Technical Disclosure[1]

1. Title

The Method and Apparatus of Extracting Rotor Speed and Associated Parameters

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Technical Disclosure

5. Abstract

A method and apparatus are disclosed for indirectly extracting rotor speed and related operating parameters from signals already generated by blade-mounted sensing systems. Rather than relying on a dedicated rotor-speed sensor, the disclosed approach utilizes signals from existing blade condition sensing arrangements, including fiber-optic and strain gauge sensor systems, whose outputs are synchronized with rotor position. These signals may be tapped from streams already transmitted for external analysis, filtered, calibrated, validated, and processed to derive rotor speed and associated parameters for use in safety-critical turbine protection functions for example rotor acceleration, slip detection etc.

6. Technical field

The present disclosure relates to wind turbine monitoring, control, and protection systems. More particularly, it relates to methods and apparatus for deriving rotor speed and associated operational parameters from existing blade sensor signals for use in turbine safety and condition-monitoring functions.

7. Background

Accurate rotor speed information is important for safety-critical turbine features. Conventional approaches may depend on dedicated sensors that are comparatively expensive and may present implementation or usability challenges. At the same time, wind turbines increasingly use blade-based sensing systems, such as blade load or blade condition sensing systems, to monitor stresses and related blade conditions. The disclosed concept recognizes that these existing sensor signals also contain information synchronized with rotor position and can therefore be processed to infer rotor speed without requiring a separate dedicated speed sensor.

8. Summary of the disclosure

The disclosure provides a method and apparatus for obtaining rotor speed and associated parameters from signals already available within blade sensing architectures. In one implementation, signals from fiber-optic sensors are tapped from streams sent to a third party for analysis. In another

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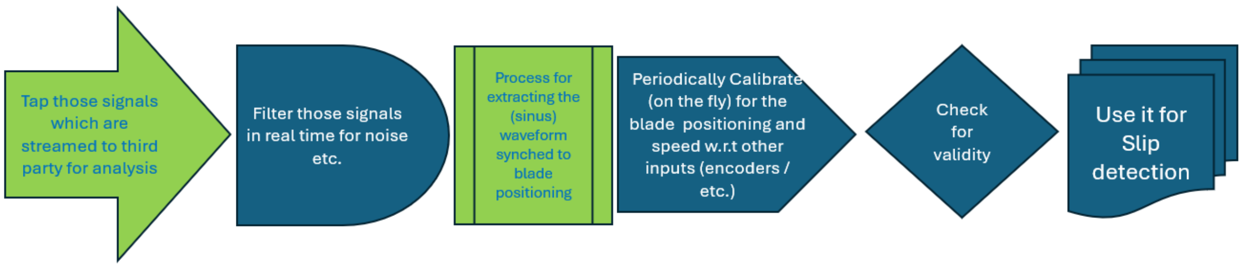
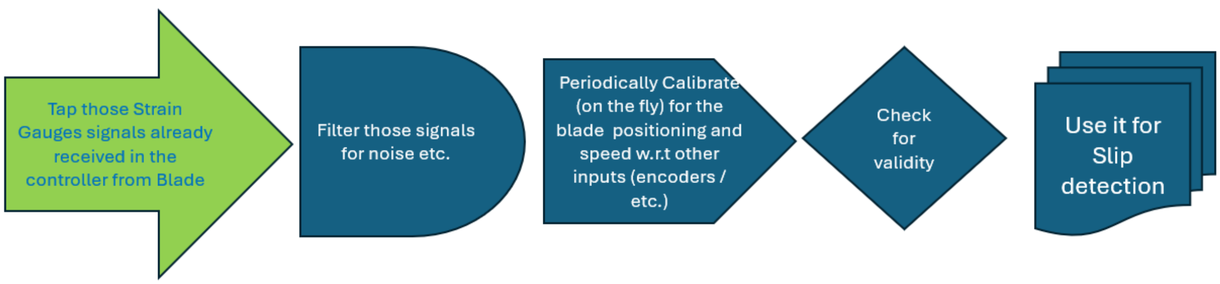
implementation, strain gauge signals already received by a controller from the blade are used. The signals are filtered in real time to reduce noise, periodically calibrated relative to blade position and optional reference inputs such as encoders, checked for validity, and processed to extract a waveform synchronized to blade positioning. From this processed signal, rotor speed and associated parameters are determined and supplied for safety or protection functions, including slip detection.

9. Brief description of drawings



[FIG. 1] Signal flow diagram showing tapping of sensor signals already streamed for external or third-party analysis.



[FIG. 2] Processing workflow including filtering, calibration, validation and slip detection.

10. Detail description

In one aspect, the system receives sensor signals from one or more blade-installed sensors. The sensors may include fiber-optic sensors, such as fiber Bragg-based sensing arrangements, or strain gauge sensors. These sensors are ordinarily deployed to assess blade condition, including stresses acting at various points of the blade.

The disclosed method leverages the observation that such signals are synchronized with rotor position. Because the sensed patterns vary with blade rotation, the signals can be processed to derive a waveform indicative of blade position and periodic rotor motion. A controller or processing module taps these signals from an existing signal path. For example, fiber-optic signals may be intercepted from data streams already transmitted to a third party for analysis, while strain gauge signals may be obtained directly from controller inputs already receiving blade data.

After acquisition, the signals are filtered, preferably in real time, to reduce noise and improve signal quality. The signals may then be calibrated periodically, including on-the-fly calibration, with reference to blade position and optionally with respect to other available inputs, such as encoder signals or other turbine measurements. A validity check may be performed to confirm that the processed signal is suitable for further use.

The validated signal is then processed to extract a waveform, including a substantially sinusoidal waveform synchronized to blade positioning. The extracted waveform is used to determine rotor speed. Additional associated parameters may also be derived from the same processed signal set, including timing, phase, rotational behavior, and indicators useful for drivetrain protection logic.

The derived rotor speed and associated parameters may be used as inputs to safety-critical functions. One expressly identified application is to predict the rotor acceleration or slip detection. Because the disclosed method reuses already available sensor data, it reduces dependence on a separate dedicated speed sensor.

Where signals are available from multiple blades, such as three blades in a wind turbine rotor, accuracy may be improved by combining information across blades. Statistical control methods, machine learning techniques, or both may also be applied to improve robustness and estimation accuracy.

11. Advantages

The disclosed approach provides multiple technical and commercial advantages, including:

- reduced reliance on a dedicated rotor-speed sensor;

- use of existing blade sensor infrastructure already present in the turbine;

- an in-house processing solution using tailored programs and algorithms for protection requirements;

- support for safety-critical functions such as slip detection, rotor acceleration etc.;

- reduced interfaces associated with separate sensing hardware; and

- significant potential cost savings, including savings that may reach large fleet-wide annual amounts.

12. Example Embodiments

In one embodiment, fiber-optic blade sensor signals are tapped from a stream already transmitted to an external analytics system. The tapped signals are filtered, calibrated, validated, and processed to derive rotor speed for use in slip detection or rotor acceleration prediction etc..

In another embodiment, strain gauge signals already received by a turbine controller are used to estimate rotor speed. Signals from multiple blades are combined to improve estimation accuracy.

In a further embodiment, statistical or machine-learning-based processing is added to improve waveform interpretation, calibration quality, or confidence in the extracted rotor-speed estimate.

13. Industrial Applicability

The disclosure is applicable to utility-scale wind turbines, including onshore and offshore turbines, particularly those already equipped with blade sensing systems for load or condition monitoring. It is useful in turbine control systems, drivetrain protection systems, retrofit monitoring solutions, and fleet-wide cost-reduction programs that seek to minimize additional hardware while preserving or improving protection capability.

14. Variations and Alternatives

Various modifications may be implemented without departing from the disclosed concept. Different sensor types may be used, provided that their signals have a measurable relationship to rotor position. The processing sequence may use different filtering, calibration, or validation techniques. Reference signals other than encoders may be used where available. Rotor speed may be derived centrally, locally, or in distributed hardware. The extracted signal may additionally support other monitoring or protection functions beyond slip or acceleration detection.

15. Conclusion

The disclosure presents a practical method and apparatus for extracting rotor speed and associated parameters indirectly from existing blade sensor signals. By reusing signals already synchronized with rotor position and applying filtering, calibration, validation, and waveform-based processing, the approach enables rotor-speed estimation suitable for safety and protection functions while reducing cost and hardware complexity.

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