Characterisation of Electrical Loading Experienced by a Nacelle Power Converter

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Abstract

The **reliability of fully rated converters** (FRC) in permanent magnet synchronous generator (PMSG) wind turbines **is critical** [1]. A **drive train model** has been constructed to **simulate the current throughput of the power modules** in the FRC in response to a variety of **isolated wind speed conditions** and simulated **wind speed profiles** to explore potentially **damaging operating conditions**. The results reveal that modelling the drive train is essential for ensuring **accurate current throughput** due to the impact of **turbine inertia and control** decoupling the wind and current profiles.

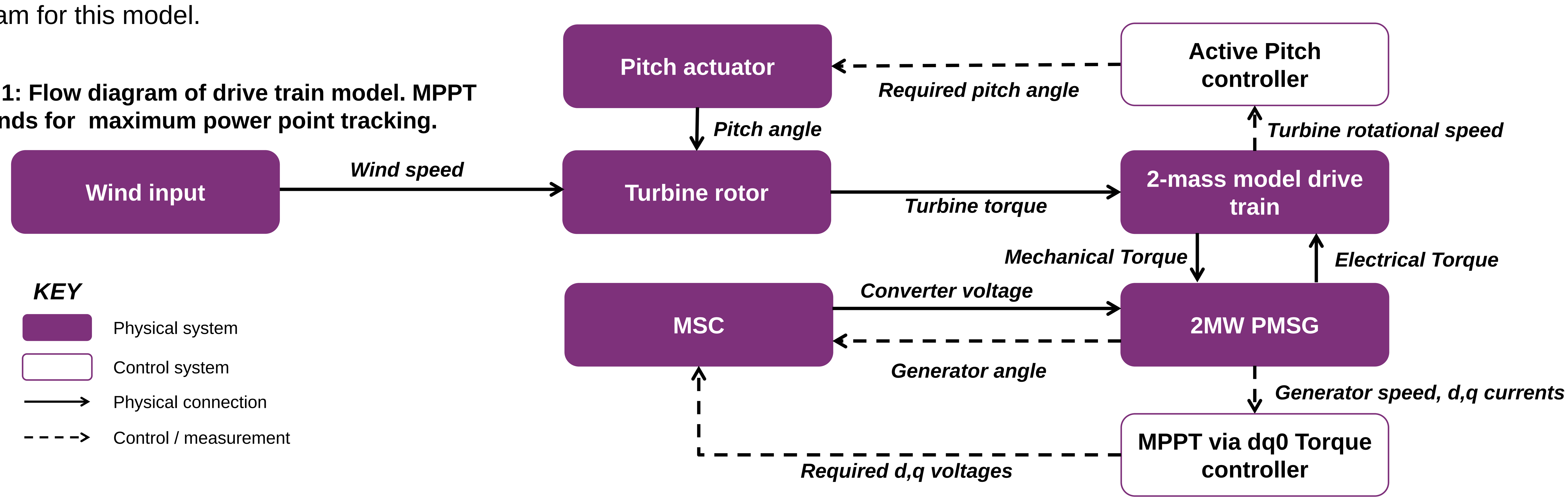
Objectives

- Provide **wind turbine drive train model** for characterisation of **current** signals that are experienced by the **machine-side converter** (MSC) at different operating points.
- Provide data for **parameterisation of an experimental rig to test the reliability** of the MSC under various operating regimes.
- Simulate current produced by the generator so the **generator can be replaced by a voltage source** in the rig.

Methods

A direct drive **wind turbine drive train model** was constructed to simulate the **current flowing through the MSC power modules**. The MSC was modelled on 2 parallel SEMIKRON SKSB1090GD69/11-MAPB stacks [2] and the **DC link** was modelled as an ideal **voltage source.** Figure 1 details the flow diagram for this model.

Figure 1: Flow diagram of drive train model. MPPT stands for maximum power point tracking.



Results

Figure 2 displays the insulated gate bipolar transistor (IGBT) and diode current throughput due to a ramp change in wind speed, alongside snapshots of the wind turbine response.

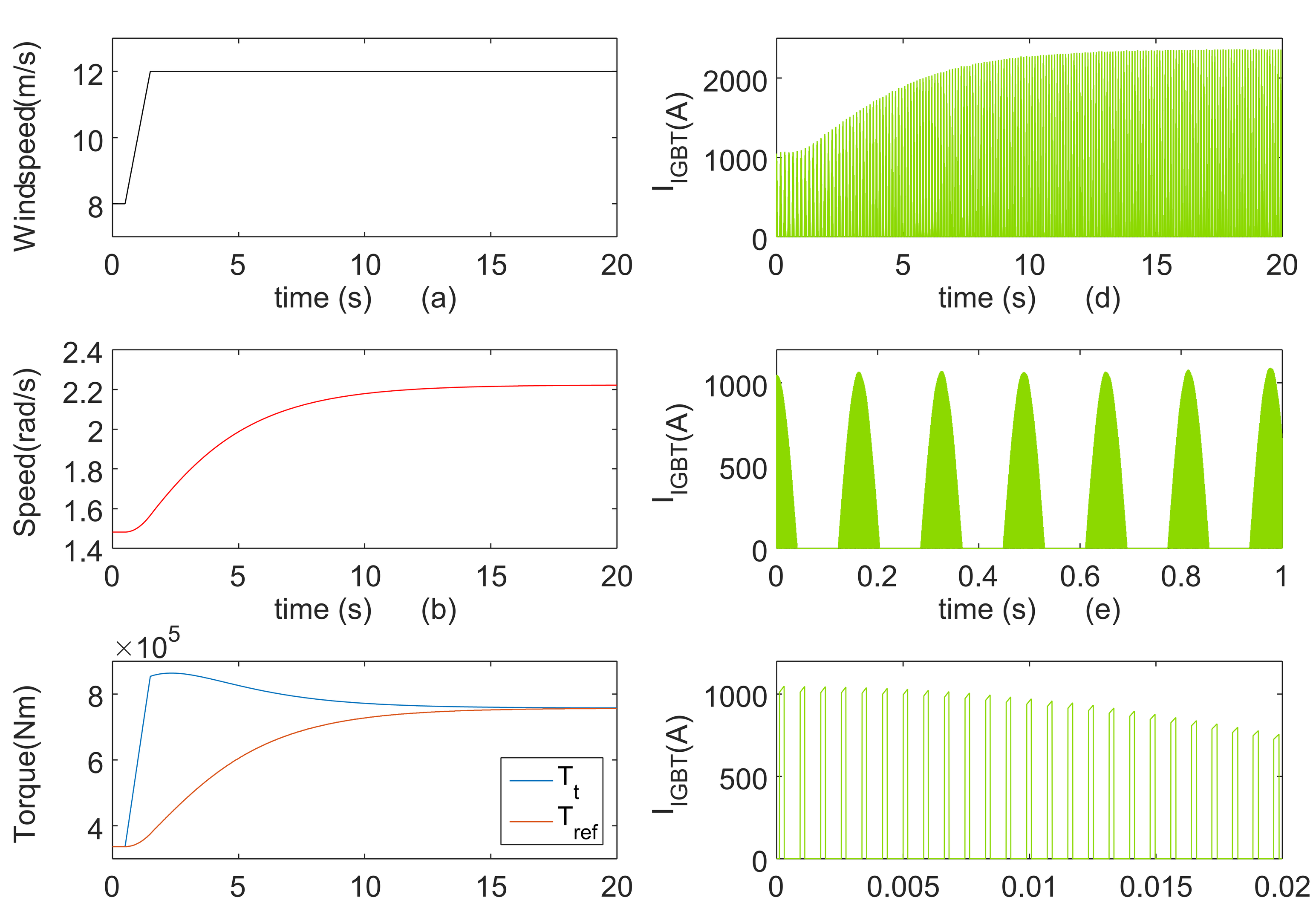


Figure 2: Turbine response to ramp change in wind speed; (a) wind speed, (b) turbine speed, (c) turbine torque (T_t) *and* reference torque (T_{ref}), and (d-f) current on one IGBT in the MSC (I_{IGBT}).

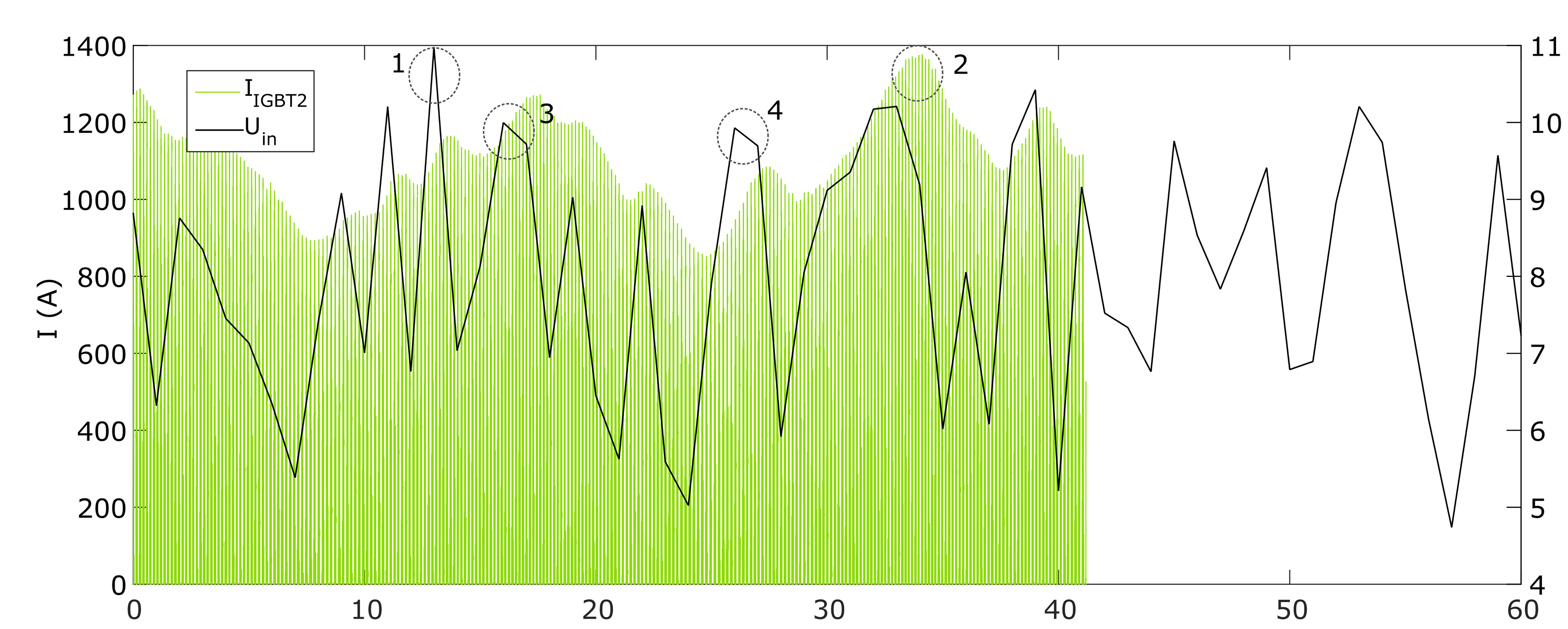


Figure 3: IGBT current response to simulated wind speed (U_{in}).

Figure 3 details the current response of one IGBT to a simulated wind speed time series. There are three points to highlight:

1. A **delay between wind speed and current** peaks due to turbine inertia.
2. The **highest wind** speed |1| does **not** lead to the **highest current** |2|.
3. **Similar wind** speeds |3, 4| do **not** give the **same current** but are **dependent on** wind speed **history**.

This highlights the complexity of current loading on the devices and the need to simulate the drive train to get accurate current profiles.

Conclusions

- A PMSG wind turbine has been modelled to simulate the FRC current response to various wind speed inputs.
- When determining the converter electrical loading the results reveal the importance of the turbine response :
  - ➢ Turbine inertia delays the current response.
  - ➢ The highest wind speed does not always give the highest current.
  - ➢ The wind speed history is as important as the immediate wind speed.
- This model will be used in conjunction with a rig to investigate the thermal loading and damage due to current.

References

1. J. Carroll, A. McDonald, and D. McMillan, "Reliability Comparison of Wind Turbines With DFIG and PMG Drive Trains," *IEEE Transactions on Energy Conversion,* vol. 30, p. 663, 2015.
2. SEMIKRON. (2013). *SKS B1 090 GD 69/11 - MA PB Datasheet*. Available: http://www.semikron.com/dl/service-support/downloads/download/semikron-datasheet-sks-b1-090-gd-69-11-ma-pb-08800136