighted key statistics of the DLC 1.2 simulations. FBsowento Next achieves over 30% mooring line fatigue reduction and 10% tower base fatigue reduction, alongside significant reduction in blade pitch activity and rotor speed overshoot. This demonstrates the improved overall performance compared to the reference turbine controller.

The FBsowento Next controller comes with comprehensive tuning services, structural integrity reports, and can be customized to meet specific design requirements. Once all model parameters are provided, the controller can be fully tuned within 1 to 2 weeks. After setup, subsequent tuning iterations based on varying floater and turbine parameters can be completed in just minutes. FBsowento Next is ideally suited for use during the pre-FEED and FEED phases of floating offshore wind turbine projects, before the selection of a wind turbine designer. Incorporating this controller early in the design process is recommended to ensure the best performance and system compliance.

Conclusions

The *FBsowento Next* feedback controller advances the state of FOWT control by employing multivariable techniques tailored to the unique dynamics of floating systems. By accounting for floater motions in its design, the controller achieves improved platform stability and significant reductions in structural and mooring line fatigue.

The demonstrated fatigue reduction of up to 30% in mooring lines underscores the controller's potential to enhance the structural integrity and lifespan of FOWTs, while also enabling material savings. The tuning can also be adjusted to achieve load reductions on other components. The fully automated tuning process further facilitates its integration into iterative floater design workflows, making it particularly suitable for use during pre-FEED and FEED project phases.

With *FBsowento Next*, floater, mooring and cable designers can optimize their systems before they enter the detailed design phase of a project. They can obtain an industry-standard, well-tuned controller, adjusted to their design, which allows them to optimize their components without the need for a detailed simulation model of the proprietary wind turbine design and the turbine controller.

This study highlights the capacity of FBsowento Next to support the development of high-performance and reliable floating wind systems, and can be applied to any type of FOWT. By addressing key challenges in FOWT control, the findings contribute to the advancement of design methodologies and the broader adoption of renewable energy in deep-water environments.

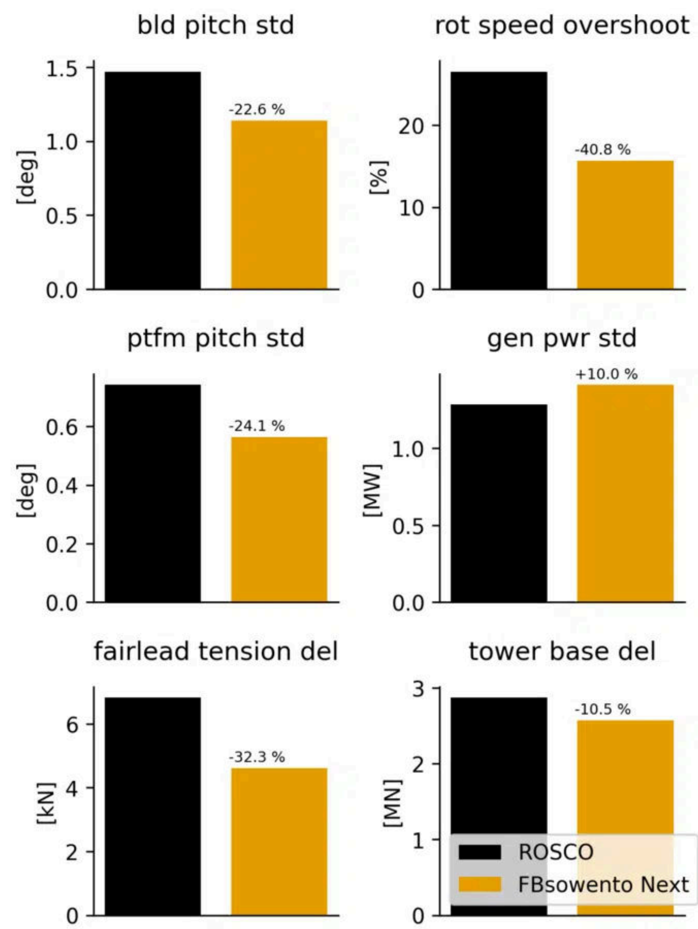

Figure 1: Life-time weighted statistics from DLC 1.2 simulations

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Appendix

Table 1: Selection of environmental conditions for operational design Load Cases (DLCs) from LIFES50+ (Krieger et al., 2006)

U_{ref} [m/s]	5.0	7.1	10.3	13.9	17.9	22.1	25.0
H_s [m]	1.4	1.7	2.2	3.0	4.3	6.2	8.3
T_p [s]	7.0	8.0	8.0	9.5	10.0	12.5	12.0
P [%]	14%	24%	25%	21%	12%	3.8%	0.74%