# Variable Speed Control with a Magnetic Power Split Device for Tidal Stream Turbines


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## 1. Introduction

The United Kingdom has an enormous tidal energy resource that is estimated to be 50% of Europe's total [1]. However tidal energy's cost is still too high to allow subsidy free operation. One area for cost reduction is the electrical subsystem of the tidal stream turbine. It has been shown in the MeyGen Phase 1a project, the largest full scale deployment of tidal turbines so far, that the greatest cause for down-time was due to the power converter unit, see figure 1. The power converter unit (PCU) for each turbine was stored on land providing easy access for maintenance and repair. However this required installing a subsea power cable, running from sea to land, per turbine. A large cost reduction would be to have a single collector cable that transports the power from all turbines to land. This can be achieved with a more reliable power converter, which is able to be located off-shore inside the turbine, see figure 2.

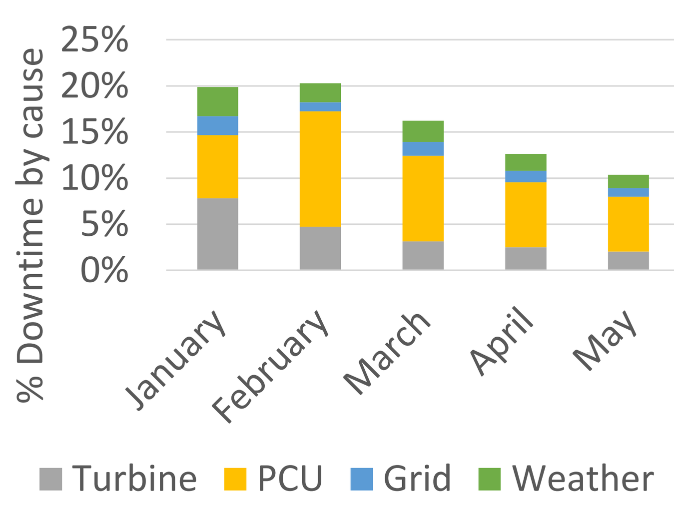



Figure 1 – MeyGen Phase 1a causes of downtime clearly shows the that power converter unit (PCU) is the greatest cause for downtime. [2]

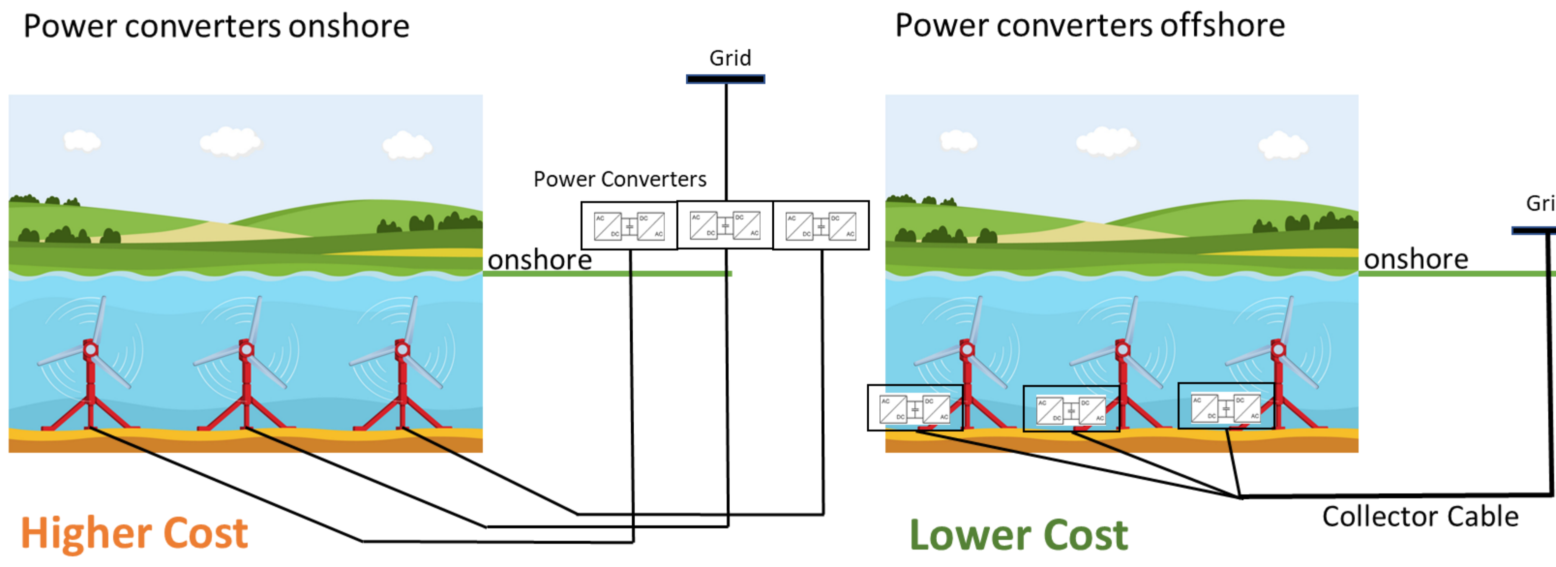



Figure 2 – Power converters place on and offshore change the cabling layout, greatly affect the cost of subsea cabling and installation.

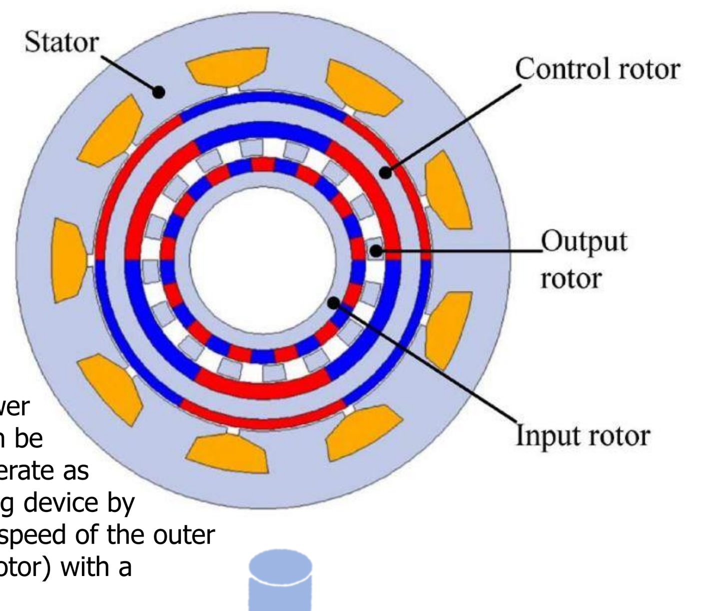



Figure 3 – A Magnetic Power Split Device can be designed to operate as a power splitting device by controlling the speed of the outer rotor (control rotor) with a machine. [4]

## 2. Project Description

This project seeks to investigate a novel energy conversion subsystem of a tidal turbine centred around a more reliable power converter, reducing the subsea cabling costs and making tidal energy a more competitive energy source. A *Magnetic Power Split Device*, figure 3, within the mechanical to electrical power conversion process enables the use of a power converter shown to be 5 times more reliable than the type of power converter currently used for tidal turbines [3]. The device is derived from the recent viability of the concentric magnetic gear, offering highly reliable gearing. A diagram of the system is shown in figure 4 along with an example of the power flows in the turbine.

**Aim: Show through simulation that the novel energy conversion system allows the tidal turbine to function as required, correctly controlling the mechanical and electrical sides for maximum power extraction.**

## 3. Methodology

Simulink is used as it allows simple implementation of differential equations that model the behaviour of dynamic mechanical and electrical systems. A stepped input torque was applied at the rotor and a stepped reference point for the speed of the control rotor is used.

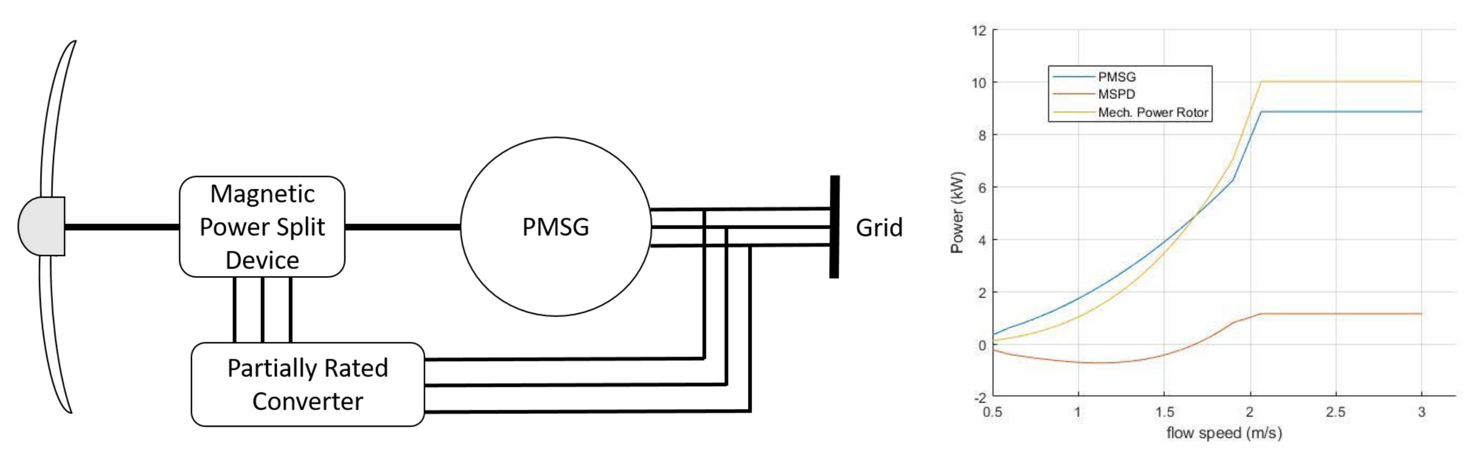
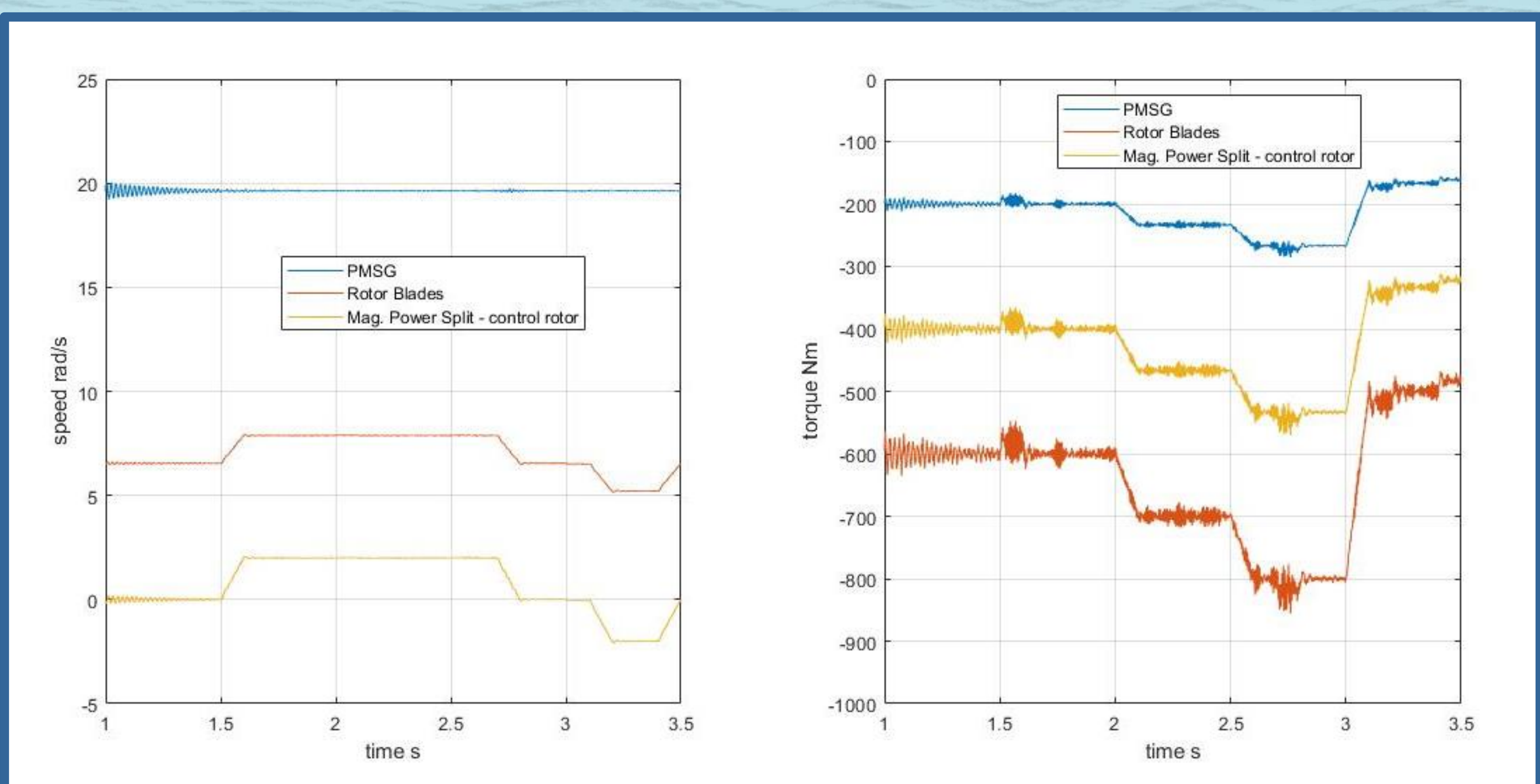



Figure 4 – A diagram of the tidal turbine, including a MPSD allowing for a direct connection between the PMSG and the grid. A partially rated converter controls the MPSD and the system. The graph shows how the power is split between the MPSD and the PMSG over the flow speed range. The converter can be designed to be as low as 15%.

## 5. Results

Figure 5 – The graphs to the right shows the mechanical speed and torque characteristics of the system. The PMSG rotor speed is held constant (*eliminating the fully rated converter in place of a more reliable partially rated converter*) while allowing variable speed regulation of the turbine blades.



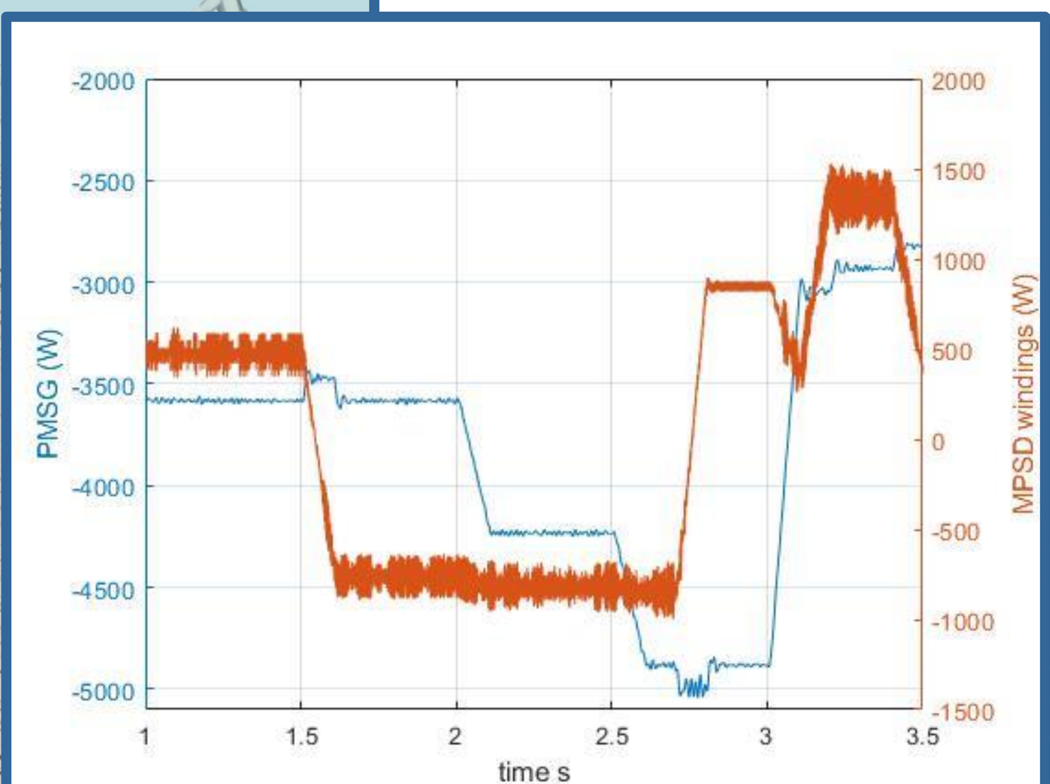




Figure 6 – The graph to the left shows how the power in the permeant synchronous generator (PMSG) directly connected to the grid varies along with the power in the magnetic power split device (MPSD) required to control the system. The power generated or consumed by the MPSD is exported or drawn from to the grid. Power is conserved in the system and similar to that of the DIFG.


**References**

[1] URL: https://www.greenmatch.co.uk/blog/2016/10/tidal-and-wind-energy-in-the-uk, accessed 29/01/2020

[2] F. Johnson, "MeyGen –The world's largest tidal array; Construction, Operation and Commercialisation", Presentation at PRIMaRE conference 2019, Cardiff

[3] 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, no. 2, 2015.

[4] Wang, J., Atallah, K., & Carvley, S. D. (2011). A magnetic continuously variable transmission device. *IEEE Transactions on Magnetics*, *47* (10), 2815–2818. https://doi.org/10.1109/TMAG.2011.2157470



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