Modular PTO for Wave Energy Converters (MP-WAVE)

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SUPPLYDESIGN BESPOKE ELECTRONICS

mocean energy

THE UNIVERSITY of EDINBURGH

Supergen Offshore Renewable Energy

Project Aims

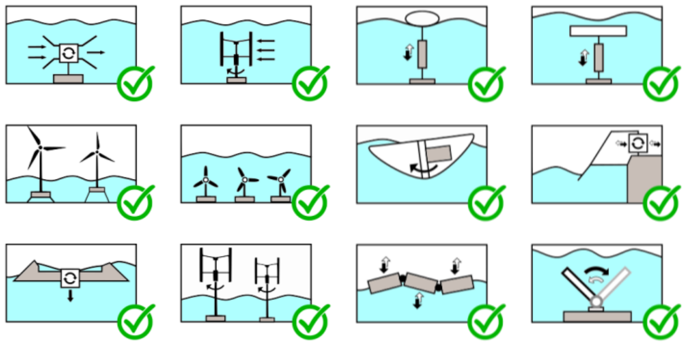
- Produce an optimized design of a modular integrated power electronics and permanent magnet generator topology

- The design and fabrication of integrated modules

- The production data which will feed into an LCOE & O&M analysis.

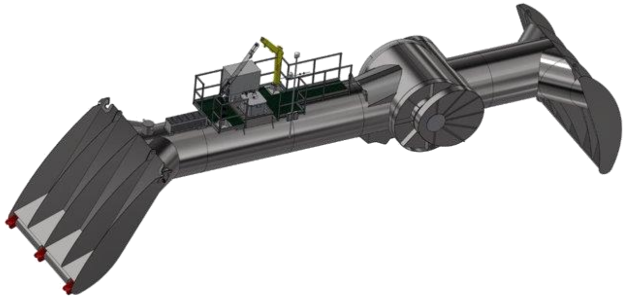
- Investigate modern materials and manufacturing processes

Project Background

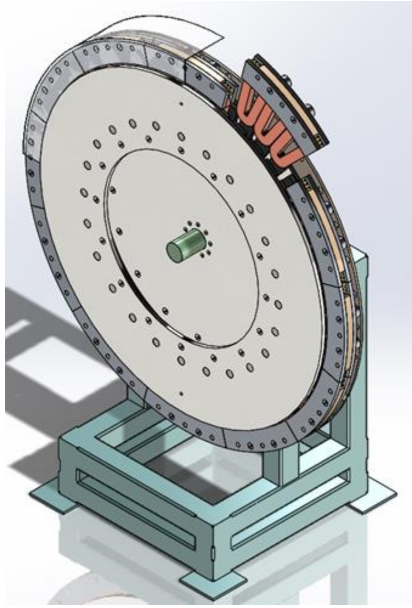


General Wave Energy and Environment Challenges

- Velocity is generally reciprocal; hence voltage is not a steady sinusoidal.
- Complex process to model with a wide variety of velocity and loading profiles
- High energy densities where power take off and power electronics survivability is key
- Remote and extreme environment where maintenance or repairing operations are difficult to achieve
- WECs have a preferred power performance region – but also must operate in extreme conditions.
- Generally, there is no provision for mechanically decoupling power take off
- When the WEC responds to very large waves, the generator may experience speeds of up to 6 times the design velocity



Modular Technology



Modular and multi stack systems have potential benefits for ORE

The CGEN Generator Technology Outline

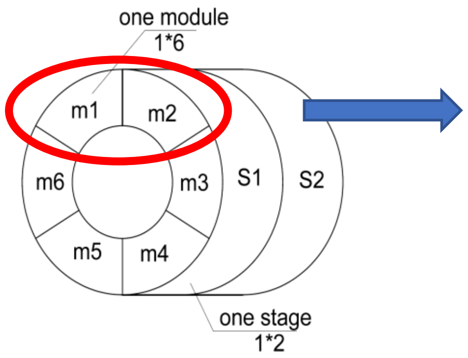
- Modular stator arrangement containing air cored stator assemblies
- Modular rotor or linear translator assemblies containing active magnetic material
- An axially stackable generator topology that can increase torque and power through the addition of C-Gen stages
- Generator divided into several axial generator stages that are electrically independent

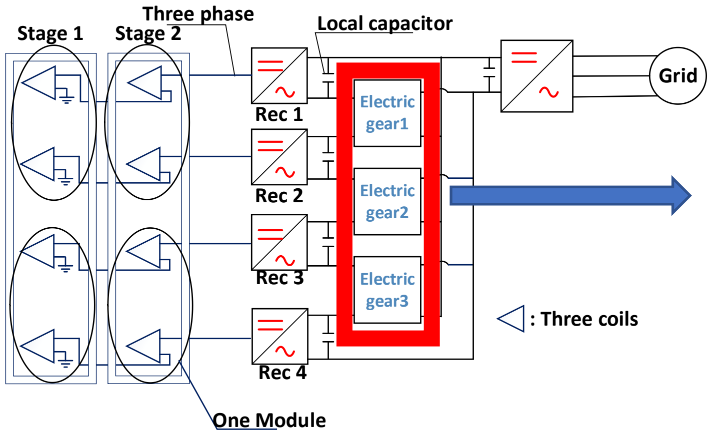
Modular power electronics lends itself to a modular and stackable generator system and could vastly increase the benefits of this technology

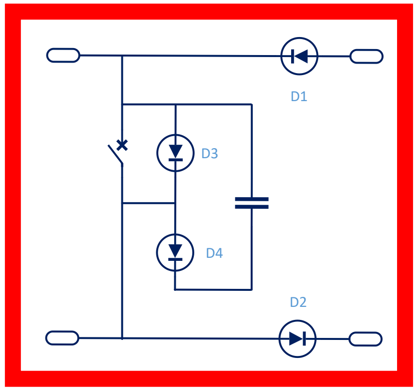
Radial Flux Generator composed of several C-Cores | Cut-away section through Rotor and Stator Module | Assembled Rotary Generator | Stacked Generators for higher ratings

Modular Power Electronics for 16kW C-GEN Machine

- A 16 kW C-GEN machine is used in this project. It consists of 2 parallel, concentric stages, with each stage formed of 6 arc-shaped.
- Two modules of the 16kW machine use the "modular power electronics technology".
- Converters are connected in parallel in the nominal state
- Converters can be transmitted to series by novel circuits-electric gears when the machine operates in the low-speed region.

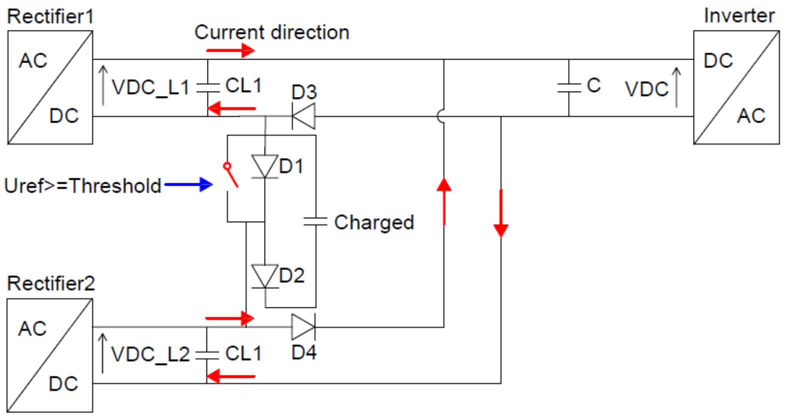


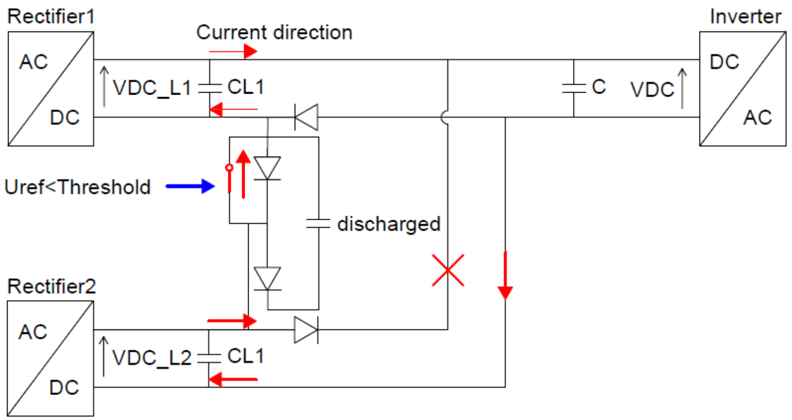




Electric gear

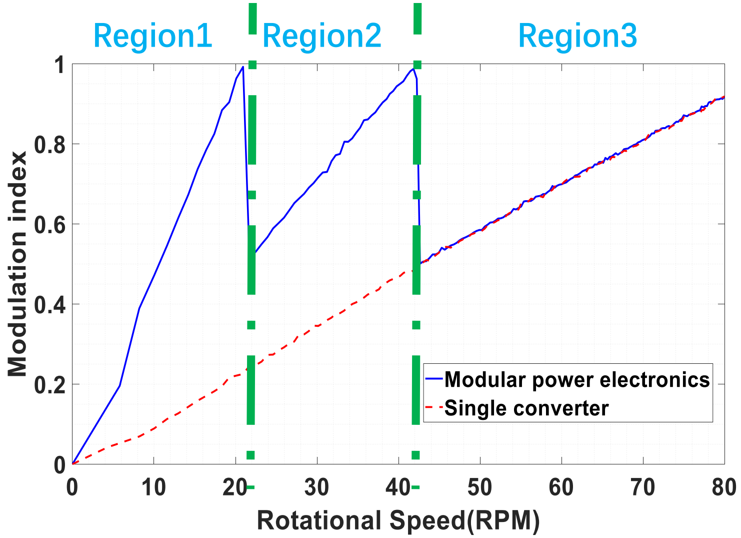
- Improve the modulation index of the rectifiers when the electrical machine operates in the low-speed region.
- The switch status is determined by the amplitude of the reference voltage (U_{ref}) used in the control system
- When the switch is open, the two rectifiers are connected in parallel , then VDC_L1 = VDC_L2 = VDC.
- When U_{ref} is smaller than the threshold, the switch is closed. The two rectifiers are connected in series ,then VDC_L1=VDC_L2=VDC/2.



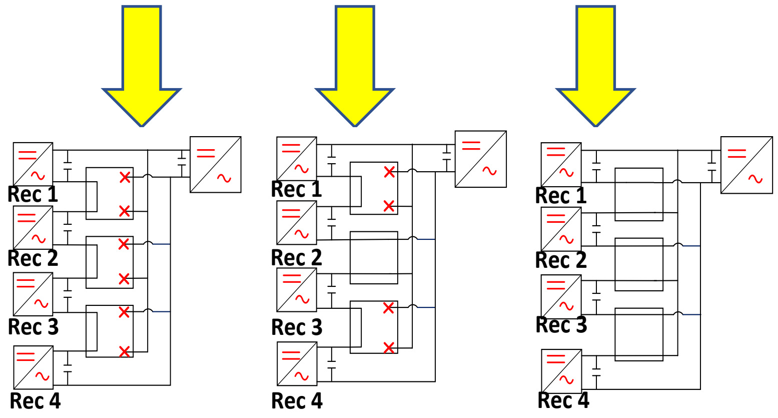


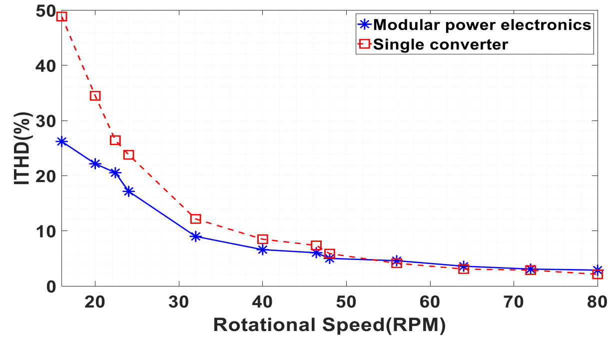
Simulation results

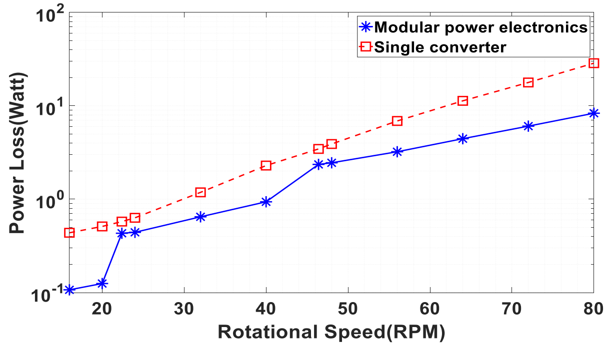
- Simulation results indicate the modular power electronics can improve the modulation index.
- The ITHD and efficiency are therefore improved.

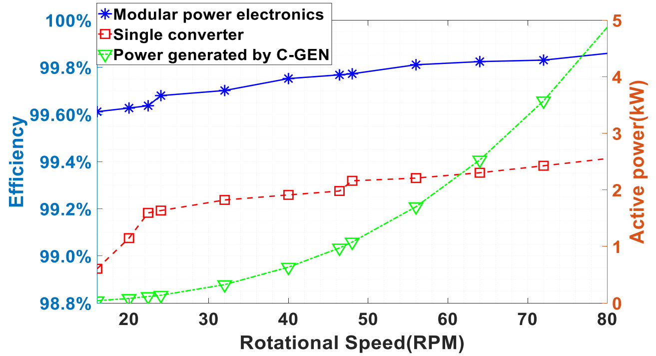


High modulation index over wide rotational speed



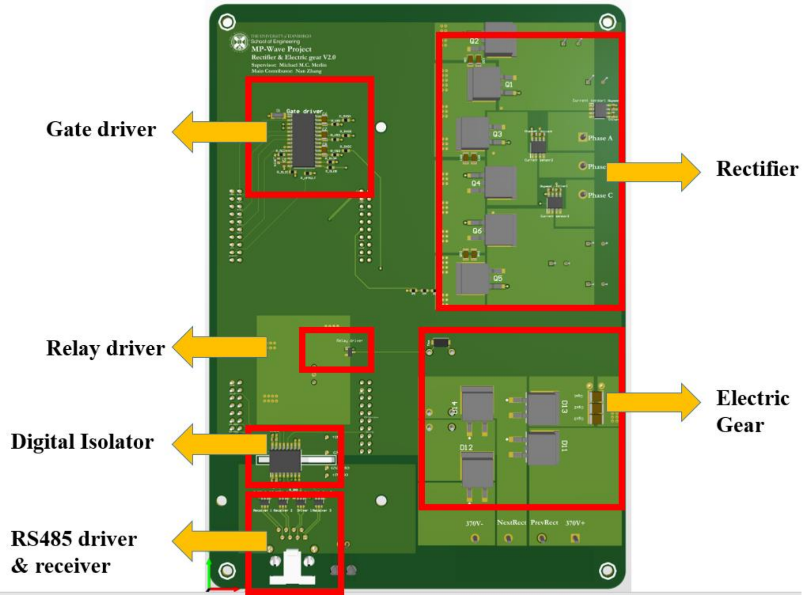




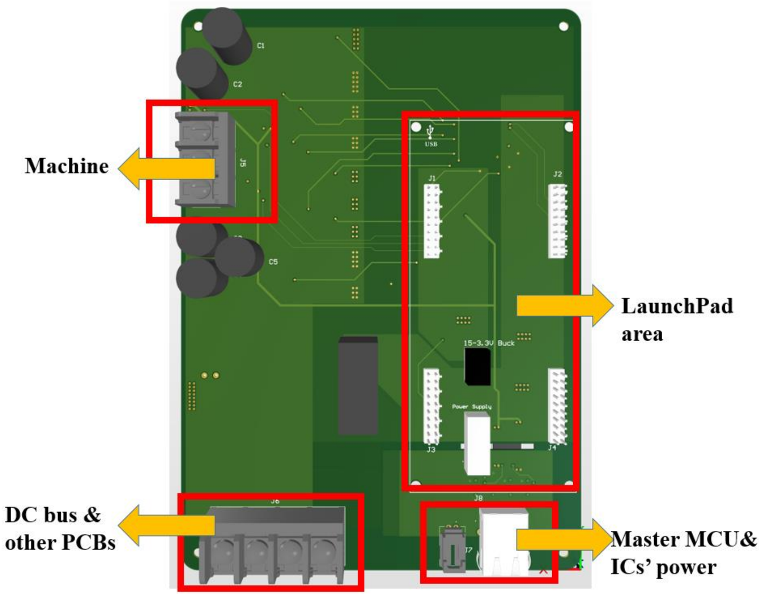


Hardware: PCB Design

- One rectifier and one electric gear are placed in the right side of the PCB, and the control system is placed in the left side
- The TI LaunchPad which contains a TMS320F28379D microcontroller (MCU) is plugged on the bottom of the PCB.
- The control program is downloaded to the LaunchPad, which can be interfaced with Matlab.



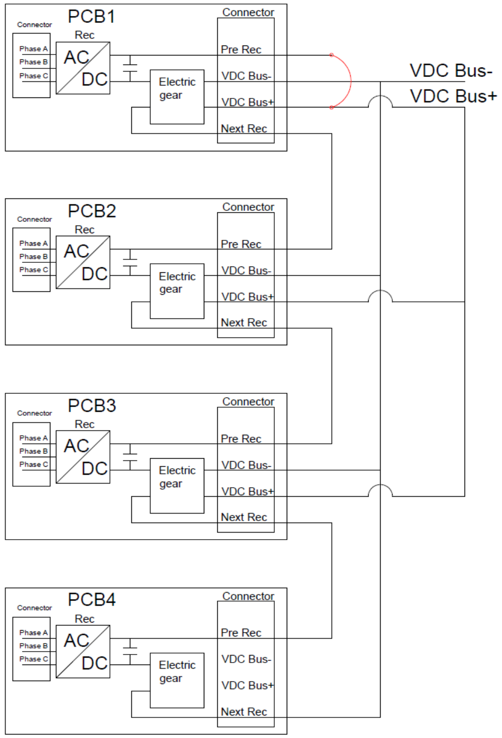
Top layer of the PCB



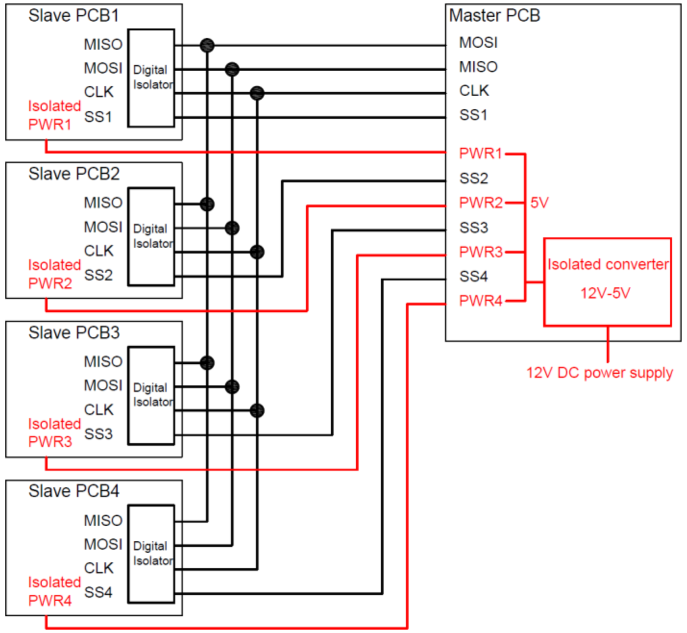
Bottom layer of the PCB

Hardware: PCB Design

- Four PCBs are connected with each other via 2.5mm^2 cables.
- The communication between the master MCU and slave MCUs is realized by RS485 standard, and the signals are transmitted through category 5 cables.
- All slave PCBs are powered by the master PCB, whose power is supplied by a 12V DC power

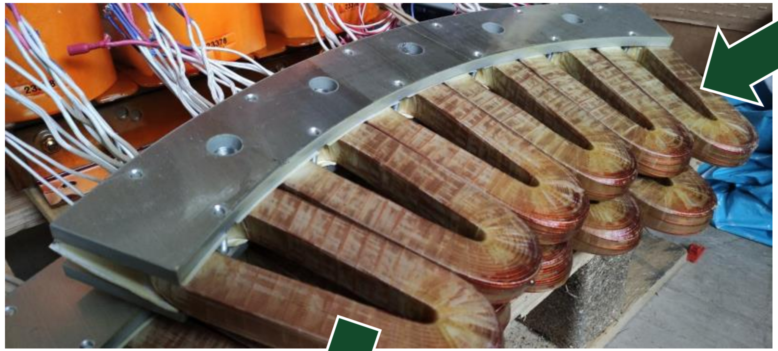


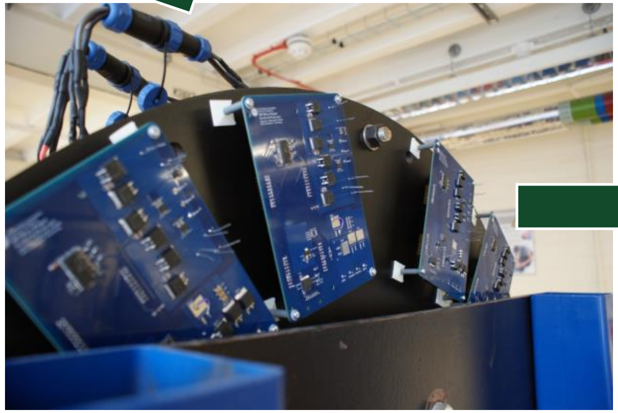
PCB connection

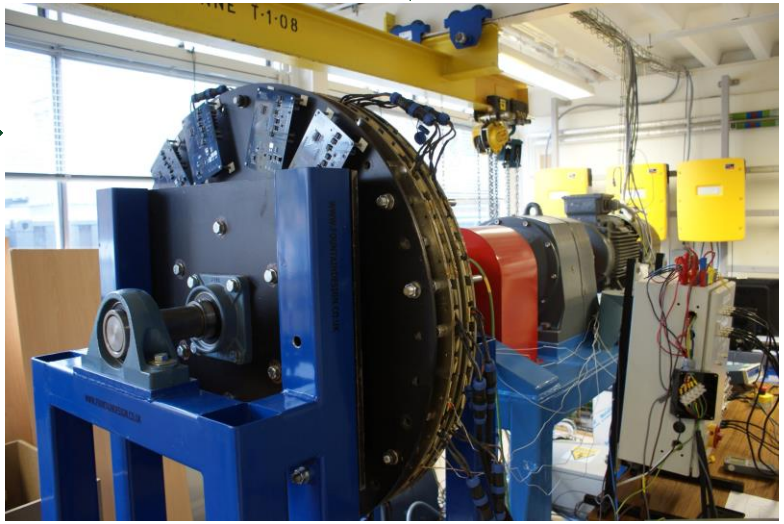


Communication schematic

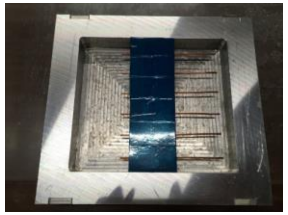
Prototype Modular PTO

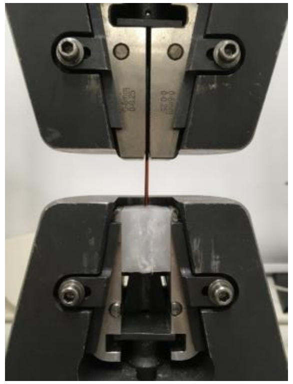






Module Material Protection Investigation





Manufacturing Assessment

- Injection moulding, compression moulding, transfer moulding, thermoforming and dip coating were assessed for suitability to pot and protect modular stator coils

Material Assessment

- Based on manufacturing techniques, suitable materials were investigated for their suitability epoxy, cross linked polyethylene, polyphenylene sulphide, polypropylene copolymer, polypropylene homopolymer and polycarbonate

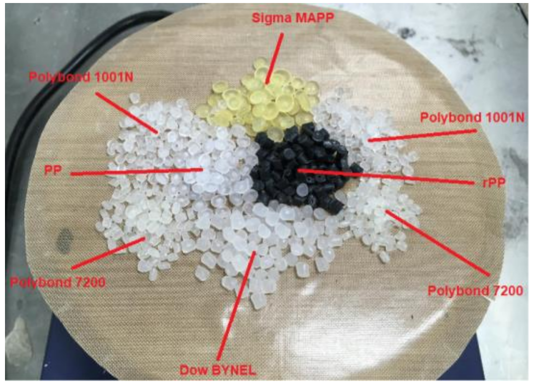
Material Modelling

- A stator blade was simulated using these materials and assessed against operational loading

Material Testing

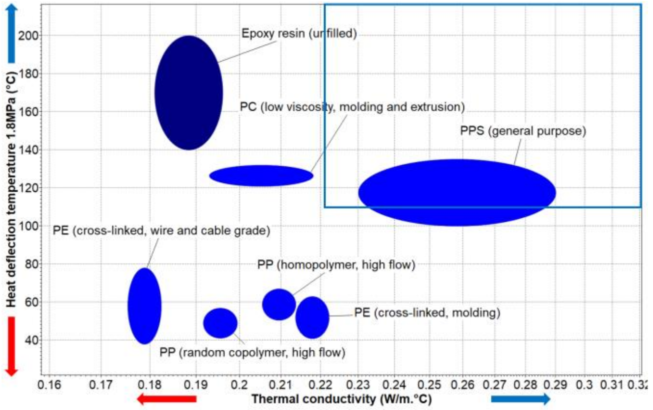
- Various compatibilizers, used to help bonding between differing materials, where investigated to aid manufacture

Module Material Protection Outcomes



Manufacturing Techniques

- Injection moulding holds significant promise → very high initial cost
- Transfer/compression moulding are possible alternatives → lower production speed
- Dip moulding provides the cheapest option



Material Options

- Polypropylene (PP) → most promising all round material
- Compatibilizers help improve the bonding of PP to different materials, including copper

Modelling Outcomes

- Polyphenylene sulphide, polypropylene and polycarbonate provide comparable support to the blade suitable for operation
- Polyphenylene sulphide performed best in all simulations