Review Response

Remote Diagnostics for Power Converter Faults in Wind Turbines Based on Converter Control System Data

Timo Lichtenstein, Martin Hippenstiel, and Katharina Fischer

We would like to thank all reviewers for their constructive and insightful comments. We have revised the manuscript accordingly. See the detailed answers to each reviewer below.

RC1: Anonymous Referee #1, 25 Oct 2025

This paper proposes a data-driven workflow for remote diagnostics of power converter faults in wind turbines using multi-source data fusion and machine learning models. This is an interesting and industrially relevant area that has received limited attention in the literature. However, there are several concerns that authors need to address before the paper is suitable for publication:

The study uses approximately 100 fault events, which is quite limited for machine learning applications. While the authors acknowledge this limitation, concerns about overfitting and generalizability remain inadequately addressed. How would this model perform on different wind farms, turbine types, or converter manufacturers?

> *We fully agree that a sample size of about 100 fault events is limited for machine learning and inherently raises concerns about overfitting and generalizability.*
>
> *For this reason, we deliberately applied a methodology that reduces the feature space and uses models with relatively few parameters (logistic regression and decision trees). The intention of this work is primarily to demonstrate that diagnostically relevant information is indeed present in the available data and that meaningful fault classification is possible in principle. More extensive validation and deeper analyses will only be feasible once data from additional wind farms, turbine types, and converter control systems become available.*

The authors report that 4 features yield the best performance, but lack sufficient explanation of why these features are most informative from a physical or engineering perspective. What do these features represent in terms of actual fault mechanisms? This would strengthen the practical applicability and trustworthiness of the approach.

> *A detailed technical interpretation of the selected features and their direct relation to specific physical failure mechanisms would, at this stage, be largely speculative. Our approach is intentionally designed as a purely data-driven method. The core idea is to exploit the available data to identify patterns that may not yet be understood or*

documented as distinct fault mechanisms, and in this way provide the user with additional decision support beyond the diagnostic capabilities of the converter itself.

We would like to acknowledge that the number of features from different sources and their concise descriptions are not self-explanatory. However, within the scope of this paper, it is not feasible to explain the exact physical origin of every single feature. Nevertheless, the four most significant features can be briefly summarized as follows:

- *FL: LSC current setpoint entropy (W3) measures the irregularity (information content) of the LSC current setpoint in time window W3. Therefore, increased entropy indicates stronger fluctuations in the commanded current.*
- *FL: LSC actuating space vector length slope (W0) describes the trend (slope) of the PWM actuating signal amplitude in the first time window W0. A non-zero slope reflects systematic changes in the converter's actuation behavior.*
- *FF: High temperature LV filter Fault flag indicates that the low-voltage filter temperature exceeds its threshold. This is directly linked to increased temperatures in the filter components, which may result from either increased power losses or cooling issues.*
- *FF: Control system Fault flag indicates an internal control system issue.*

Using "time until restart" as a proxy for fault severity is problematic, as it conflates actual fault severity with operational factors like technician availability, spare parts logistics, weather conditions (for offshore access), and maintenance scheduling decisions. A more direct measure of fault severity would strengthen the study.

It is correct that, without service data as ground truth, an assessment of fault severity can be influenced by several external factors. However, it should be noted that, after consultation with the wind farm operator, we set the threshold to 1 hour. This period is, on the one hand, sufficiently long to exclude remotely resettable faults, while, on the other hand, being short enough for reactive maintenance measures not to be carried out yet.

It's unclear how this model would operate in practice. Since it's trained only on fault events, how would it handle normal operational data in real-time deployment? Would it continuously monitor and classify every time point, or only activate when a fault flag is triggered? If the former, false alarm rates (precision/recall on normal vs. fault conditions) should be evaluated.

This algorithm is not intended for continuous data monitoring. As the used datasets are generated at the time of trigger events of the converter, it is designed as a remote *diagnostic tool to support service operators in their prioritization and decision-making. However, the results of this work can be seen as a precursor for a continuous monitoring of the high-resolution data of the converter control.*

The paper can benefit from comparison with simpler baseline methods (e.g., rule-based systems using only fault flags) or existing industry practices to demonstrate the actual improvement over current diagnostic procedures and establish the practical value of the proposed approach.

When carrying out the same analysis of the paper using only event data and the available operating data, we only obtain R2 values and F1 scores around 0.6. These values indicate a limited diagnostic performance and highlight the need for the richer information of the fast logs.

RC2: Anonymous Referee #2, 29 Dec 2025

It is an interesting paper - both in terms of methodology as well as the data available for the data-driven prediction of fault types in a wind turbine. When reading it -

I miss a system diagram showing where the data are coming from in the wind turbine - all the variables which are defined could be nice to see in such figure.

We have added a system-level diagram (new Fig. 1) that illustrates where the different data streams originate in the wind turbine (turbine control vs. converter control) and how the operating data (OD), fault logs (FL), and event data (OS, FF) are processed in our workflow.

The paper also concludes that only the fast sampled data are usefull - it is not clear in the figures how that can be seen - a little more details

Features with higher absolute logistic regression coefficients (see Tab. 2 and Fig. 2) are considered to have a greater impact on the model performance. These features are then added to the model in descending order of importance (see Fig. 3b). Among the first 16 selected features, only one originates from OD and one from OS; all remaining features are derived from FF and FL data. We enhanced the manuscript to point this out in a clearer way.

An initial discussion on how general the structure applied can be transferred to other turbines

We added a comment in the summary that it can generally be applied for any turbine system where trigger data from the converter control is available.

CC1: Dingrui Li, 05 Dec 2025

This paper utilized data-driven approach for converter fault diagnostics. The results from the paper are practical and useful for actual industrial applications, while the academic innovations are limited. Here are my detailed comments:

The proposed approach utilized the data from converter control, which may not be available in other scenarios. In real applications, it is common that only the converter vendors have access to the control data. How will the converter customers utilize the proposed approach?

> *The research paper is intended to showcase the possibilities of advanced diagnostics with access to extended data. It is clear to us that the use of these data is not a typical use-case for the technical operation. For the shown data set, the fault flags (FF) and high-resolution fast log data (FL) around the trigger were readily available to the operator. Also 1-min operating data (OD) can nowadays typically be acquired, if desired. Nevertheless, the research paper is generally intended to showcase the possibilities of advanced diagnostics with access to these extended data source. It is clear to us that this may not usually be the case.*

The authors utilized the Park Transformation to convert the data to dq coordinates, which can transform the three-phase AC balanced components to DC components. However, during fault conditions, the converter output may not be balanced; as a result, the Park Transformation may not lead to DC components. Will the unbalanced components affect the data analysis?

> *We would like to point out that there is indeed an error in the manuscript. Instead of the Park transformation, the Clarke transformation has been used, resulting in a rotating space vector from which the magnitude and angular velocity were calculated, which will be corrected in the resubmitted version. Furthermore, it is correct that a balanced voltage system leads to steady (DC) quantities. Nevertheless, after the transformation (either Park or Clarke), we still obtain a time series. However, under fault conditions these signals can indeed become partly chaotic. It is precisely these deviations from steady-state behavior that allow the different fault severity to be distinguished. An explanation has been added to the manuscript.*

The decision trees and regression are not new approaches. Can the authors highlight the innovation of the proposed approach?

> *In this work, we focus on a systematic investigation of the diagnostic possibilities when extended converter control data is available, which to our knowledge has not*

been studied in this form before. Therefore, the innovation is in the data-driven analysis of converter control signals and the derived findings, rather than in developing new machine learning techniques.

For the results, it will be better if the system configuration or parameters can be introduced

The proposed methodology is designed to be system-agnostic, so the configuration of the specific wind turbines and converters used are not essential for this approach and would mainly increase the complexity and length of the paper.

Changes made to the manuscript

We change the following part of our manuscript.

- *Between line 57 and 58: We added a flow diagram of the data sources and their subsequent processing*
- *Line 64: We added a reference to Fig. 1*
- *Lines 89-95: The description of the Clarke transform and the resulting features was updated*
- *Line 147: A deeper explanation that OD and OS features are not present in the most relevant features is added*
- *Line 161: A statement regarding the general applicability of our methodology is added*