Wind Turbine Power Converter Demonstration Reliability Test Facility

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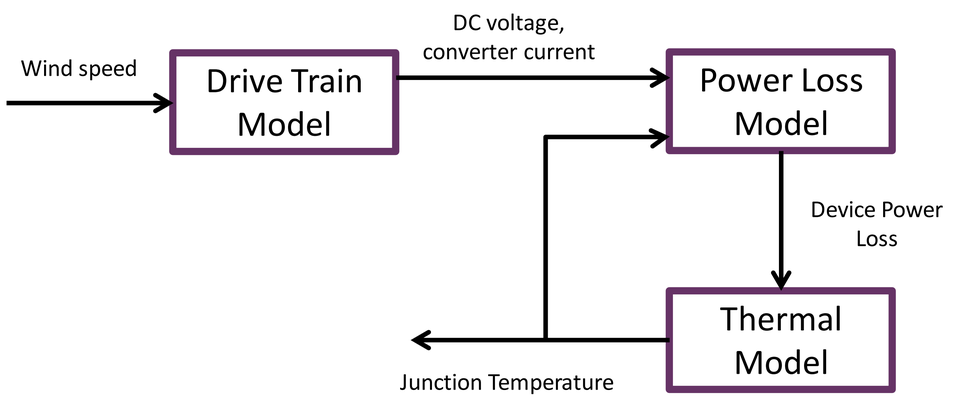
Abstract

Power converter reliability is critical for permanent magnet synchronous generator (PMSG) wind turbines[1,2]. Insulated gate bipolar transistors (IGBTs) are the core component of modern power converters. However, these otherwise reliable components demonstrate significantly reduced reliability and lifetimes in renewable energy systems when compared with conventional applications. Conventional component testing, carried out under narrowly defined and unrealistic operating conditions, vastly overestimates the lifetime of IGBTs when compared with experiences from renewable energy systems. **This project aims to construct, demonstrate and verify an industrial-scale prototype test facility for reliability testing of IGBTs under wind turbine operational conditions.**

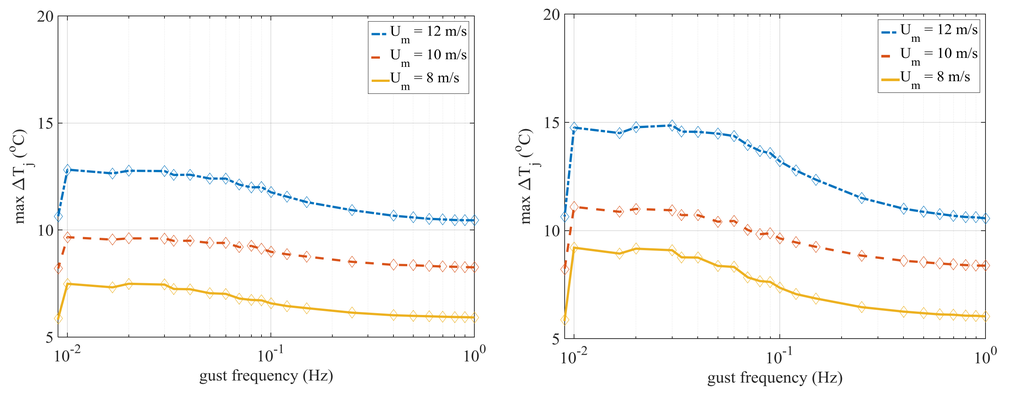
Objectives

- To construct an industrial-scale prototype facility for reliability testing of power electronic device.
- Identify the wind speed operating conditions causing the greatest damage to the power modules.
- Validate the prototype's operation against conventional testing approaches.
- Provide recommendations to Anecto on improved testing methodologies.
- Provide recommendations for large-scale implementations of the system for adoption in in commercial device testing and certification.

Power Module Thermal Modelling



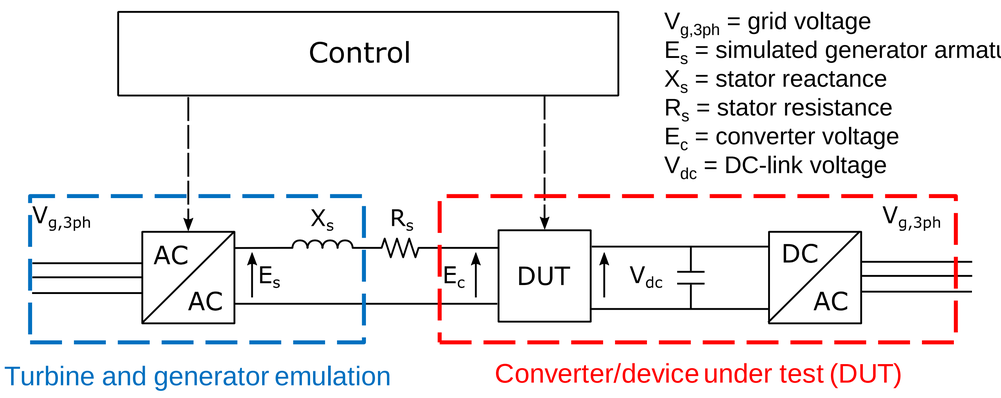
2MW PMSG wind turbine fully-rated converter thermal loading model[3]



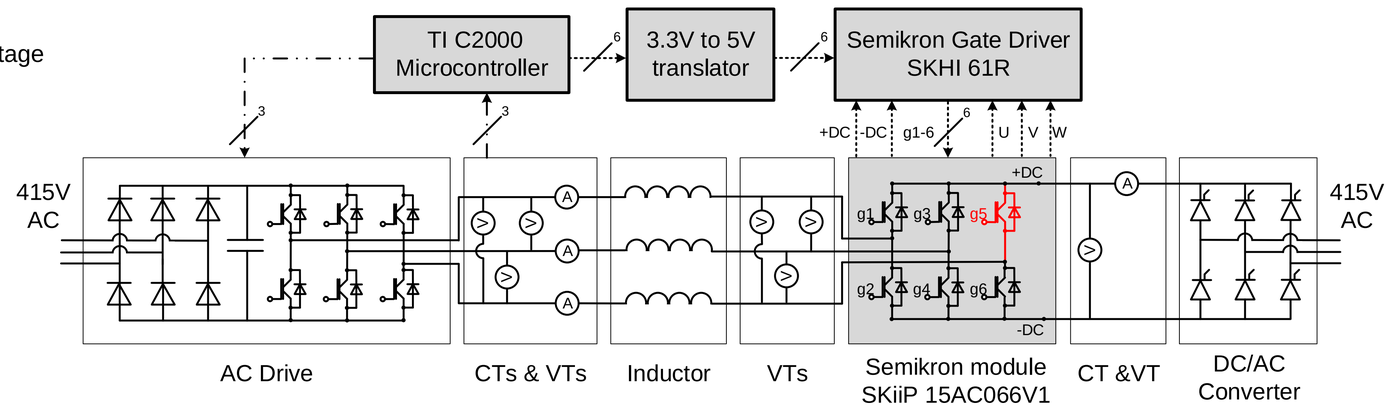
Response of the variation of junction temperature (T_j) of an IGBT to square wave wind speed time series with varying gust frequency, mean wind speed and wave amplitude of (a) 0.5m/s, (b) 1m/s[4]

- The IGBT switching pattern at high wind speeds causes intermittent T_j profiles, varying the device thermal loading significantly.
- The lower the frequency of wind speed variation, the higher the T_j.
- Only wind speed variations with gust frequencies below 0.2Hz have a significant impact on T_j.

Experimental Validation

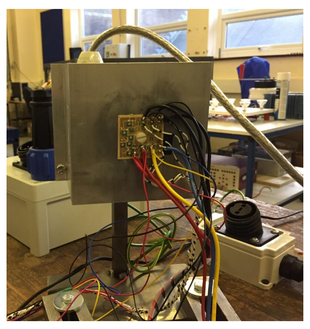


Schematic diagram of the PMSG wind turbine machine-side converter experimental rig

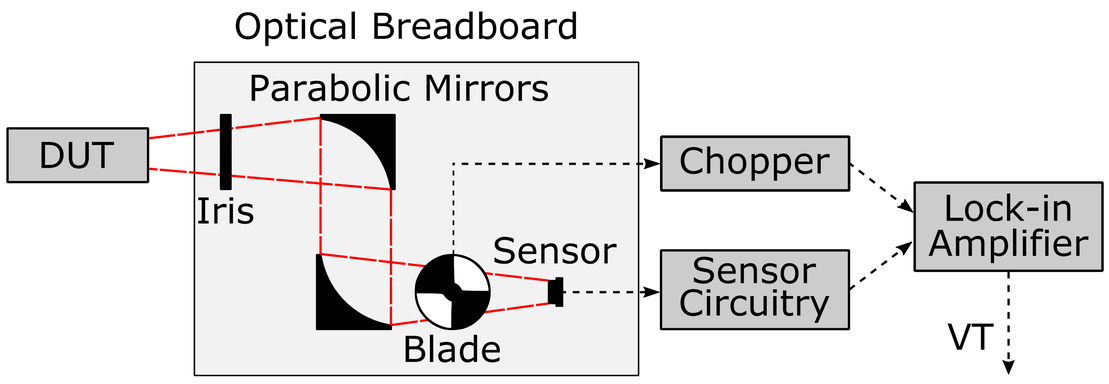


Electrical circuit diagram of the industrial-scale prototype power converter demonstration reliability test facility

The **wind profiles found to have the most critical simulated thermal loading profiles will be emulated and applied to the DUT**. The damage accumulated on the DUT will then be monitored to validate whether higher T_j causes accelerated failure as suggested by manufacturing data.



DUT mounted on the heat sink



DUT thermal monitoring optical set-up

The DUT temperature is measured by an **IR PbSe Photoconductor sensor** (1.5-4.8μm wavelength range). Its fast response time (i.e. 10μs) allows to track the fast T_j changes associated to the high device switching frequency (in the kHz range). Traditional temperature monitoring devices on modules typically have slow response times and are not able to pick up T_j due to their distance from the devices and therefore cannot be used for this type of analysis.

Testing conditions:

1. Fixed wind speed profiles at a range of wind speeds
   - Explore impact of electrical frequency on thermal loading
   - Direct comparison against conventional testing techniques
2. Simple square wave inputs
   - Characterisation of the impact of wind speed frequency and magnitude on the DUT thermal profile
   - Comparison against simulation studies
3. Real wind speed profiles
   - Demonstrate the flexibility of the rig
   - Power converter thermal loading characterisation under complex loading conditions

Conclusions

An experimental rig that applies PMSG fully-rated converter wind turbine specific operating profiles to a machine-side converter power module has been proposed.

A number of test conditions will be implemented to verify power module simulated thermal loading profiles, validate the use of cycle life vs. T_j profile manufacturing data, and determine the wind turbine operational profiles that cause the most damage to the machine-side converter.

The final aim of this project is to validate the prototype's operation against conventional testing approaches and provide recommendations on improved testing methodologies.

References

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2.Spring, M., Davies, P., Gaal, G., Sepulveda, M.: 'Top 30 chart for wind turbine failure mechanisms', Proc. EWEA Annual Event, 2015.
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4. Smith, C.J., Crabtree, C.J., Matthews, P.C.: 'Impact of wind conditions on thermal loading of PMSG wind turbine power converters', IET Power Electronics, 2017 (under review).

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