

Technical Disclosure¹

1. Title

Sensor System and Control Method to Improve Calibration of Floating Wind Turbines

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5. Abstract

A sensor system and control method are disclosed for improving calibration of blade load measurement systems in floating wind turbines. The system uses inclinometers and accelerometers to measure tower motion during calibration. Measured motion is used to correct reference moment calculations, filter motion-affected calibration data, and support selection, binning, or weighting of data used in regression. In some implementations, an active ballast system is controlled to maintain a defined tower inclination during calibration. The disclosed approach improves calibration accuracy under floating platform dynamics.

6. Technical field

The disclosure relates to wind turbine sensor calibration and control, and more particularly to calibration of blade strain-based load measurement systems in floating offshore wind turbines.

7. Background

Floating offshore wind turbines are exposed to platform motion caused by waves and changing sea conditions. Unlike fixed-bottom turbines, floating turbines may experience surge, sway, heave, roll, pitch, and yaw. These motions can affect calibration routines used to convert blade strain measurements into blade load values such as edgewise and flapwise moments.

In conventional calibration, a known static gravitational blade moment is used as a reference. The reference moment is calculated from blade weight, blade geometry, sensor position, drivetrain tilt angle, hub cone angle, blade twist angle, rotor position, and blade pitch angle. The blades are often pitched to a defined angle while the rotor rotates slowly, and sensor outputs are compared with the calculated reference moment to determine calibration factors.

For floating wind turbines, tower motion can introduce significant error into the reference moment calculation. This may reduce calibration quality, degrade load estimation, and increase the risk of nuisance faults. There is a need for a calibration approach that accounts for floating platform dynamics.

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8. Summary of the disclosure

The disclosure provides a sensor system and control method for improving calibration of floating wind turbines by measuring tower motion and using the measured motion to compensate the calibration process.

The system may include inclinometers and accelerometers configured to measure tower inclination and acceleration. These measurements may be used as correction terms in the reference moment calculation. The control method may also filter out data that is significantly affected by tower motion and may select, bin, or weight calibration data used in regression.

In embodiments having an active ballast system, tower inclination may be actively controlled during calibration to maintain a target orientation. The disclosed approach improves calibration accuracy without requiring calibration to be limited only to calm sea conditions.

9. Brief description of drawings

NIL

10. Detail description

Floating wind turbines are mounted on floating foundations that move in response to waves and sea state. These movements create time-varying changes in the turbine orientation and motion state, which may influence calibration of blade strain sensors. The calibration system may be used with fiber optic sensors or other blade strain sensors that measure blade deformation associated with edgewise and flapwise loading. During calibration, the rotor may be positioned at a defined pitch angle and rotated slowly while sensor measurements are collected.

In one aspect, the system includes one or more inclinometers arranged to measure tower inclination, such as pitch and roll. One or more accelerometers may be used to measure tower acceleration, including vertical or heave-related acceleration.

The measured tower motion can be incorporated into the calibration reference calculation. For example:

- Tower pitch may be used to correct drivetrain tilt angle.
- Tower roll may be used to correct rotor plane lateral tilt or rotor position.
- Tower heave acceleration may be used to modify the effective gravitational acceleration term used in the reference moment.
- Tower inclination may be used as feedback to control an active ballast system, if present.

The control method may also evaluate the quality of calibration data. Data points strongly influenced by tower motion may be removed from the regression set. Alternatively, selected points may be binned or weighted based on motion severity or expected data quality. The corrected or filtered data may then be used in a regression function to calculate calibration factors that convert strain measurements into blade edgewise and flapwise moments.

This approach can be applied during commissioning, maintenance, or recalibration of floating wind turbines.

11. Advantages

The disclosed system and method may provide one or more of the following advantages:

- Improved calibration accuracy for blade load sensors
- Better compensation for floating platform motion
- Reduced error in reference moment calculation
- Lower likelihood of nuisance faults caused by bad calibration
- Increased operational flexibility compared with calibration limited to calm sea states
- Improved robustness of regression-based calibration results
- Compatibility with active ballast control for further stability during calibration

12. Example Embodiments

Embodiment 1:

A floating wind turbine includes blade strain sensors, one or more inclinometers, and one or more accelerometers. During calibration, measured tower pitch and roll are used to correct the reference moment calculation before regression is performed.

Embodiment 2:

A control system evaluates tower acceleration during calibration and excludes sensor samples that exceed a motion threshold. Remaining samples are used to calculate calibration factors for blade load conversion.

Embodiment 3:

A floating wind turbine foundation with an active ballast system receives inclination feedback during calibration. The ballast system adjusts the foundation to maintain a defined inclination while sensor data are collected.

Embodiment 4:

Calibration data are grouped into bins according to tower motion conditions. Each bin is assigned a weight in a regression calculation to improve calibration robustness.

13. Industrial Applicability

The disclosure is applicable to floating offshore wind turbines, including turbines deployed on floating platforms or floating foundations. It may be used during turbine commissioning, recalibration, maintenance, or performance optimization. The approach is particularly useful for turbines operating in environments where calm sea conditions cannot be reliably maintained.

14. Variations and Alternatives

The disclosed concepts may be implemented in different forms. For example:

- Different motion sensors may be used in place of, or in addition to, inclinometers and accelerometers
- Motion correction may be applied to different components of the reference moment calculation

- Data filtering thresholds may be fixed, adaptive, or model-based
- Regression may be linear or non-linear
- Active ballast control may be omitted in systems without ballast capability
- The method may be used with different types of blade load sensors, not limited to fiber optic sensors

A different approach to the same calibration problem is to limit calibration to calm sea states. However, this reduces flexibility and may not be practical for all installations.

15. Conclusion

The disclosed sensor system and control method improve calibration of floating wind turbine load measurement systems by compensating for tower motion during calibration. By measuring motion, correcting reference moments, and filtering or weighting calibration data, the method increases calibration accuracy and reliability in floating offshore environments.

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