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# Reliability of power converters in wind turbines: Results of a comprehensive field study

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## Abstract

The power-converter system in wind turbines is a frequent source of failure and, as such, a driver of repair cost and downtime. As a basis for the development of effective countermeasures, it is crucial to understand the prevailing mechanisms and causes of converter failure in wind turbines. This poster presents results of a statistical analysis of comprehensive failure and operating data. The data covers converter-failure events reported during 2003-2015 and includes more than 4600 operating years of variable-speed wind turbines with doubly-fed induction generators, electrically-excited synchronous generators and with induction generators.

## Background and Motivation

Power converters in wind turbines (WT) have high failure rates [1-3], although the fatigue-induced failure mechanisms known from power electronics in other applications appear to play a minor role in wind turbines [4]. On this background, the German Innovation Cluster on Power Electronics for Renewables has been established, with the overall objective to enhance the reliability and availability of power converter systems in wind turbines. It builds on a systematic analysis of the comprehensive failure and operating data provided by the project partners, on directed field measurement campaigns and on post-mortem analysis of failed converter hardware to identify the main root causes of failure.

A previous paper of the authors [5] presented first results of statistical analyses carried out within this project. Based on a data subset covering 1269 WT operating years, it identified the 'phase module' to be the most frequently failing subsystem and main repair-cost driver within the power-converter system.

## Innovation Cluster on Power Electronics for Renewables

Project duration: 2014 – 2017
Budget: 4 Million Euro
Coordination: Fraunhofer IWES
Subjects:

- Field-experience based root-cause analysis and reliability improvement
- Model-based investigation of dynamic interaction of electrical and mechanical drivetrain components
- Condition monitoring of electrical components
- Fault-tolerant generator / converter concepts

Further information: www.power4re.de

Consortium:

SUZLON, wpd, WOODWARD, FeCon, SSB Wind Systems, juwi, Gothaer, AVAILON, itec, LEINE LINDE SYSTEMS, VATTENFALL, EWE, BENDER, ZOPF, ENERGY CONSULT, SEMIKRON, Institut für Antriebssysteme und Leistungselektronik, Fraunhofer IWES, ForWind

## Objectives

The present analysis aims to:

- disseminate state-of-the-art converter reliability data based on a large fleet of wind turbines and to deepen the analysis of 'phase-module' failures,
- clarify if high converter failure rates are still an issue in contemporary turbine generations or limited to old fleets,
- investigate if certain operating points of wind turbines are afflicted with a higher risk of converter failure.

## Methods

The converter failure data has been derived from maintenance reports and turbine logbooks. Only faults requiring on-site repair and the consumption of material or spare parts are counted as failure events. Average failure rates are considered in this analysis and are calculated as described in [5].

Failures of the following components are considered as converter-system failures: 'phase module' (including IGBT modules and corresponding driver boards, DC-link capacitors, busbars; exciter and rectifier in turbines with EESG), converter control board, cooling system, main circuit breaker, grid-coupling contactor, other converter components such as fuses, crowbar and filters.

**Table 1: Failure data underlying the present analysis**

| | |
|---|---|
| Covered WT operating years | 4665 |
| Considered time period | Years 2003 – 2015 |
| Number of wind turbines | 1659 |
| Generator-converter concepts of wind turbines | Doubly-fed induction generator with partially rated converter (DFIG)<br>Induction generator with full power converter (IG+FPC)<br>Electrically-excited synchronous generator with full power conv. (EESG)<br>Single turbines with permanent-magnet sync. generator and FPC |
| Turbine rated power | 500 kW - 3600 kW |
| Turbine commissioning dates | 1997 – 2015 (unknown in some cases) |

## Results

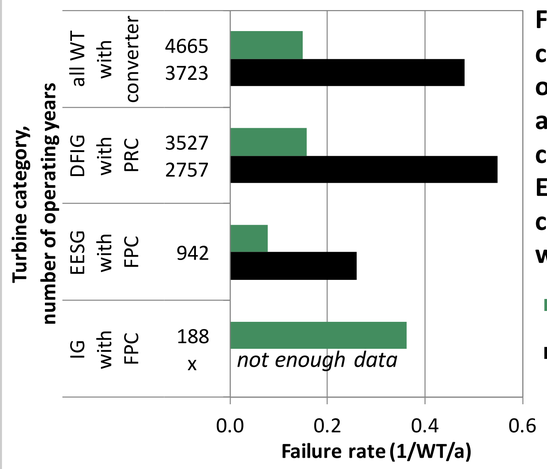


**Fig. 1: Average converter failure rates of turbines with DFIG and partially rated converter (PRC), with EESG and full power converter (FPC) and with IG and FPC**

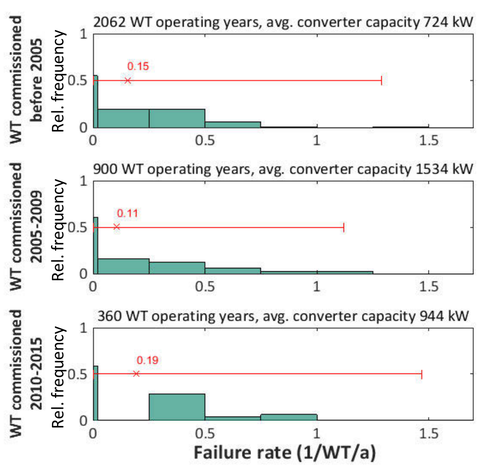


**Fig. 2: Histograms of turbine-individual failure rates of the converter-component category 'phase module', for WT commissioned before 2005 (top), during 2005-2009 (middle) and during 2010-2015 (bottom); only WT with ≥2 years of data included; red marker: average, whiskers: range from minimum to maximum failure rate**

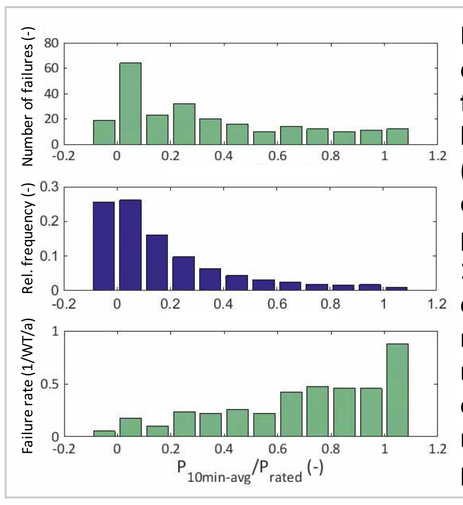


**Fig. 3: Distribution of converter (phase-module) failures of a fleet of DFIG-based WT over active power (top); distribution of operating time over active-power bins, derived from 10min-averaged SCADA operating histories (middle); resulting failure rates (i.e. number of failures per year of operation in this load range) over bins of active power (bottom)**

## Conclusions

- The results underline the continued need for effective converter reliability improvements also in contemporary turbine generations.
- The evaluation of 10min-SCADA and failure data has revealed an increased probability of converter failure towards full-load operation (DFIG-WT only).

## Acknowledgments

The present work was carried out within the Fraunhofer Innovation Cluster on Power Electronics for Renewables. We gratefully acknowledge the partial funding by the initiative "Niedersächsisches Vorab" of the German Federal State of Lower Saxony as well as the contributions of our project partners.

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