e-DRIVE

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SUPERGEN GRAND CHALLENGES

Review of Magnetic Gear Technologies and their Applications in Marine Energy

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Background

- PhD looking at non mechanical speed enhancement options for marine energy converter.
- After a technology review it was decided to focus on magnetic gears.
- Part of the SuperGen Marine, e-Drive project.

e-Drive

"e-Drive will develop an integrated electrical power take off (PTO) system with non-mechanical speed enhancement and integrated, reliable, flexible power electronics.

This PTO will provide adaptive control over a wide range of operating regimes, taking into account nominal and extreme load conditions. This will require the development of novel, integrated, low speed generators with speed enhancement, power converter topologies and associated control to replace more conventional hydraulic systems."

- www.edrive.eng.ed.ac.uk

e-Drive

A collaborative project between the University of Edinburgh and Newcastle University with industrial partners:

- Albatern Wave Energy
- Columbia Power Technologies
- Technalia
- Carnegie Wave Energy
- Turbo Power Systems

and academic partners:

- Delft University of Technology
- Universidad de Chile
- Universidad Nacional Autónmade México.

Why Magnetic Gears?

Issues with wave and tidal energy:

- High operation and maintenance costs
- Highly variable forces
- Low frequency

e-DRIVE

Why Magnetic Gears?

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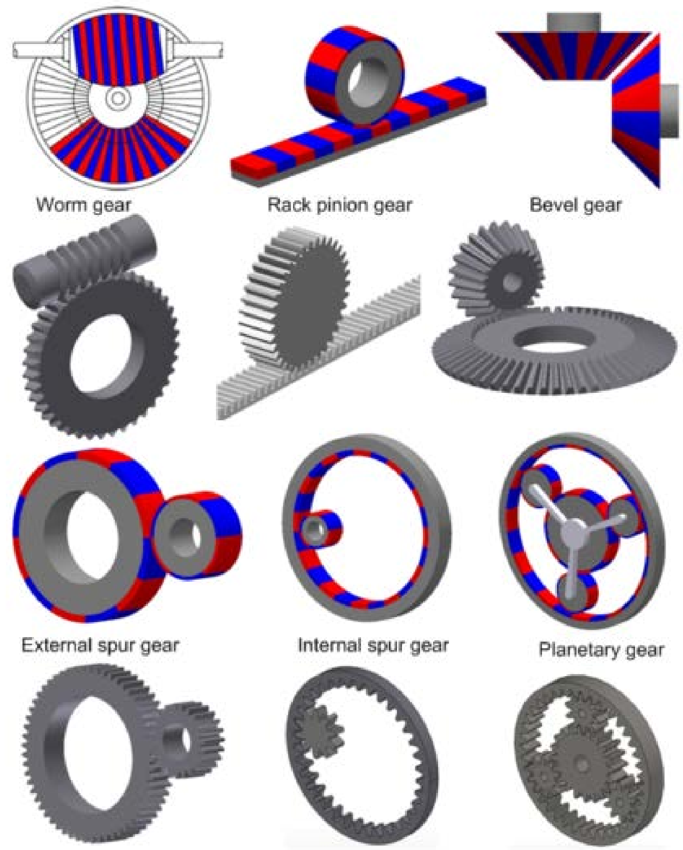
- Traditional mechanical gears are a leading cause of downtime with the highest associated costs to repair.
- Opting for a direct drive system requires a physically larger system due to high pole number, increasing installation complexity. Additionally, studies have shown that the required power electronics result in comparable down times.
- Intermediary power take off systems, such as hydraulics, are proposed as an alternative but often suffer from poor efficiency and O&M issues.

The Magnetic Gear Solution

- Contactless torque transfer
- Machine sizing
- Overload protection

Magnetic Gear Development

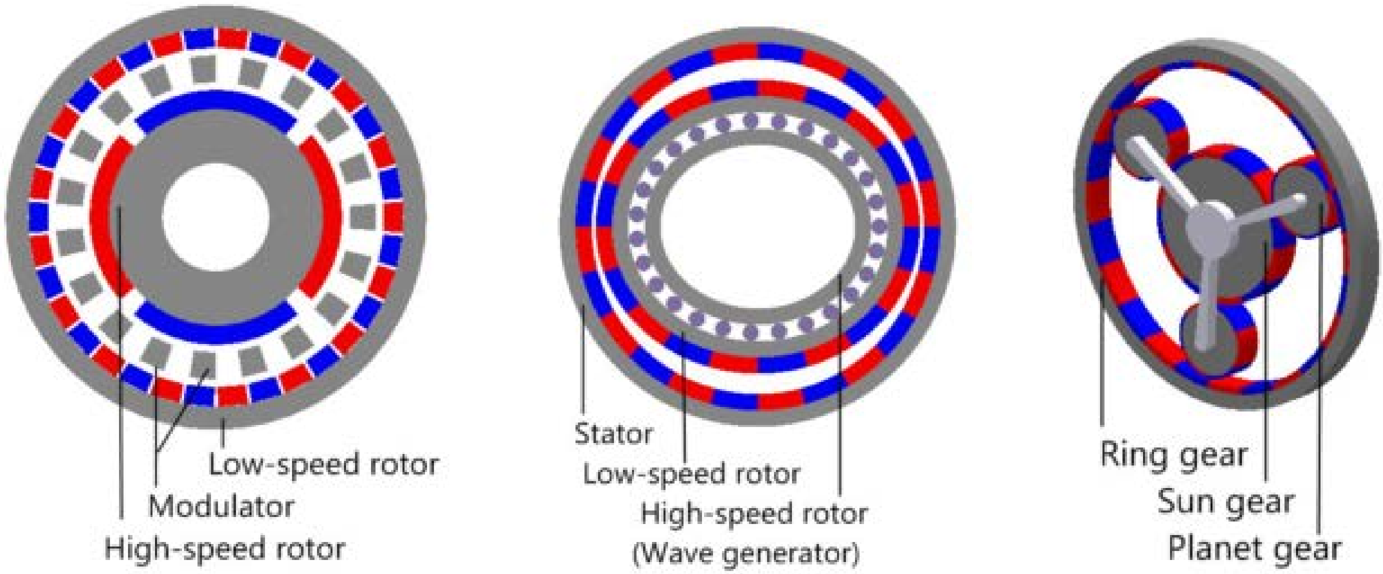
- First proposed in the early 20th century
- Based on traditional gears
- Low development and utilisation due to design and poor magnetic material
- Renewed interest in the 1980’s with the development of neodymium iron boron (NdFeB)



(-S. Tlali, P.M. and Wang, R.-J. and Gerber, “Magnetic gear technologies: A review,” 2014)

Modern Magnetic Gears

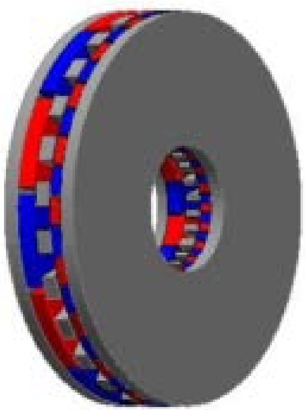
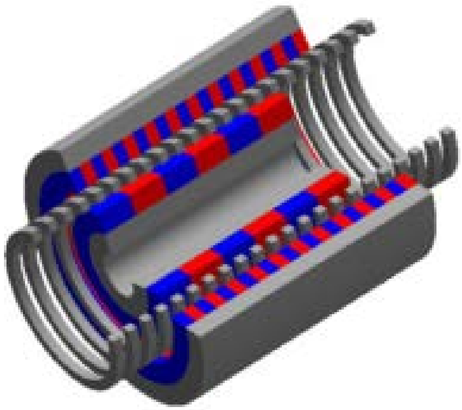
- 3 leading designs: Field flux modulated, harmonic and planetary.
- Comparable torque densities (100-200 $\mathrm{kNm/m^3}$)



(-S. Tlali, P.M. and Wang, R.-J. and Gerber, "Magnetic gear technologies: A review," 2014)

Ferromagnetic Pole Field Modulated Magnetic Gear

- Simplest to implement
- High permeant magnet material utilization
- Versatile (concentric, axial and linear forms)

(- S. Tlali, P.M. and Wang, R.-J. and Gerber, "Magnetic gear technologies: A review," 2014)

Gear ratio determined by:

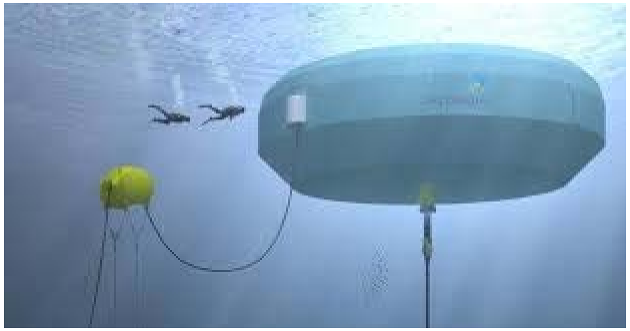
$$G_r = \frac{p_l}{p_h} = \frac{q_m - p_h}{p_h}$$

Capable of torque densities of between 70 and 150 kNm/m^3

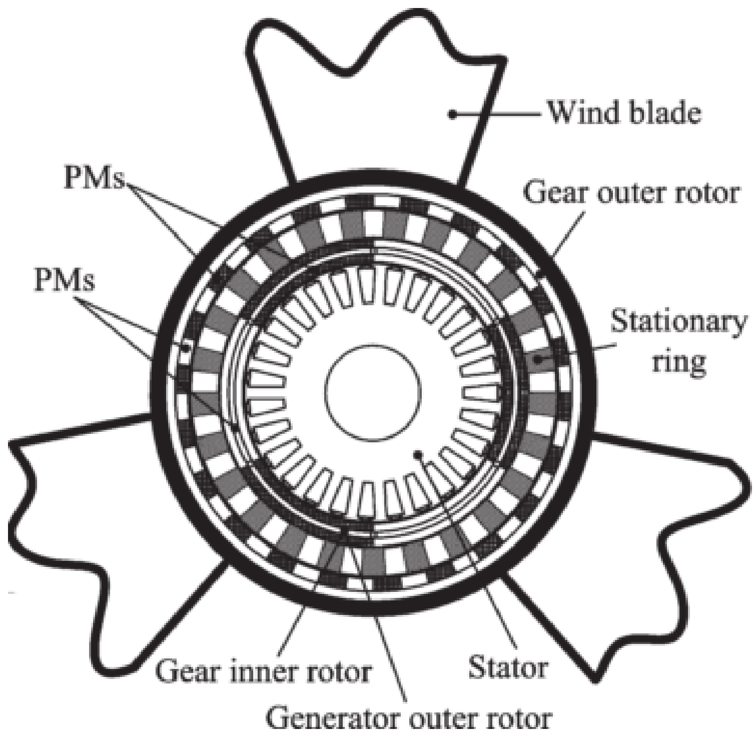
Application to Marine Energy Devices

3 device types:

- Bladed tidal turbine
- Heaving buoy wave energy converter
- Oscillating wave surge converter

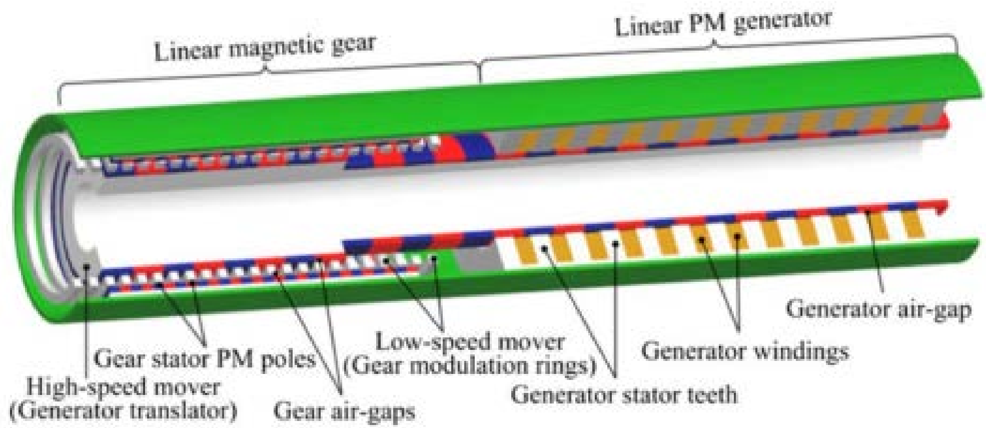


Bladed Tidal Turbine



(-L. Jian, K. T. Chau, and J. Z. Jiang, "A magnetic-geared outer-rotor permanent-magnet brushless machine for wind power generation,", 2009)

Heaving Buoy Wave Energy Converter



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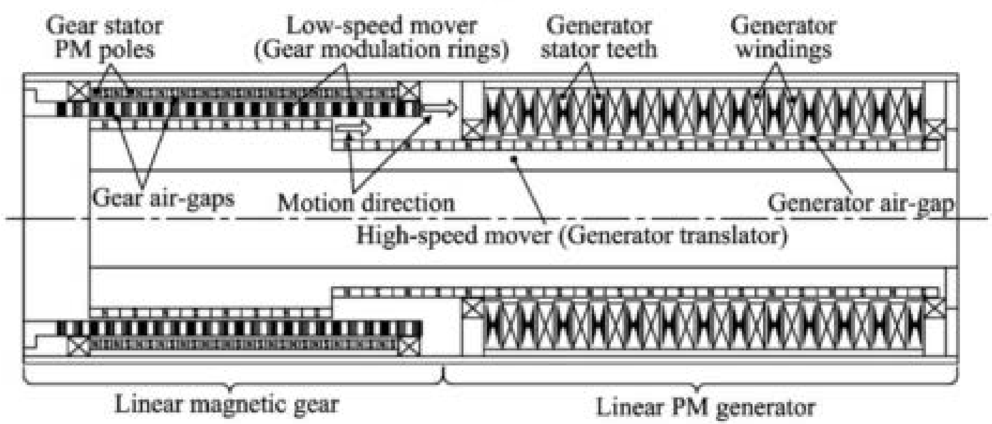

(b)

(-W. Li, K. T. Chau, and J. Z. Jiang, "Application of linear magnetic gears for pseudodirect-drive oceanic wave energy harvesting," 2011)

Oscillating Wave Surge Converter

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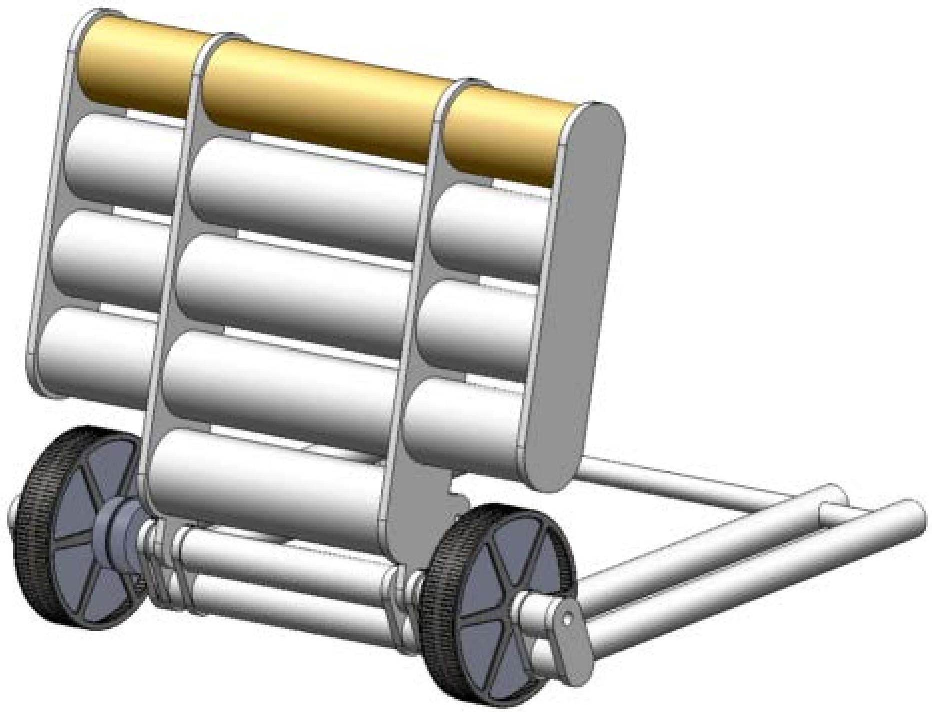

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Acknowledgments

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Thank You
Any Questions?