Black Start from Offshore Wind

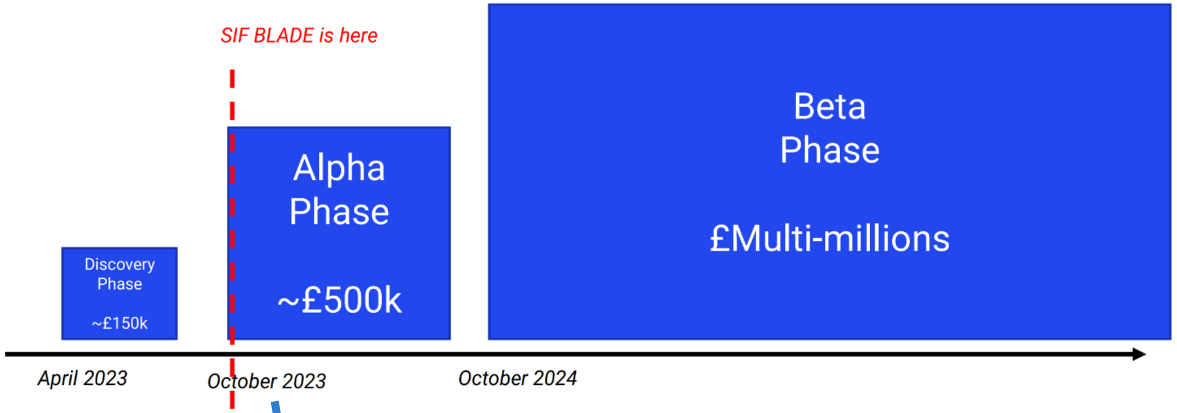
- Ben Gomersall
- The National HVDC Centre

SIF BLADE Overview

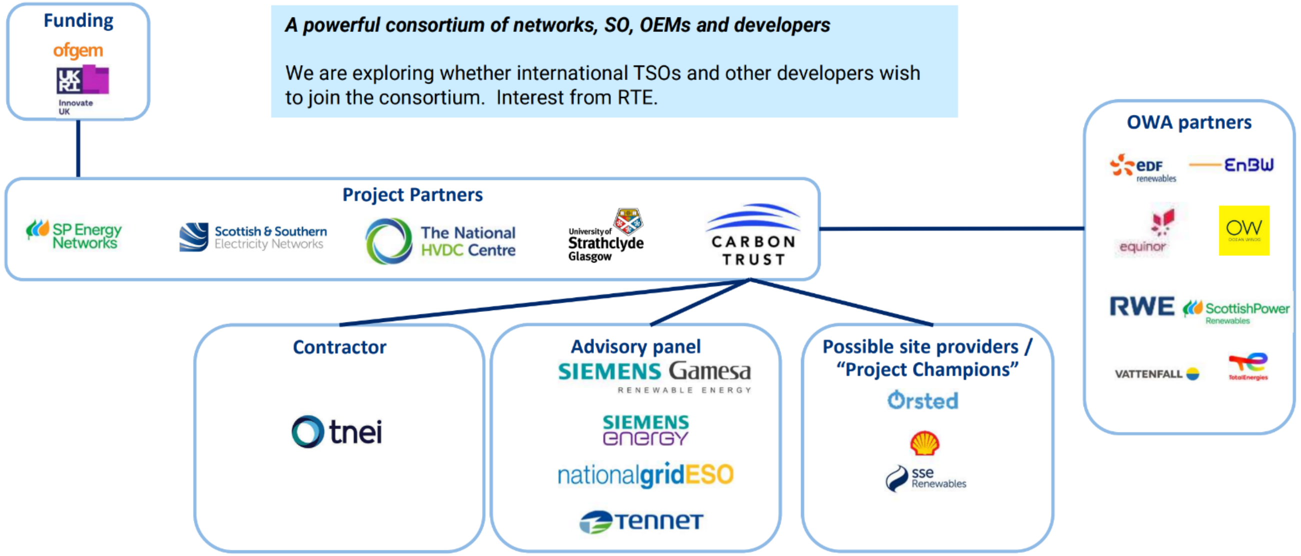
SIF BLADE: **Bla**ck Start **De**monstrator from Offshore Wind

<u>Innovation challenge:</u> *improving system resilience and robustness* ***(restoration from offshore wind)***

- Consortium of industry TOs, ESO, OEMs, offshore wind developers, and academia – led by SP Energy Networks



- Discovery Phase (3 months): Feasibility and literature review
- Alpha Phase (6 months): Proof of concept
- Beta Phase (up to 5 years): Demonstration



The Case for Coordinated Offshore Network Restoration

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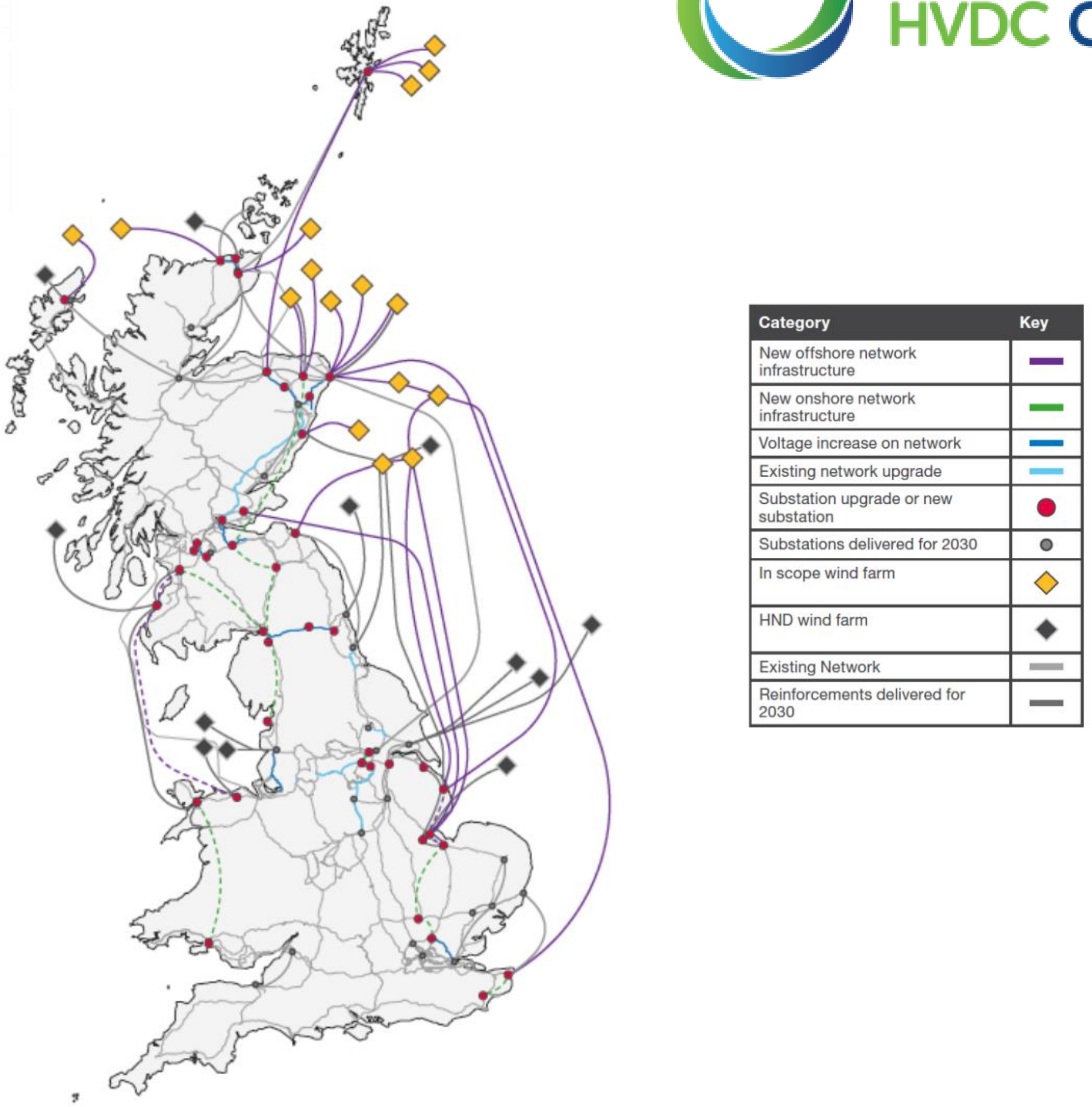
Holistic Network Design (HND)

- Published by system operator for how to connect future offshore wind
- 2030: up to 50 GW of offshore wind capacity
- 2035: up to 80 GW of offshore wind capacity

*If consensus is that wind is to play an integral role in future restoration scenarios, must **explore** options to utilise the coordinated offshore network and its resources*



Overview

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Define basis for generic modelling: MTDC – Realistic config and separation from parallel workstreams

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Develop generic model in RTDS/RSCAD environment

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Characterised HND restoration scenarios for time-domain simulation studies

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Perform studies and sensitivities to assess feasibility, benefits, and challenges

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Outcomes to inform future development including validation with HIL

Generic Modelling Basis

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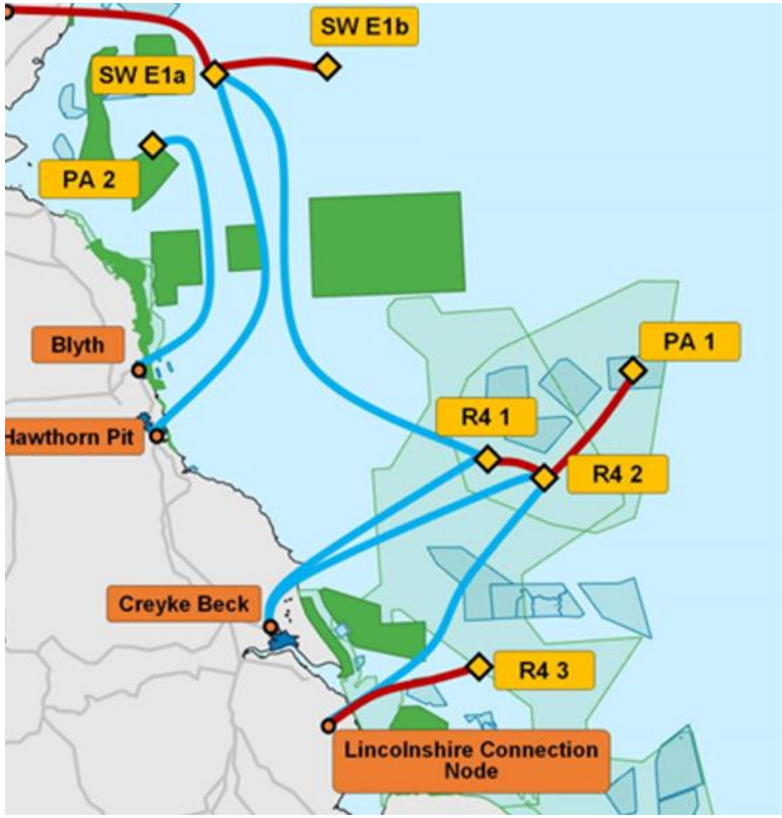
Other Workstreams in the project

- **WP1:** Strathclyde/SPEN looking at scenarios pertaining to P2P-AC
- **HVDC-BLADE:** RWTH AU looking at scenarios pertaining to P2P-DC



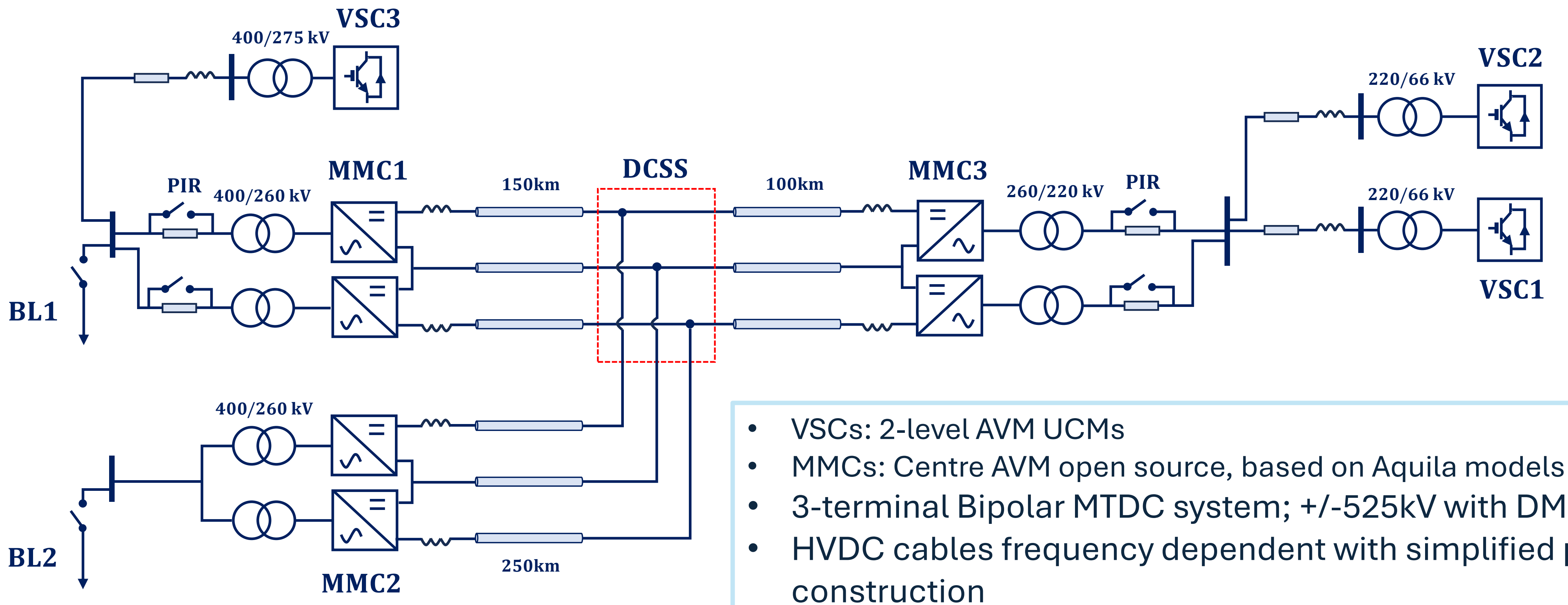
Our Focus

- Scenarios pertaining to **DCSS-based MTDC** configurations, integrating one or more offshore windfarm and onshore BESS

HND Observations

- 2 **parallel connected windfarms** offshore (AC)
- ... being connected via an offshore **DCSS**
- ... all integrated connection corridors with onshore system are DC

Generic Model



- VSCs: 2-level AVM UCMs
- MMCs: Centre AVM open source, based on Aquila models
- 3-terminal Bipolar MTDC system; +/-525kV with DMR
- HVDC cables frequency dependent with simplified physical construction
- Onshore restoration simulated through switching PQ loads
- DC smoothing reactor 15mH – small to assess worse-case transients

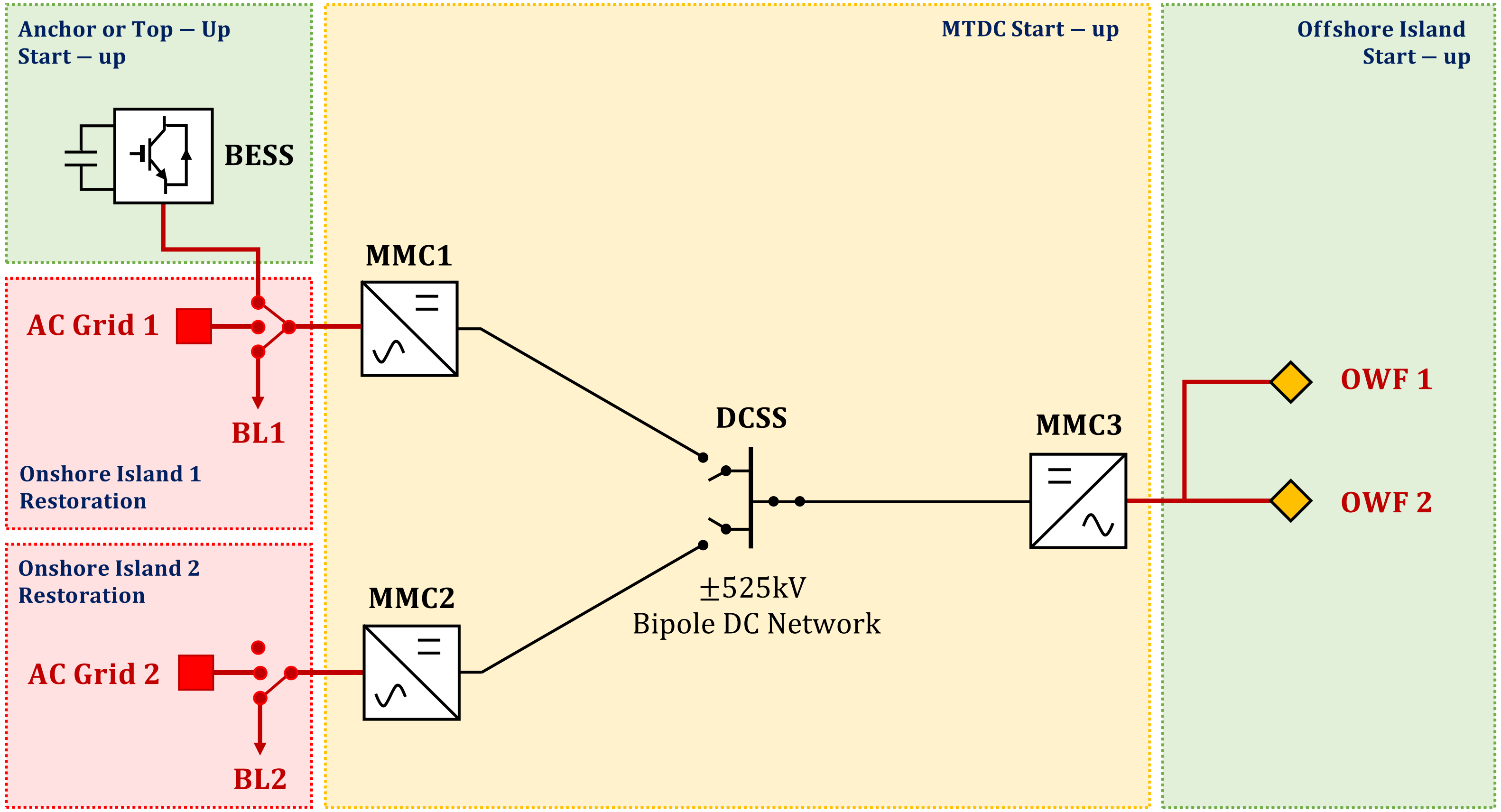
Main Modelling Limitations

- Conservative representation of cable capacitance by pi representation.
- Generalised GFM representation of wind farms as a single VSC aggregate rather than individual turbines and strings – therefore ignores local level interactions and requirements at turbine level.
- VSCs modelled as a grid-side inverter with an ideal DC source behind it – behaves more like a battery and perhaps an optimistic portrayal of wind farm response times.
- Simple block load representation of demand reconnection
- Have not considered resynchronisation of independent onshore power islands

System Start Up

1. **Offshore island:** VSCs + AC assets
2. **MTDC:** MMCs, cables, DCSS
3. **Onshore system:** Supporting generation and block loads

GC0156 Definitions: ESRS
Anchor: Generator with the ability to start-up and support reenergisation of the NETS without need for external voltage source
Top-Up: Generator not required to self-start, but can be ready to connect on instruction once external voltage source becomes available, to support demand reconnection



VSC1 DC Network Energization

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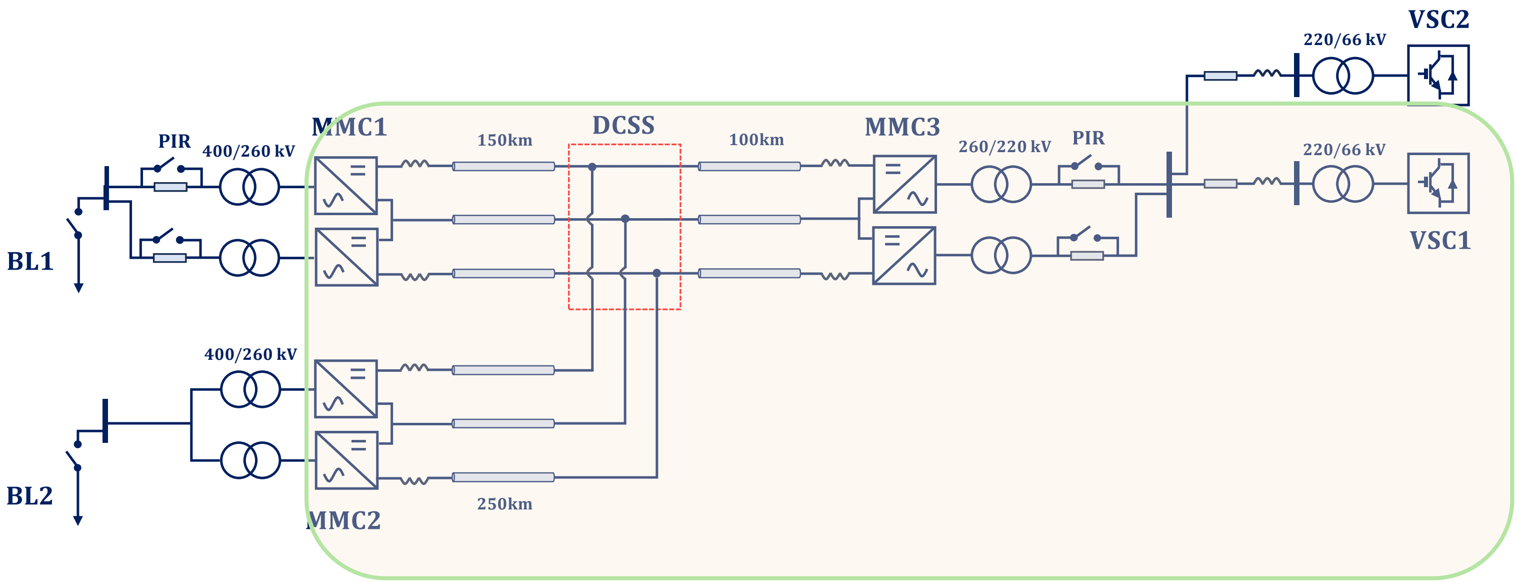
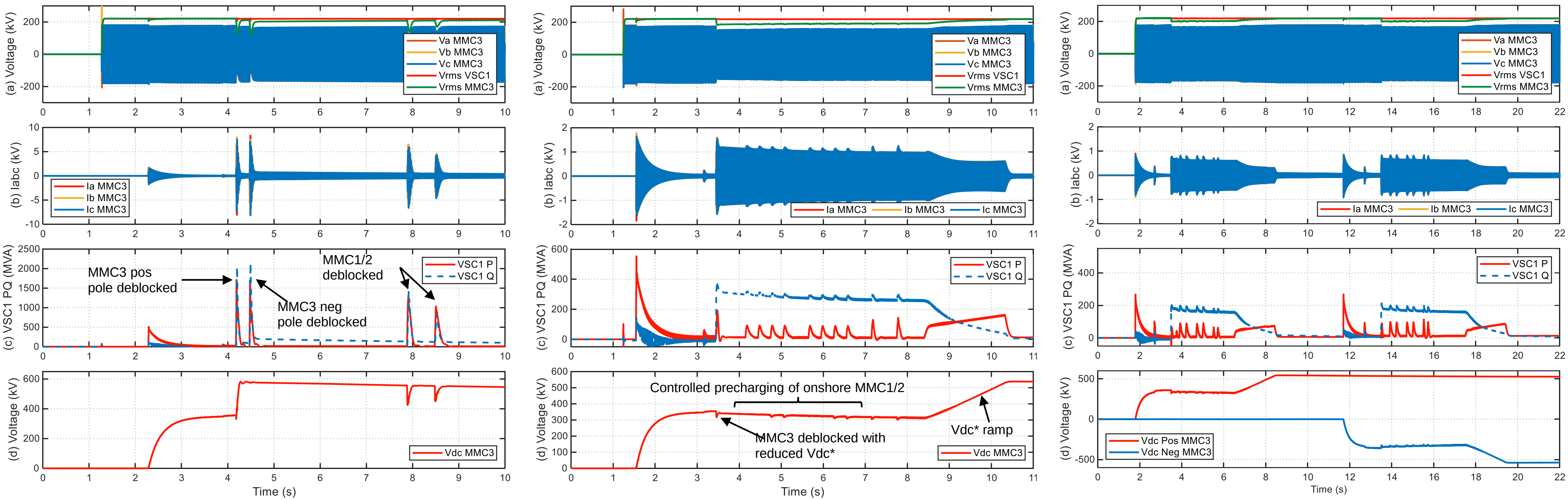
- VSC1 Anchor generators
- All breakers are initially closed.
- The converters are deblocked simultaneously in the first case
- The convertors are deblocked sequentially in the second case



VSC1 DC Network Energization

HVDC Energisation Feasibility



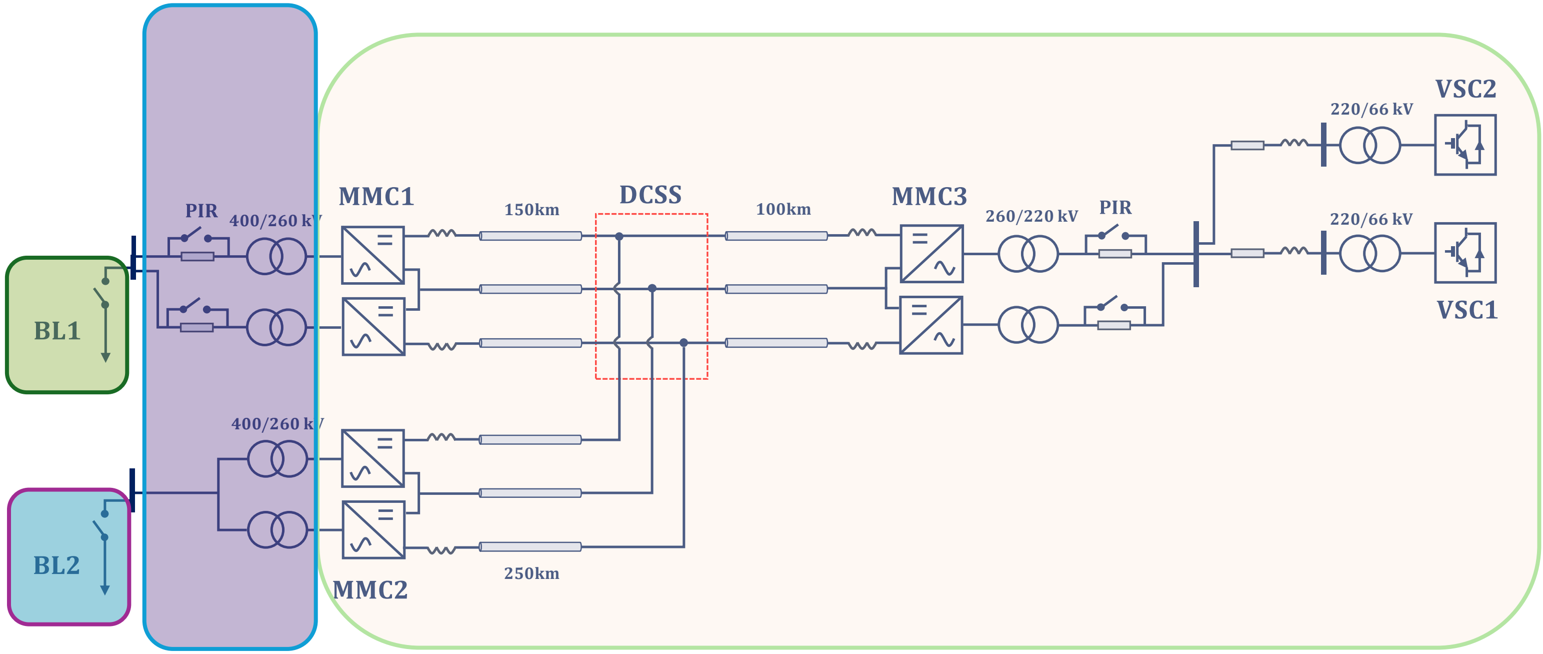
(a) No smooth start-up scheme

(b) Smooth start-up, poles energised simultaneous

(c) Smooth start-up, poles energised sequentially

VSC1 & VSC2 Combined Soft Start + block loading

- VSC1 & VSC2 Anchor generators
- All breakers are initially closed.
- The converters are deblocked simultaneously
- Voltage ramped at 0.5pu/s
- Energisation of the onshore AC system and block loading



VSC1 & VSC2 Combined Anchor Soft Start

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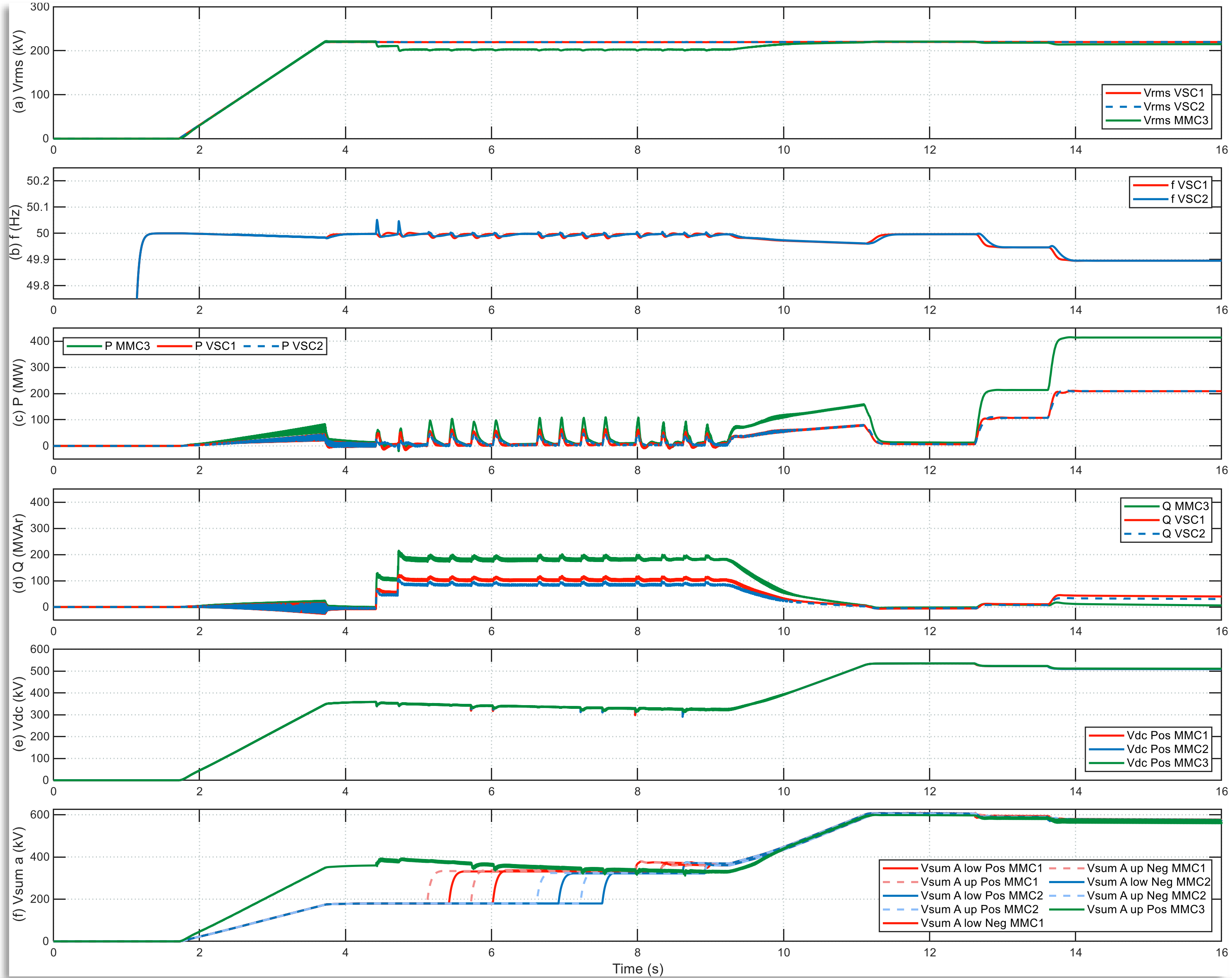

Time	Event
t=1.2s	VSC1/ VSC2 deblocked simultaneously
t=1.8s	VSC1/VSC2 $v_{ac}^{ref} = 0 \rightarrow 1pu\ (0.5pu/\ s)$
t=4.25s	MMC3 pos pole deblocked $v_{DC}^{ref} = \sqrt{2}V_{LL}^{ac}$
t=4.5s	MMC3 neg pole deblocked $v_{DC}^{ref} = \sqrt{2}V_{LL}^{ac}$
t=5.1–6.1s	MMC1 controlled precharging
t=6.7–7.7s	MMC2 controlled precharging
t=8–9s	MMC1 and MMC2 sequential pole deblock
t=9.2–11.2s	MMC3 $v_{DC}^{ref} = 0.6pu \rightarrow 1pu\ (0.2pu/\ s)$
t=12, 12.5s	MMC1 ramps $v_{ac}^{ref} \rightarrow 1pu$, Block Loading 1
t=12.5s, 13.7s	MMC2 ramps $v_{ac}^{ref} \rightarrow 1pu$, Block Loading 2

Table. 1 Switching Sequences for Coordinated Soft Start-Up

Power sharing and soft-start capability, minimised instantaneous power requirements and inrush

Conclusions

- Demonstration of MTDC coordinated restoration through various study scenarios and sensitivities

- Demonstration of HND value:
  - Support two independent onshore power islands simultaneously
  - Improved restoration speeds through higher MW capability with multiple service providers
  - Coordination of several providers for power sharing (AC-connected and DC-connected)

- Challenges:
  - PQ requirements for Bipolar HVDC schemes can be significant
    - Mitigations include sequential pole energisation, sufficient PIR sizing, soft-start, use multiple OWFs
  - Parallel OWFs providing combined Anchor service could require master control for synchronised dispatch of deblocking signals and voltage orders
  - Sequences and DC-PIR specification for start-up sequences involving DCSS

Next Steps - Network specific

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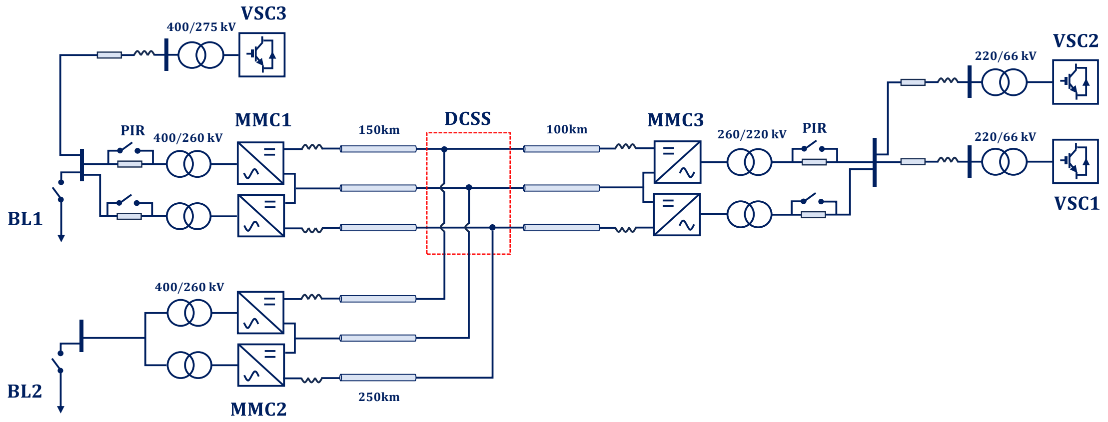

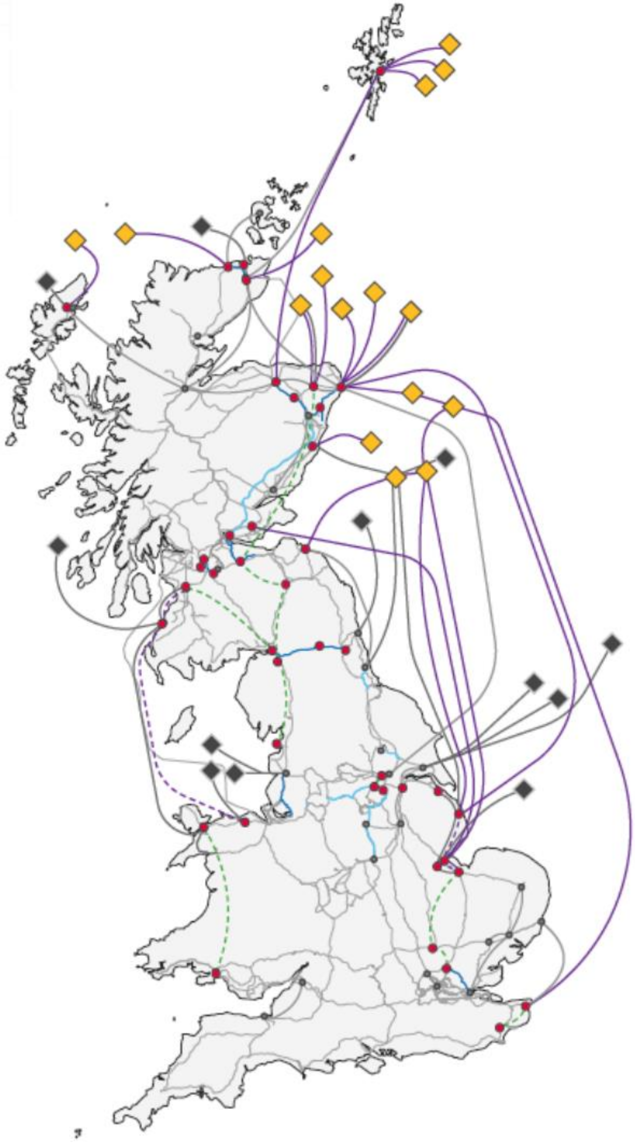

Category	Key
New offshore network infrastructure	
New onshore network infrastructure	
Voltage increase on network	
Existing network upgrade	
Substation upgrade or new substation	
Substations delivered for 2030	
In scope wind farm	
HND wind farm	
Existing Network	
Reinforcements delivered for 2030	

Next Steps - HIL

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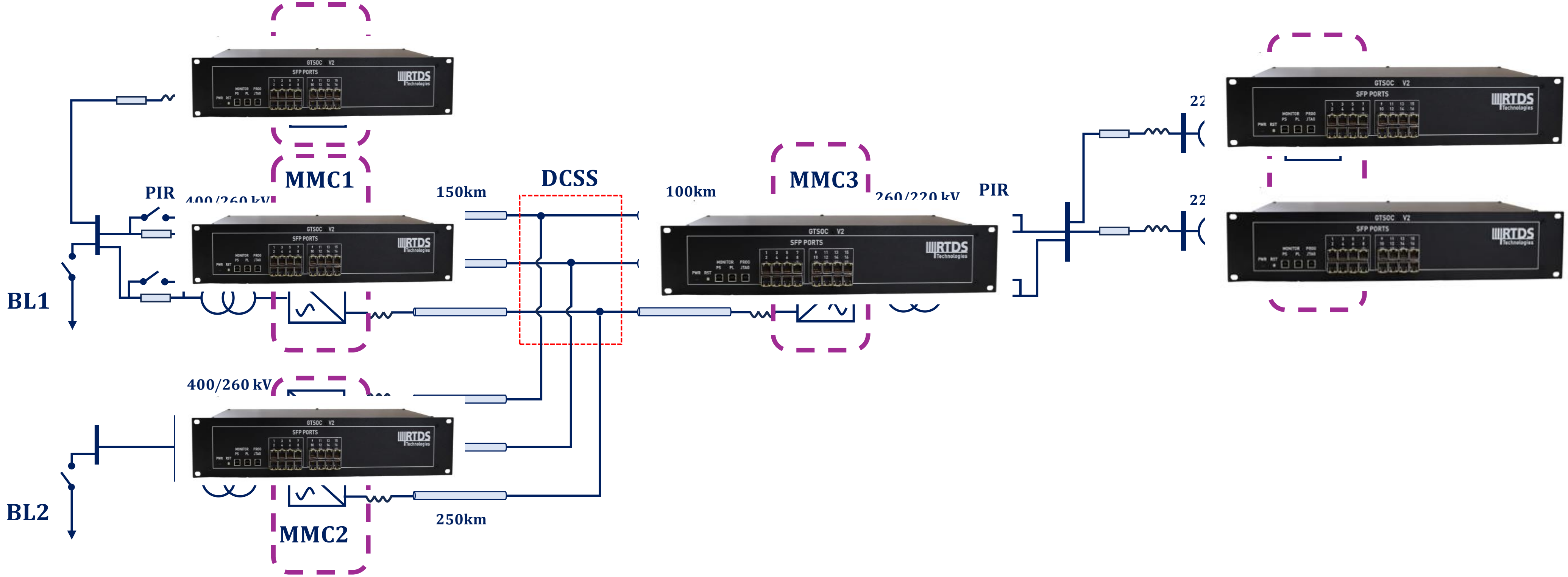
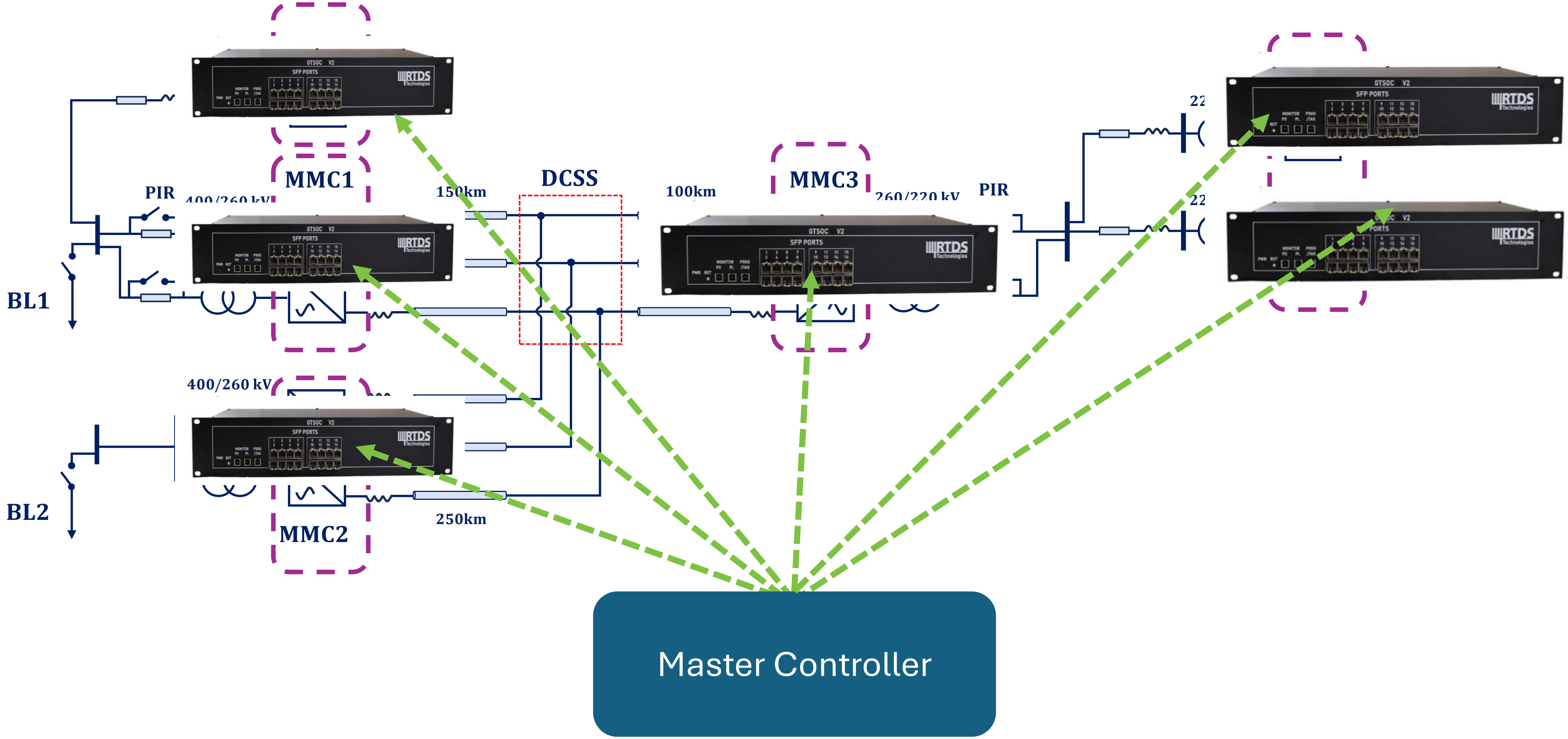


Next Steps – Master Controller design



Thanks for listening.

Any questions, please?

- For further information, please visit **www.hvdccentre.com** ; OR email: **info@hvdccentre.com/**

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