EDRIVE - MEC

EPSRC Supergen Marine Grand Challenge

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4.2 Electrical Generator Concepts and Design

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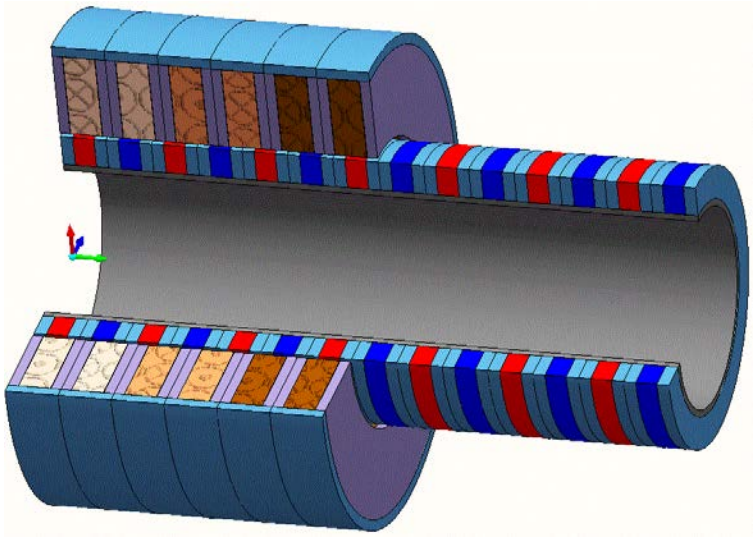
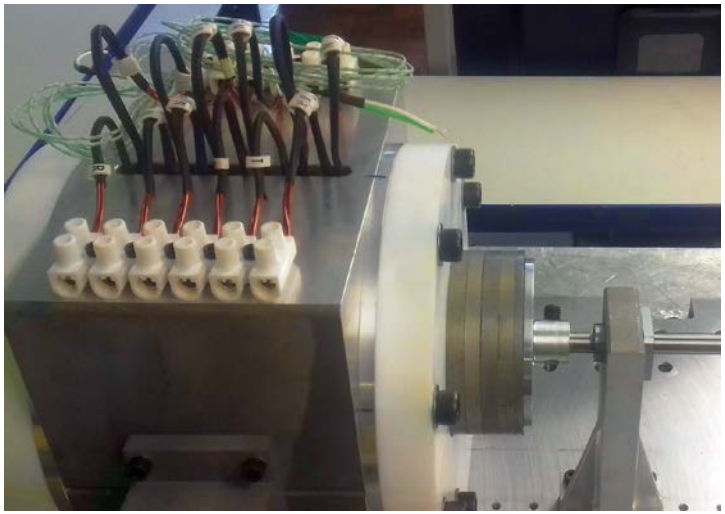
Overview

- Electrical machine options
- Summary of design process
- Prototype design

Linear generator development

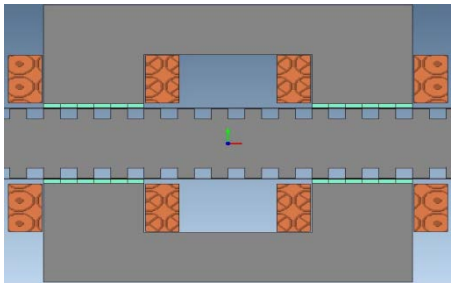
- High force or Torque Density
- Tend to use permanent magnet machines

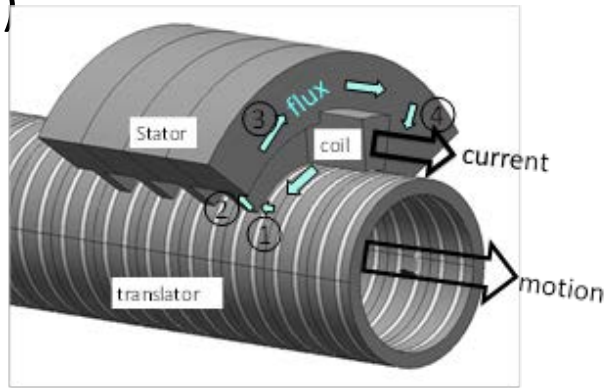


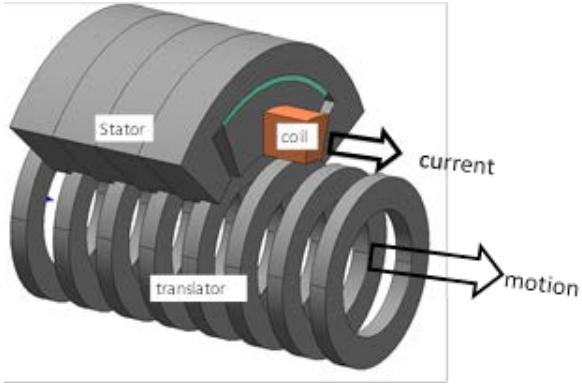


Linear generator development

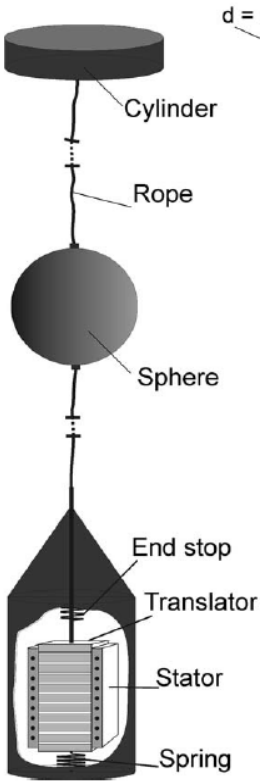
- Capital cost driven by magnet mass
- Use topologies with efficient magnetic circuit
- topologies being designed
  - Consequent pole
  - Vernier hybrid machine (VHM)
  - Transverse flux (TFM)
  - Flux switching (FSM)







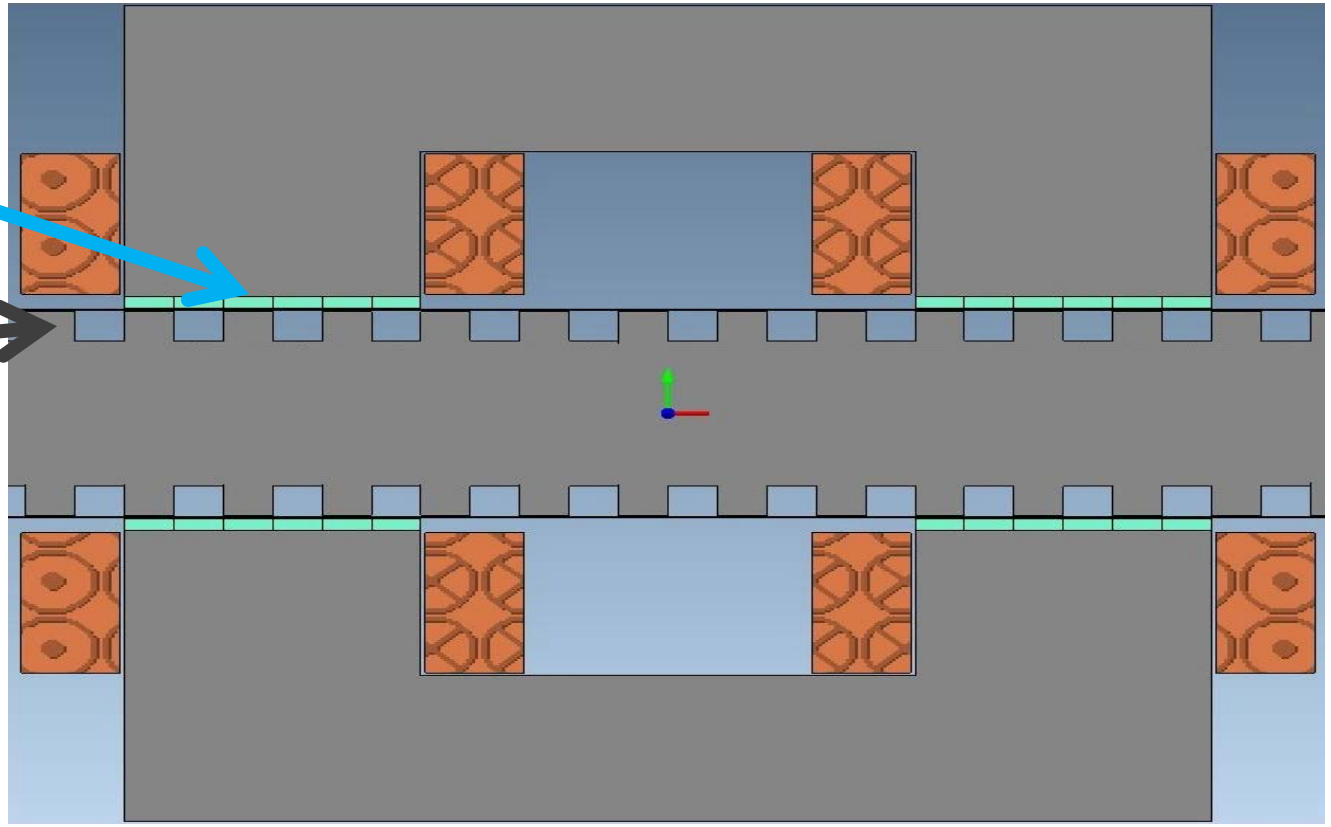
Design task



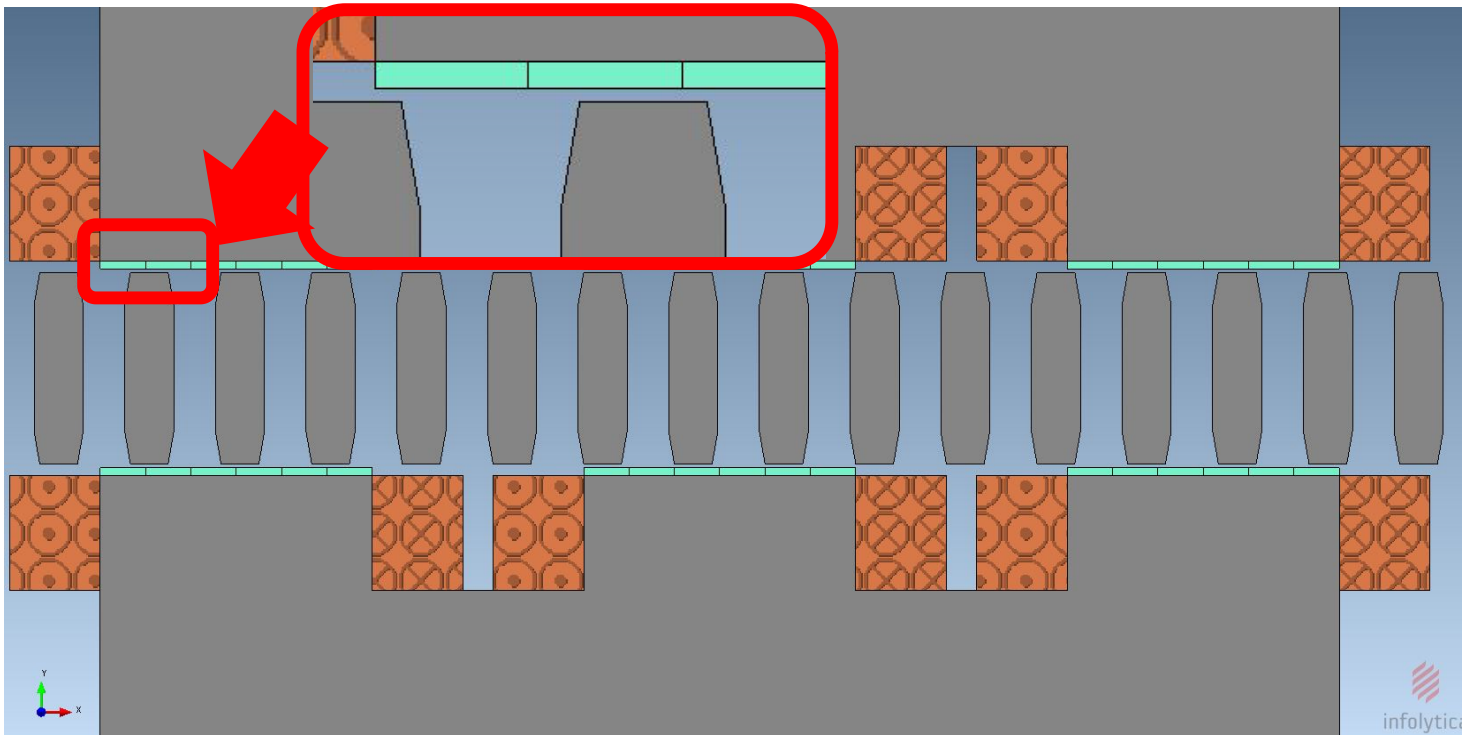
parameter	Value	Unit	comment
Number of modules	10		10 identical 3 phase units to make one single module
Average real power output	25	kW	
Rated force	44	kN	Average force over electrical cycle
Overload force	81	kN	Average force over electrical cycle
Amplitude of oscillation	1.375	M	(i.e.2.75m peak to peak)
V_{phase} output	240	V_{rms}	Limit of DC voltage
Current density	3.5	A/mm^2	RMS over full mechanical cycle
	7	A/mm^2	Peak value at peak of rated power
	12	A/mm^2	RMS at overload condition
	17	A/mm^2	Peak value at peak overload power

Benchmark machine

Magnets
+
Teeth
=
magnetic
gearing



Maximise performance

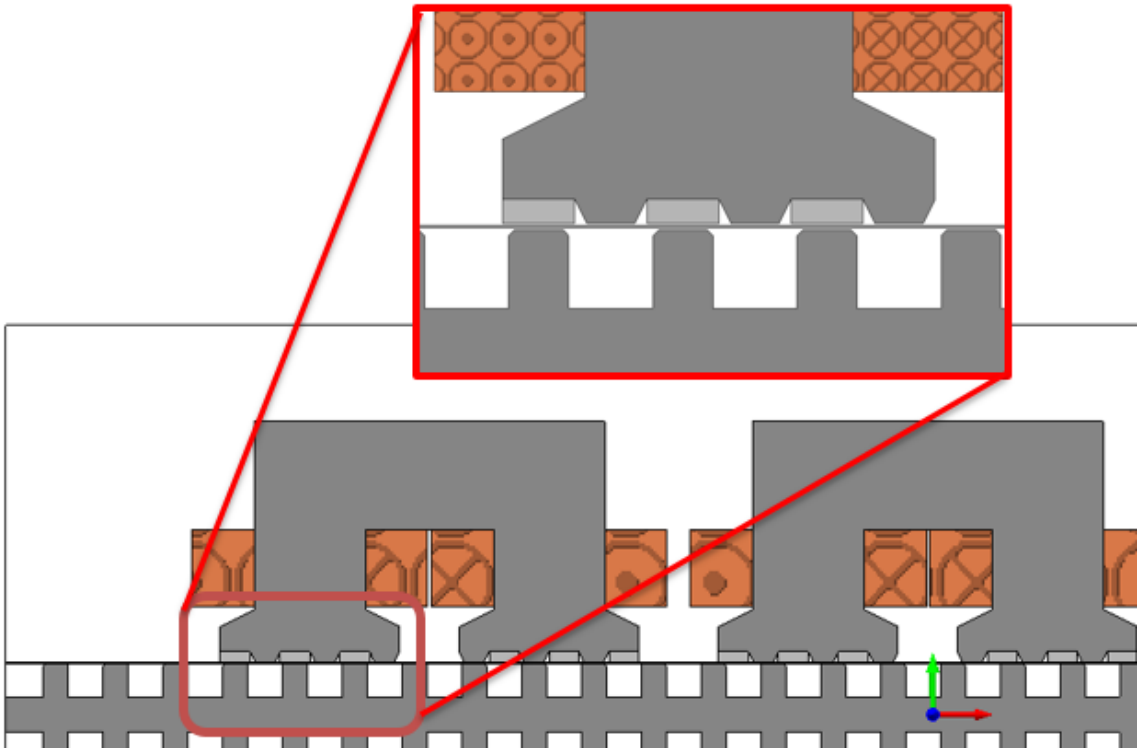


Initial results

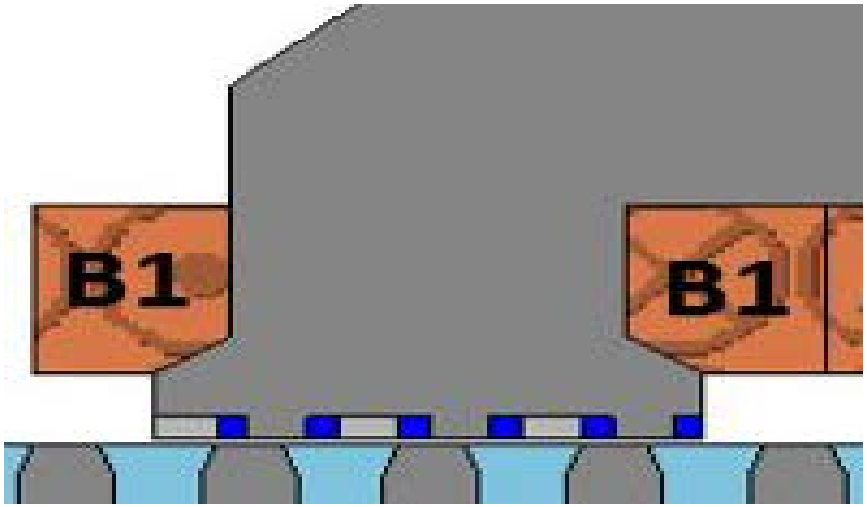
Parameters	C-core VHM	E-core VHM	Improved E-core LVHPM
Magnet thickness (mm)	4	4	2.1
Force (kN)	4.9	4.8	5.6
Cogging (kN)	0.6	0.5	0.2
Back EMF / turns (V)	0.98	1.1	1.3
Magnet mass (Kg)	2.55	2.55	1.34
Stator mass (Kg)	83	83	68
Translator mass (Kg)	44	44	13

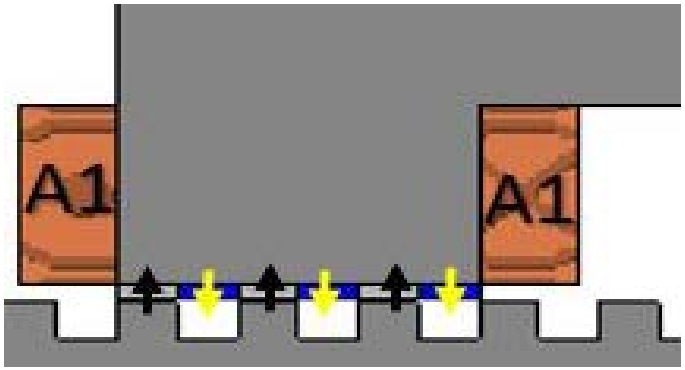
Consequent pole:

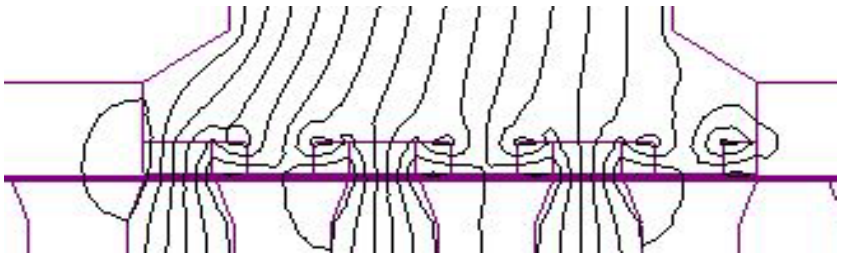
Minimise magnet material

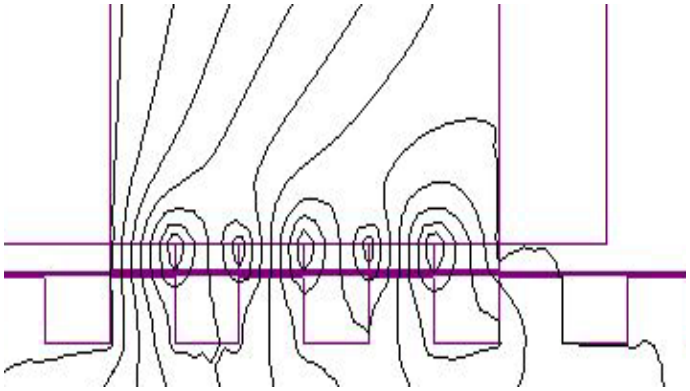


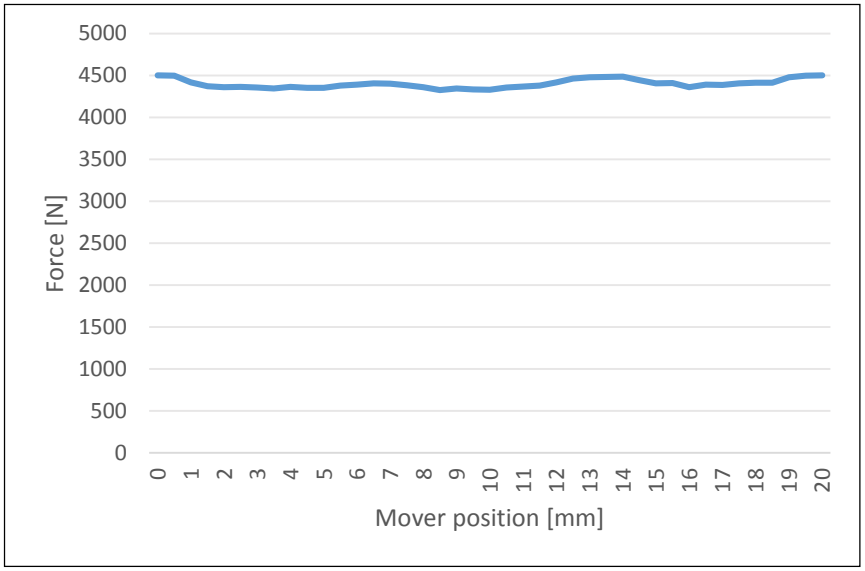
Consequent pole:
Minimise magnet material

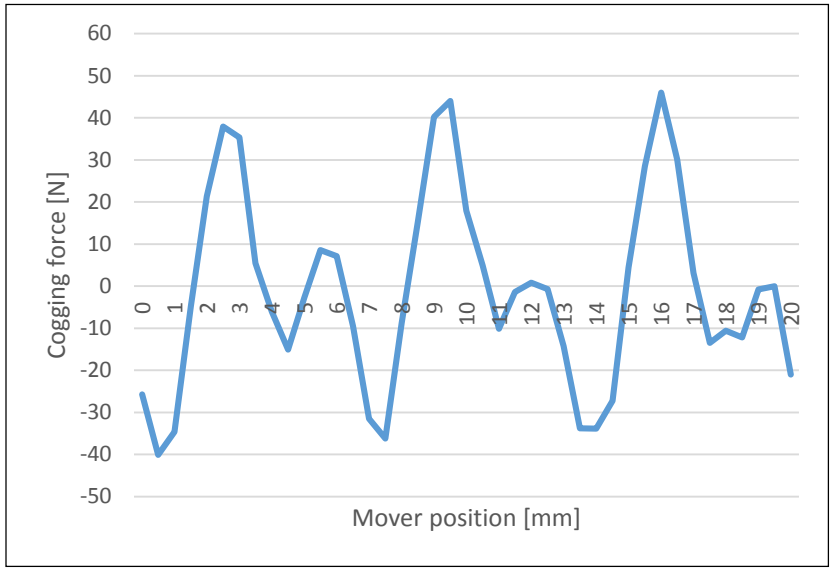










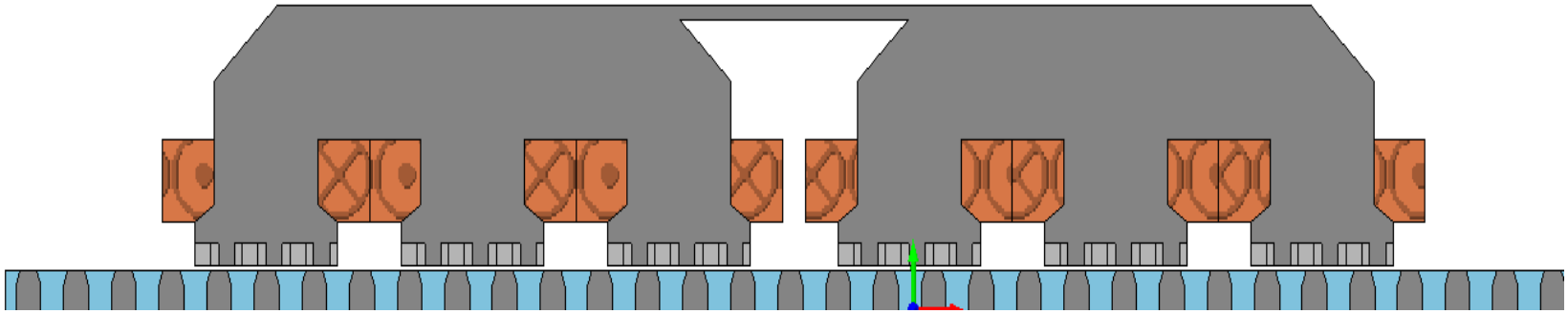


	2.5 kW (single module tested in lad)	25 kW full machine
Force	4.4 kN	44 kN
Force ripple	4%	8%
Cogging torque pk-pk	86 N	172 N
V phase	240 Vrms Limit of DC voltage	

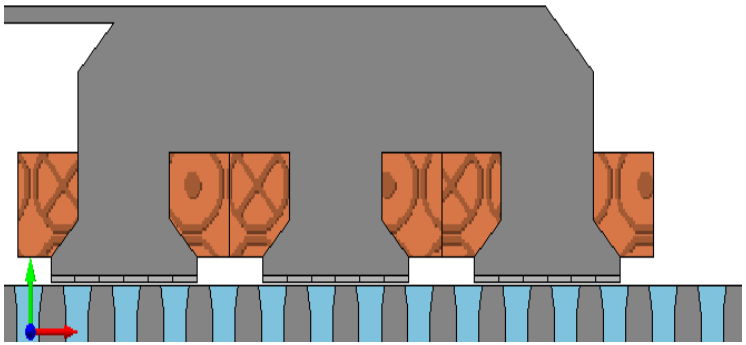
	2.5 kW (planned prototype)	25 kW (full machine)
Active length (m)	0.6	3.2
Axial length (m)	0.08	0.2
Machine height (m)	0.2	0.2
Magnet mass (kg)	1.05	10.5
# turns/ coil	41	
Magnet width (mm)	12	
Magnet thickness (mm)	4	
Stator mass (kg)	42.3	423
Coil mass (kg)	13	130
Active mover mass (kg)	8.75	80.8

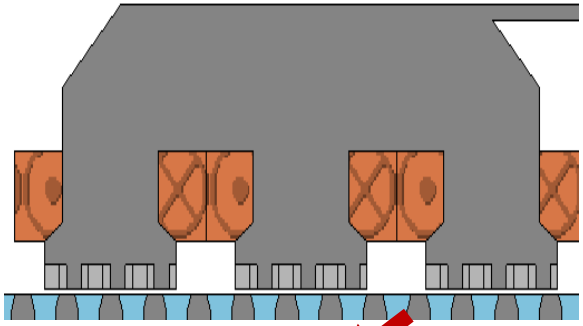
Power Factor = 0.2

Power factor v mag mass

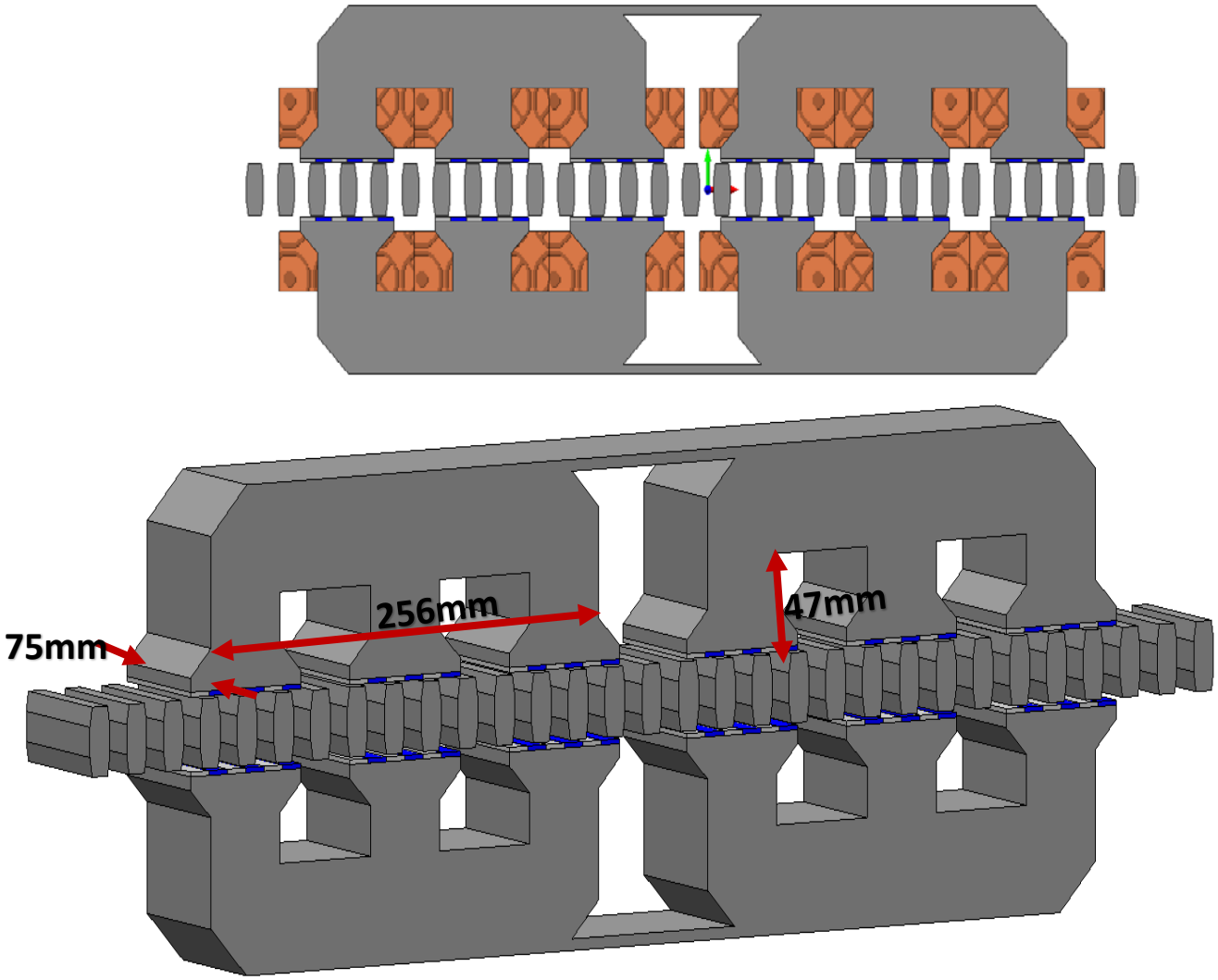


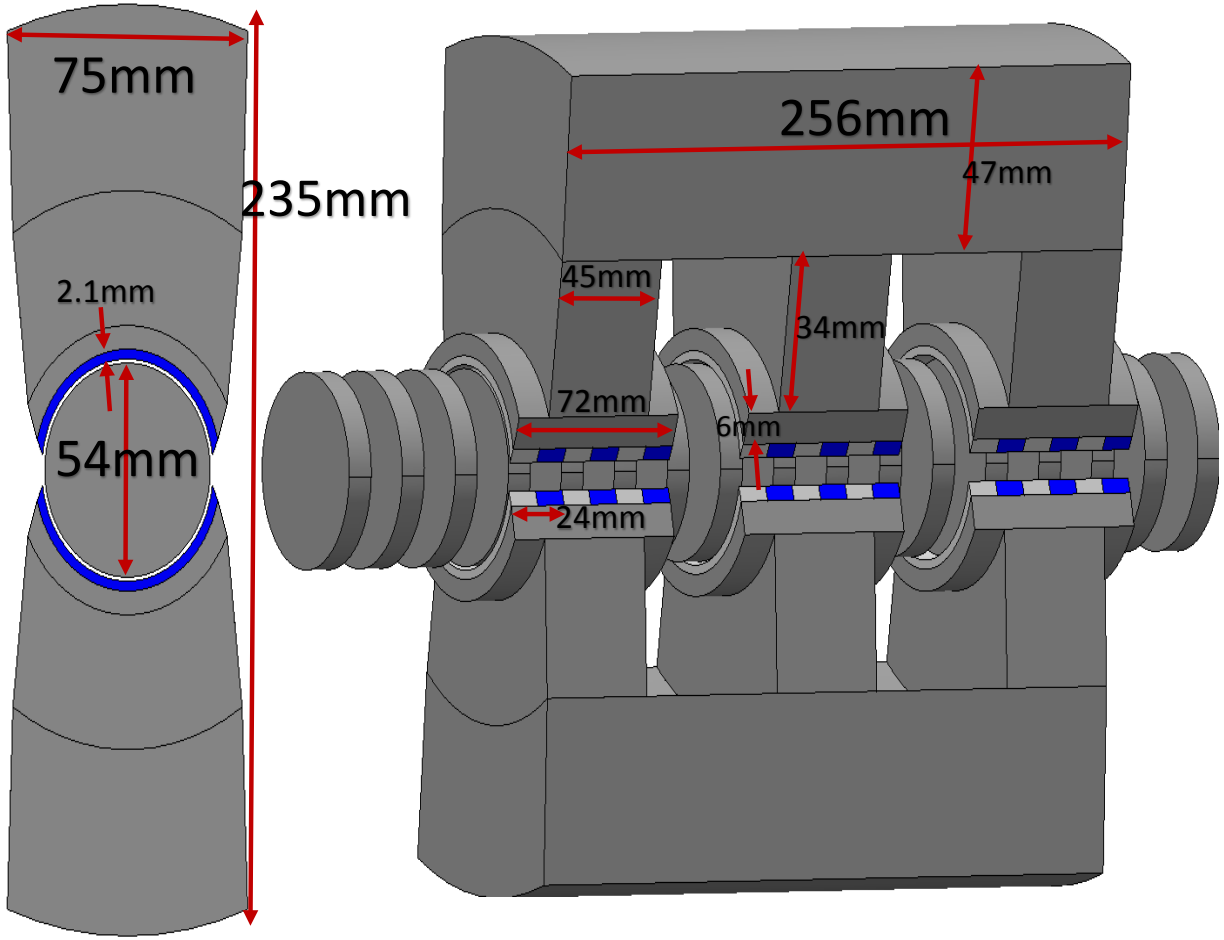
		AG=1_mag=8mm	AG=2_mag=8mm	AG=1_mag=4mm	AG=2_mag=4mm
PF	Lx=75mm	0.38	0.17	0.21	0.09
	Lx=110mm	0.68	0.37		
	Lx=150mm	0.79	0.35	0.52	0.17
	Lx=225mm				0.26





2.5KW prototype models			Design#1	Novel#1
Module				
	Number of magnets		72	108
Stator mass	Kg	magnets	1.02	2.59
		copper	13.6	12.4
		total	41.5	45.3
No Load	N	Cogging	182.6	114.5
	V	Back EMF	40.4	70
Rated current	N	Force	4435	4400
		Force Ripple	310	376
	V	Terminal Voltage	*255*	*185*
		Power factor	0.23	0.39


75mm
256mm
47mm


75mm
235mm
2.1mm
54mm
256mm
47mm
45mm
34mm
72mm
6mm
24mm

Machines summary

- Slow speed machines tend to imply permanent magnet topologies
- Good magnetic circuit implies poor power factor
- Balance between VA rating and magnet mass
- Have designed for 2.5kW and 25kW
- Have preliminary designs for laboratory prototypes