Comment on "Virtual sensing for strain estimation in wind turbine support structures based on a single accelerometer" by Thurn et al. (2026)

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Thurn et al. (2026) present a model-based approach for virtual sensing of wind turbine support structures for full-field strain estimation using a single DC-capable accelerometer. The method is explicitly aimed at the quasi-static frequency range and is presented as enabling strain estimation while saving costs by relying solely on accelerations from a single accelerometer as input. The concept is technically interesting, but this central claim is stronger than the method formulation and validation evidence can support.

1. The proposed single-accelerometer virtual sensing is theoretically conditional on an accurate structural model, rather than being established solely from one acceleration input.

The proposed approach requires a structural analysis model as its basis. The static bending line, modal shapes, and strain-transfer relations used by the method are all extracted from the finite-element (FE) model. The reliability of the estimated strain therefore depends fundamentally on whether the FE model can represent the true displacement-to-strain transfer from the measurement point to the target point. This is the critical issue. The paper itself acknowledges that, in the offshore application, the FE model is constructed from design assumptions and neglects manufacturing and construction deviations, uncertainty in soil-stiffness distribution, mass and stiffness asymmetry, and the influence of varying environmental and operational conditions on both the tilt constant m and the frequency-dependent transfer function $H_{w\rightarrow\varepsilon}(f) = \varepsilon_{t,FE}(f)/w_{t,FE}(f)$. Some discrepancy between FE prediction and true structural response is therefore unavoidable. Under a single-accelerometer configuration, the measurement does not contain sufficient independent information to identify, separate, or correct these model-induced errors. The method thus strongly relies on a prior FE-predicted response mapping without providing a theoretical mechanism to handle modeling error, parameter and loading uncertainty, or transfer-relation mismatch. In this sense, the claim of "saving costs by relying solely on accelerations from a single accelerometer as input" is theoretically questionable, because the method is not supported by one accelerometer alone, but by one acceleration measurement together with a sufficiently accurate structural model. Although the paper describes the framework as "a novel model-based approach", its application to practical offshore wind turbine support structures lacks a firm theoretical foundation unless modeling error is explicitly addressed.

2. The low-frequency displacement estimation is governed by a prior kinematic assumption rather than by independent identification from measurement.

In the proposed method, the measured acceleration is decomposed into structural inertial acceleration and a gravity-induced component due to tilt, and the tilt constant $m = w'/w$ is defined as the ratio between tilt and lateral displacement in the quasi-static bending line extracted from the FE model. This quantity is then embedded directly in the combined tilt-error compensation and double integration used for displacement estimation. The method therefore does not identify the actual low-frequency rotation-displacement relation from measurement, but prescribes it through the quasi-static bending line of the prior model. In the offshore proof-of-concept study presented in the paper, this modelling assumption is further specified by assuming that rotor thrust is the dominant load in the quasi-static frequency range, so that the quasi-static values of $H_{w\to\varepsilon}$ are determined from the static bending line resulting from a horizontal force applied at the tower top. The low-frequency displacement estimation is therefore explicitly dependent on load modelling and on the assumed structural representation. If the true quasi-static response is influenced by soil-structure interaction, varying environmental and operational conditions, structural asymmetry, or other load components, systematic bias should be expected. The paper also states that low-frequency noise can still cause long-term drift, and that, in the offshore case, both measured and estimated strains had to be high-pass filtered at 10^{-4} Hz, which impeded the determination of static strains. Accordingly, the kinematic assumption underlying the low-frequency estimation cannot be regarded as guaranteed in practice, because it is affected by both modelling error and measurement technology, and a single acceleration measurement provides no mechanism to identify or correct this deficiency.

3. The validation evidence is too narrow to support a full-field reconstruction.

The laboratory study is a controlled beam experiment with simple geometry, a prescribed top displacement boundary condition, and an updated FE model with near-perfect mode-shape agreement. Accordingly, the paper concludes only that strains can be reliably estimated from one accelerometer for a known excitation. That result cannot be directly extended to an operating offshore wind turbine under uncertain support conditions and variable environmental loading. The offshore validation is similarly limited. It uses 9.5 h of part-load data, evaluates signals after low-pass filtering at 1 Hz, and validates strains only near the transition piece at one elevation. It provides no independent evidence at the fatigue-critical locations around the mudline or below it, even though the paper itself notes that such regions are of primary interest in offshore wind turbine support structures. The reported field deviations in damage-equivalent strain range from about 6 % to 21 %. The field study therefore supports, at most, a local proof of concept near the transition piece, not full-field strain reconstruction throughout the support structure.

In summary, the paper is more appropriately interpreted as a model-assisted proof of concept for quasi-static response estimation under strong prior assumptions. In practical offshore applications, however, obtaining a truly predictive finite-element model is intrinsically difficult. The response of a monopile wind turbine is governed by uncertain support conditions, soil-structure interaction, nonlinear damping and loading effects, and time-varying environmental and operational conditions. Moreover, the structural state itself evolves over time through processes such as scour, marine growth, and damage accumulation, all of which can alter the actual static and dynamic behaviour of the system as well as the associated response transfer. Under such conditions, a sufficiently accurate FE model cannot be assumed a priori. Nor can a single acceleration measurement realistically provide a basis for model updating capable of resolving such multi-source uncertainties and improving the predictive accuracy of the FE model to a practically sufficient level. One sensor therefore does not provide enough information to compensate for these modelling deficiencies. The paper therefore does not demonstrate that the spatial observability limit of single-point monitoring has been overcome, nor that robust full-field strain estimation from one accelerometer is generally available for offshore wind turbine support structures.

Reference:

Thurn, J., Jonscher, C., Hofmeister, B., Zorzi, G., and Rolfes, R.: Virtual sensing for strain estimation in wind turbine support structures based on a single accelerometer, Wind Energ. Sci. Discuss. [preprint], https://doi.org/10.5194/wes-2026-5, in review, 2026.