Magnetic Continuously variable transmission (CVT)

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The problem

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- There are no definitive solutions for tidal turbine powertrains that cover; **reliability, size and efficiency**.
- There are some known **issues**:
  - Mechanical gear boxes failures cause low availability [1]. However gearing allows lighter/smaller/cheaper generators.
  - Fully rated converters (FRC) on permeant magnet synchronous generators (PSMG) have low reliability [1]. However PMSG are the more efficient generators [2] so are preferable.
- A **solution** is needed that improves on these previous problems:
  - Magnetic gears (MG) have no contact torque transfer, meaning **no wear or lubrication** needed. This hugely increases the reliability of MGs over mechanical gears.
  - MGs have the potential to be designed as continuously variable transmission (CVT). This **enables the use of a partially rated converter instead of a FRC** for an integrated CVT - PMSG..

Magnetic CVT Topology

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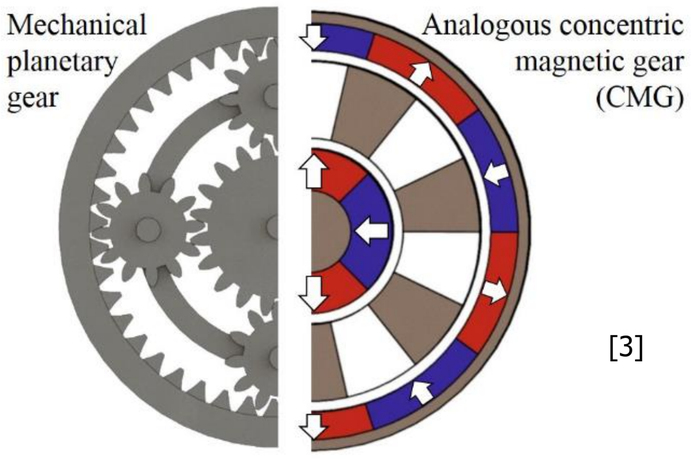
A magnetic gear and CVT work similarly to a planetary gear. There are three rotors in both topologies. To obtain a fixed gear ratio between two of the rotors the third must be stationary. For example, in the planetary gear the outer ring is kept stationary. However if the outer ring of the planetary gear is rotated at a certain speed a different gear ratio now exists for between the other two rotors. Exactly the same principal occurs for the magnetic gear, if the third (normally outer rotor is rotated at a given speed the gear ratio between the other two is controlled.



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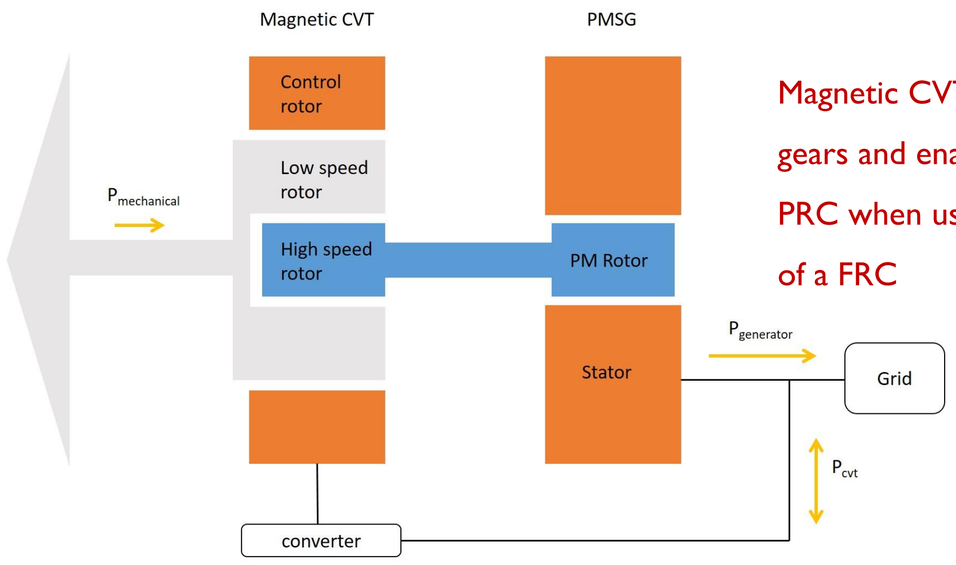

Magnetic CVTs are very reliable gears and enable the use of a PRC when using a PSMG instead of a FRC

Tidal Turbine Power Train

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- The magnetic CVT regulates the gear ratio. This enables variable speed operation of the turbine and constant synchronous speed operation of the generator.
- The generator runs at its most efficient speed, while the aerodynamics also operate at their most efficient speed.
- When the turbine is operating subsynchronously then power is drawn from the grid by the CVT, and it acts as a motor.
- When the turbine is operating suprasynchronously then power is injected to the grid by the CVT, and it is now acting as a generator.
  - Due to this effect of the CVT acting as a motor/generator constant torque/speed is supplied to the generator meaning that it can be directly connected to the grid.

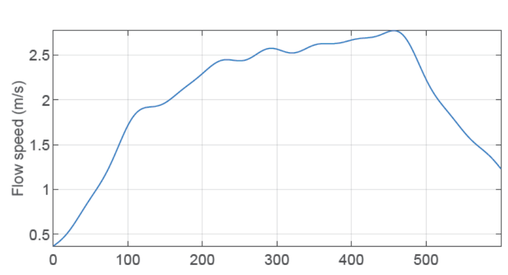
Simulation – Tide to Wire model

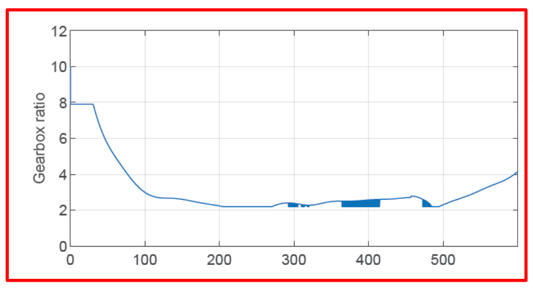
4

A simple, preliminary, model of tidal turbine with a CVT in the power train has been realised, to investigate how the CVT would operate with in the system.

- Input flow velocity is synthesised and represents the average flow speed across the rotor.
- The tidal turbine is **stall regulated** and is modelled via its $C_p - \lambda$ curve and $P = \frac{1}{2} C_p \rho A v^3$.
- Given the torque and rotational speed of the turbine a gear ratio is selected to maintain synchronous speed input to the generator.

C_p - power coefficient, λ – tip speed ratio, ρ – density of water, A – area of rotor, v – flow speed,





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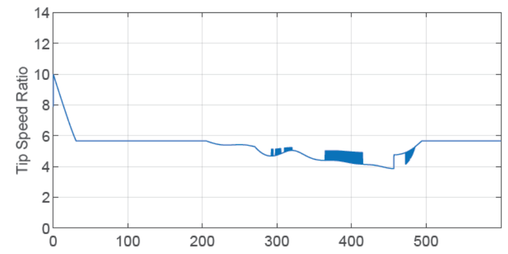

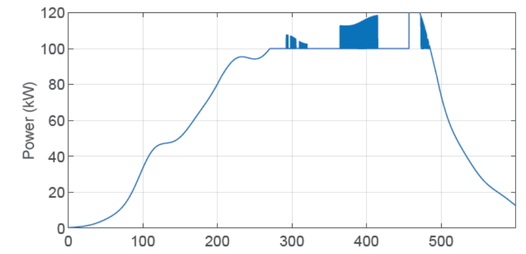

Simulation results

- The gear ratio varies between **2 - 8**
- The CVT maintains **constant speed input to the generator at 50 Hz** electrical frequency while allowing **variable speed operation of the turbine.**
- Numerical instability of the model occurs around rated power – work is on-going to correct this.

References

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