EDRIVE - MEC

EPSRC Supergen Marine

Grand Challenge

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5.1 Power Electronics Converter Developments

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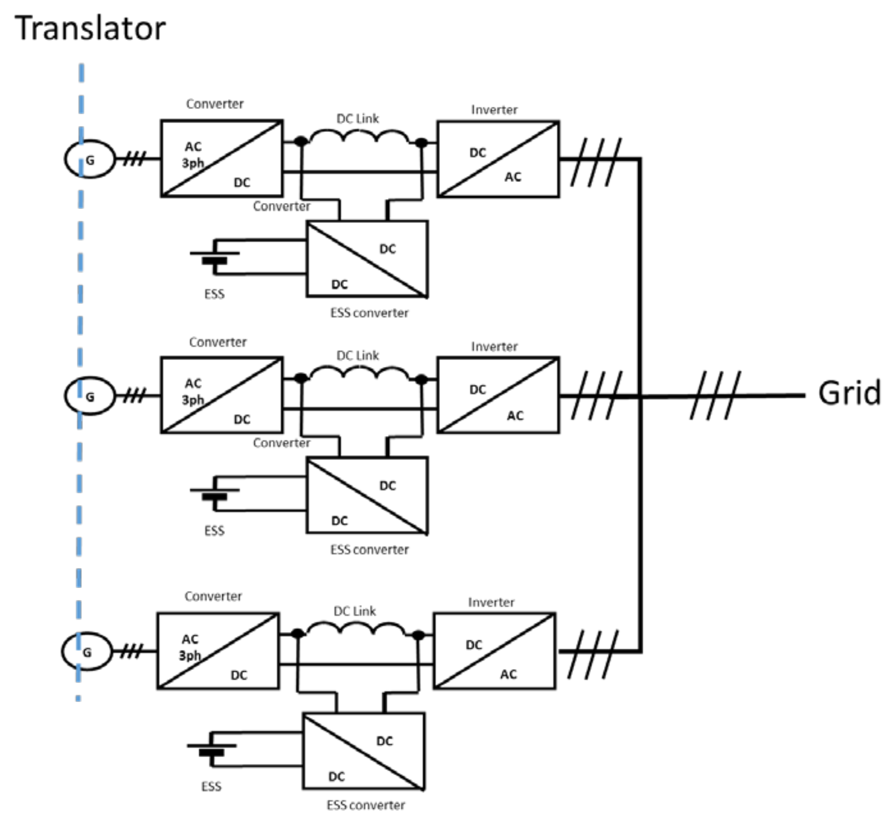
Overview

- Introduction to Electrical Power Converter (EPC)
  - Generator interface
  - Electrical energy storage
  - Grid interface
- Current source converter, generator interface
  - Modular concept
  - Space vector control
  - Initial simulation results

EPC configuration

- Modular approach for fault tolerance
  - machine built in sections
    - minimise ripple currents due to 2^{nd} harmonic in DC-link.
    - Loss of one section will not result in loss of entire WEC output
- Energy storage (EES) is required
  - Rating TBD
  - WEC reactive energy control and power smoothing



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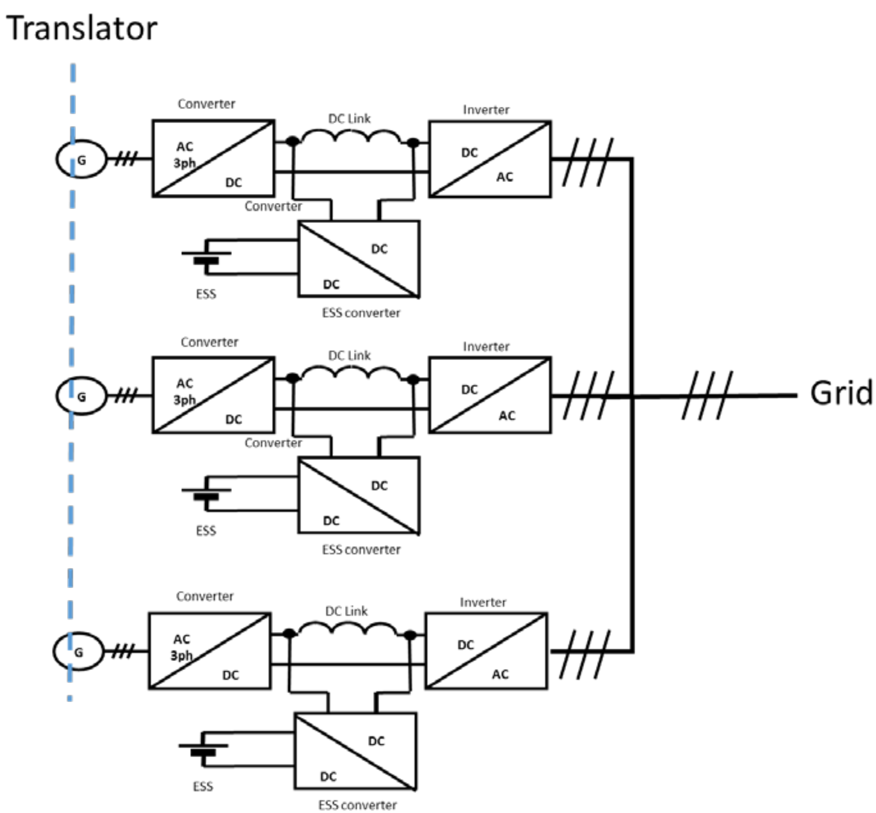
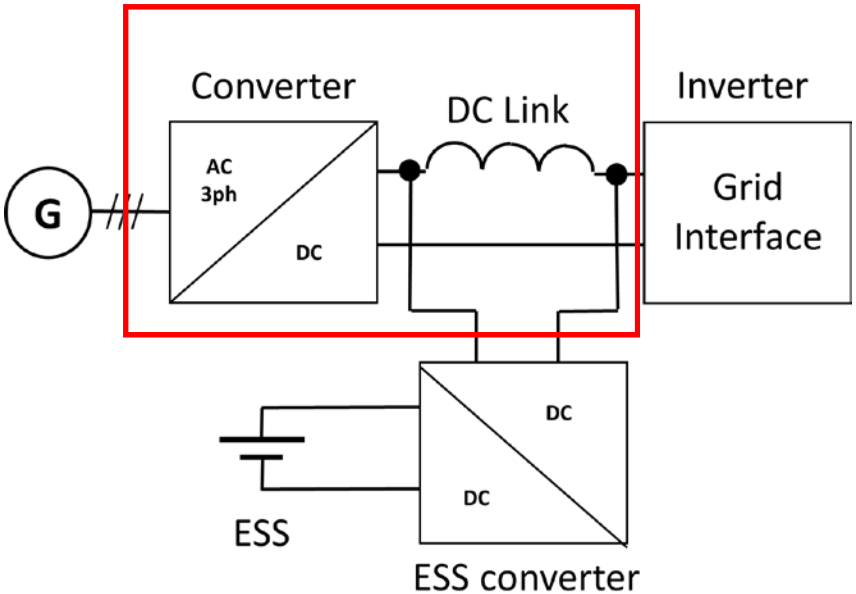
EPC configuration

- Direct grid interface at 11kV assumed
  - Conceptual
  - realistic requirement in WEC array
  - Multilevel inverter with isolation fed by multiple generator interfaces
- Housed within WEC or generator housing
  - Dimensional analysis required



Generator interface - CSC

Current Source Converter (CSC)



Why current source?

- Improved reliability in DC-link over electrolytic caps
- Potentially better utilisation of devices (modulated link current)
- Comparable efficiency due to use of modulated link and RB-IGBT's
- Potentially reduced EMI

Energy Storage

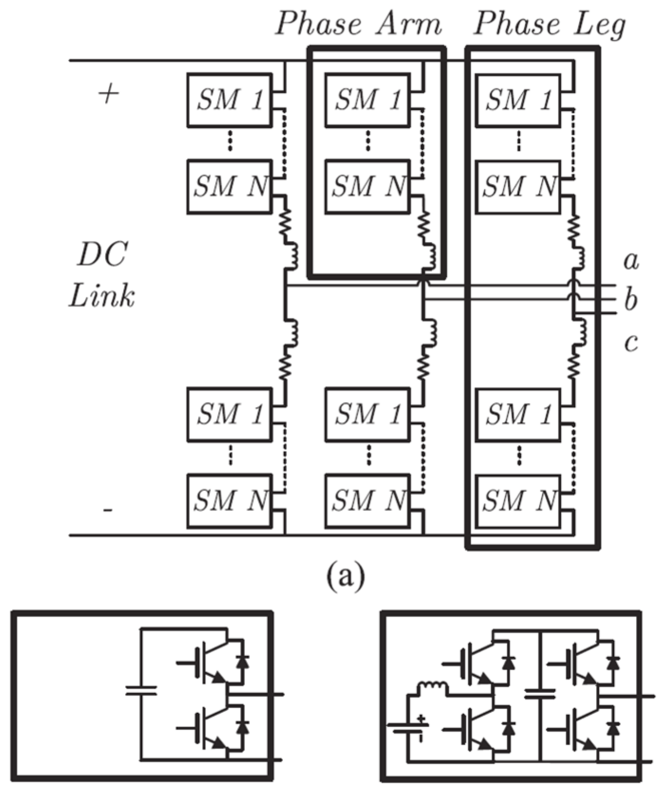
	Supercapacitor	LiNiMnCo battery
Specific Power (W/kg)	500-100,000	500-2400
Energy Density (Wh/L)	10-30	230-550
Specific Energy (Wh/kg)	2.5-15	126-210
Cost ($/kWh)	300-2000	300-600
Cycle Life	>100000	1200-1950

Other investigators have suggested that supercapacitor ESS could be applied to WEC's [1]. The advantage of the supercapacitor is the relatively high power capability and cycle life, but the energy density is quite low.

[1] G. Brando, A. Dannier, A. D. Pizzo, L. P. D. Noia, and C. Pisani, "Grid connection of wave energy converter in heaving mode operation by supercapacitor storage technology," *IET Renewable Power Generation*, vol. 10, pp. 88-97, 2016.

Grid interface

- multiple modules integrated to multilevel grid interface
- Details TBD, this is an area for Chile



(a)
(b)
(c)

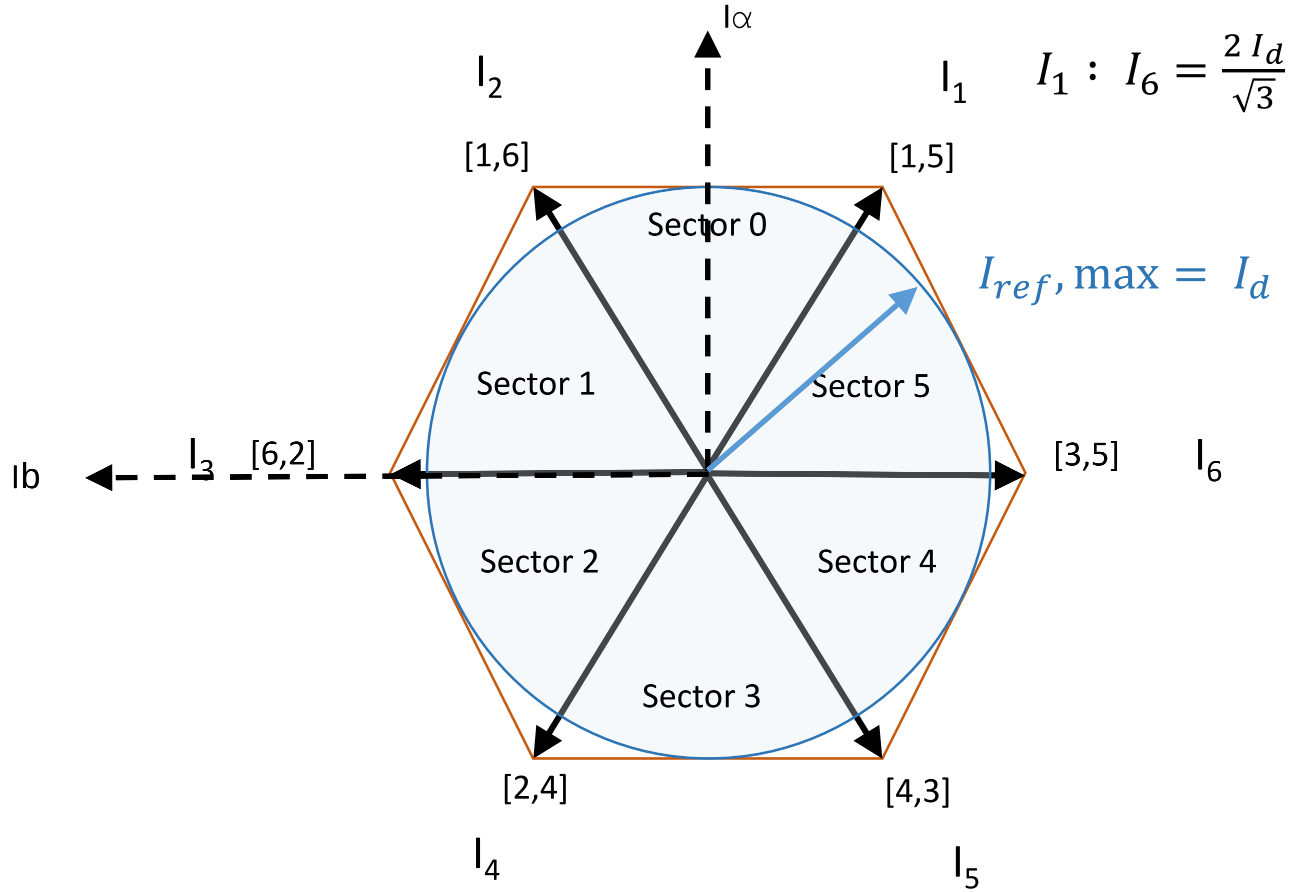
Grid interface challenges

- no galvanic isolation between the generator module/converter
- Insulate whole chain to withstand MV potential to ground and between generator modules.
  - excessive challenges in the machine design
  - increase the failure risk should one module fail.
  - Incorporating galvanic isolation by utilising a high frequency transformer within the chain is desirable.
- Tolerance of the multilevel inverter to a range of DC voltages at the module level requires further consideration.
  - If the ESS terminal voltage is coupled directly an individual module the overall step levels will change accordingly.
  - There are a number of multilevel inverter topologies based upon the Z-source concept that have built in buck-boost capability and could advantageously be combined with the generator interface and ESS.
- Optimising component count, cost, and reliability and ensuring overall complexity remains manageable.

CSI space vector control

- well-known method for the determination of device switching arrangements in a voltage source PWM inverter.
- Similar approach can be used in Current Source Inverters (CSI) by taking into account the particular switching requirements:
- Only energise two devices at any one time
- new device is energised before the previous device is switched off (overlap time).
- only one device switches at any one transition
- two zero states where no current passes to / from the load
- illegal state of open circuiting the DC link replaced by a Z –state - switching off all of the upper or all of the lower devices to charge the Z-source network.

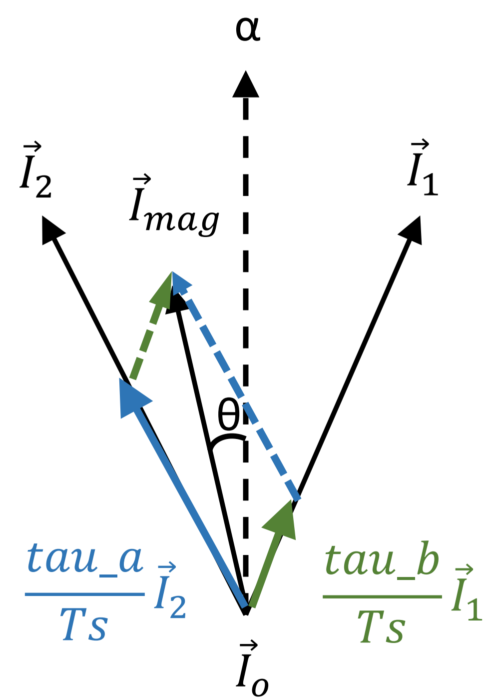
Sector definition



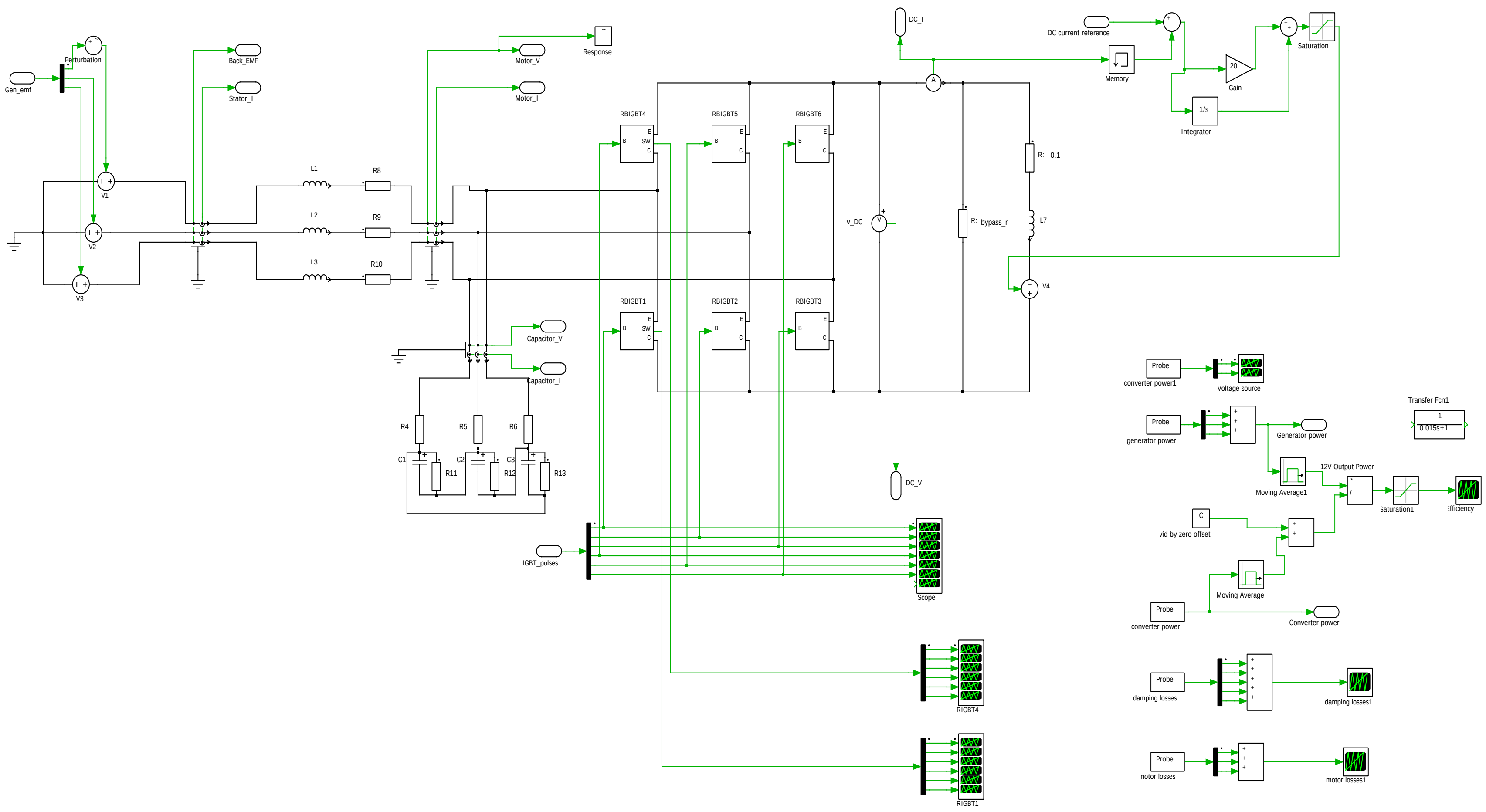
Vector control within sector

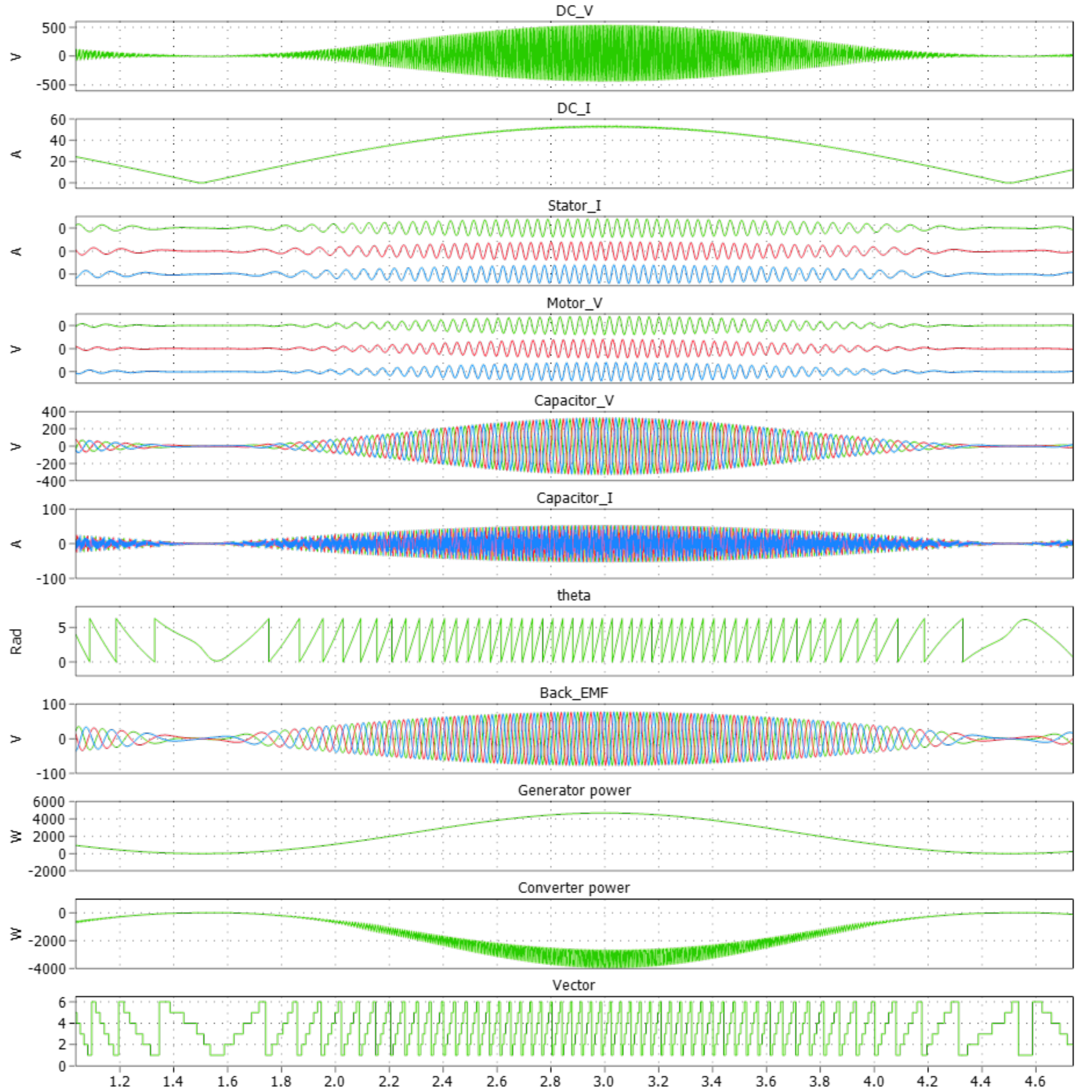
	State 0 ($\vec{I}_2$)	State 1 ($\vec{I}_1$)	state 2 ($\vec{I}_o$)
SW 1	on	on	on
SW 2			
SW 3			
SW 4			on
SW 5		0n	
SW 6	0n		

t=0 t=tau_a t=(tau_a + tau_b) t=Ts



PLECS model for CSI




DC_V
500
0
-500
V
DC_I
60
40
20
0
A
Stator_I
A
Motor_V
V
Capacitor_V
400
200
-200
-400
Capacitor_I
100
-100
theta
Rad
5
Back_EMF
Generator power
6000
4000
2000
-2000
W
Converter power
-2000
-4000
Vector
6
4
2
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
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4.6

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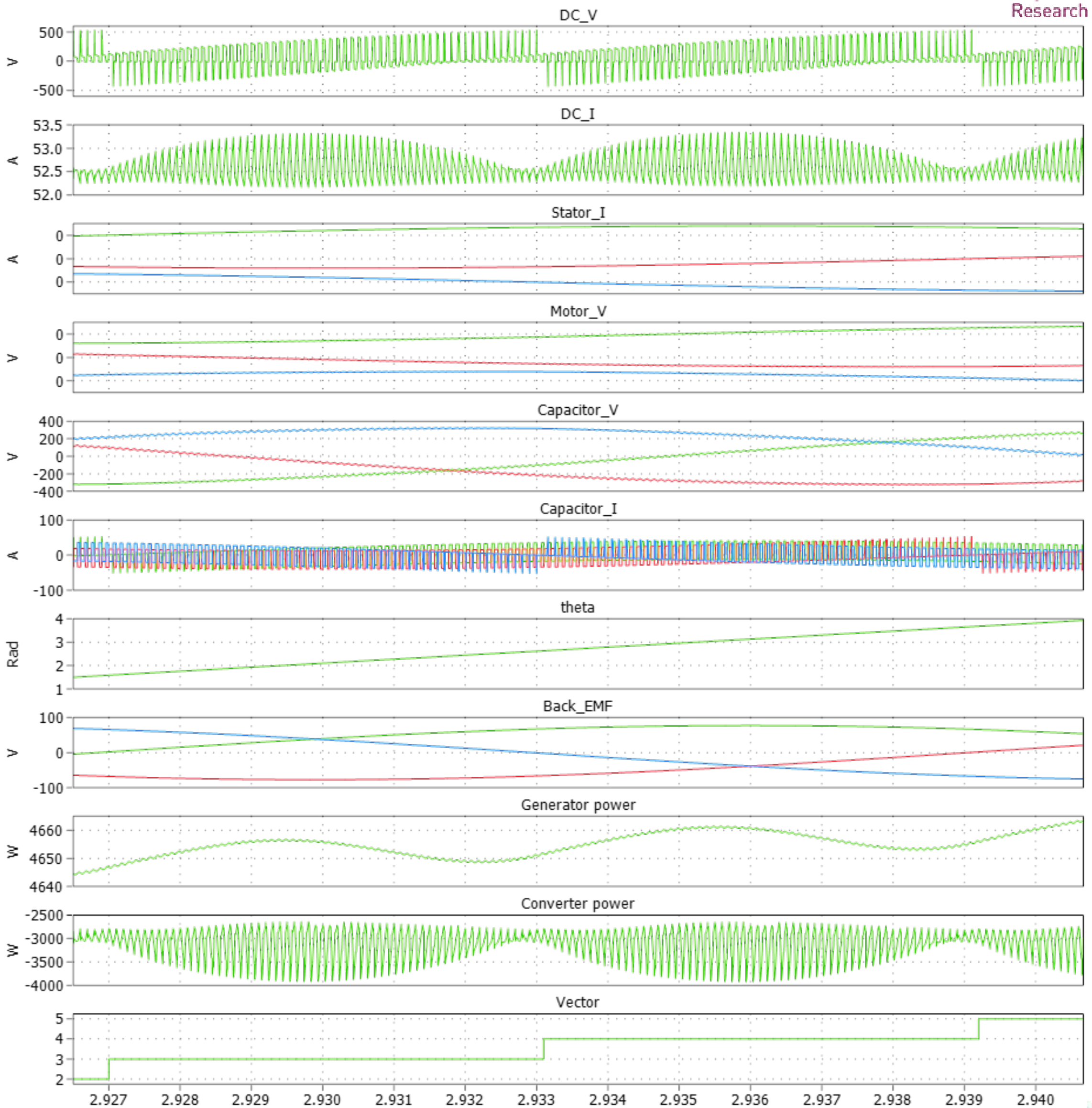

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Conclusions

- Modular topology selected for E-Drive
- CSC functionality for the E-Drive application has been validated by simulation
- Next steps:
  - Component dimensions, ESS requirements and comparative analysis with VSC
  - Prototype development
  - Control development

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Questions

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