2022 Energy Innovation Summit – HVDC Centre Presentations

The National HVDC Centre

The Energy Innovation Summit (The Summit) was held on 28-29 September 2022 at SEC in Glasgow. This document contains the presentations given by the experts working at the HVDC Centre.

Wednesday, 28th Sept 2022

10:15 **Offshore Functional Design to Support Project Aquila**
Dr Dong Chen

12:15 **NIA AC Protection Solution in Weak Network Conditions**
Nikhil Sharma

13:30 **Project INCENTIVE Innovative Control and Energy Storage for Ancillary Service in Offshore Wind**
Shangen Tian

15:30 **Network-DC**
Suresh Kumar

Thursday, 29th Sept 2022

10:45 **HVDC-WISE**
HVDC-based Grid Architectures for Reliable and Resilient WideSpread hybrid AC/DC Transmission Systems
Dr Md Asif Uddin Khan

Scottish & Southern Electricity Networks

Offshore Functional Design to Support Project Aquila

Sept 2022

by Dong Chen, PhD

The National HVDC Centre

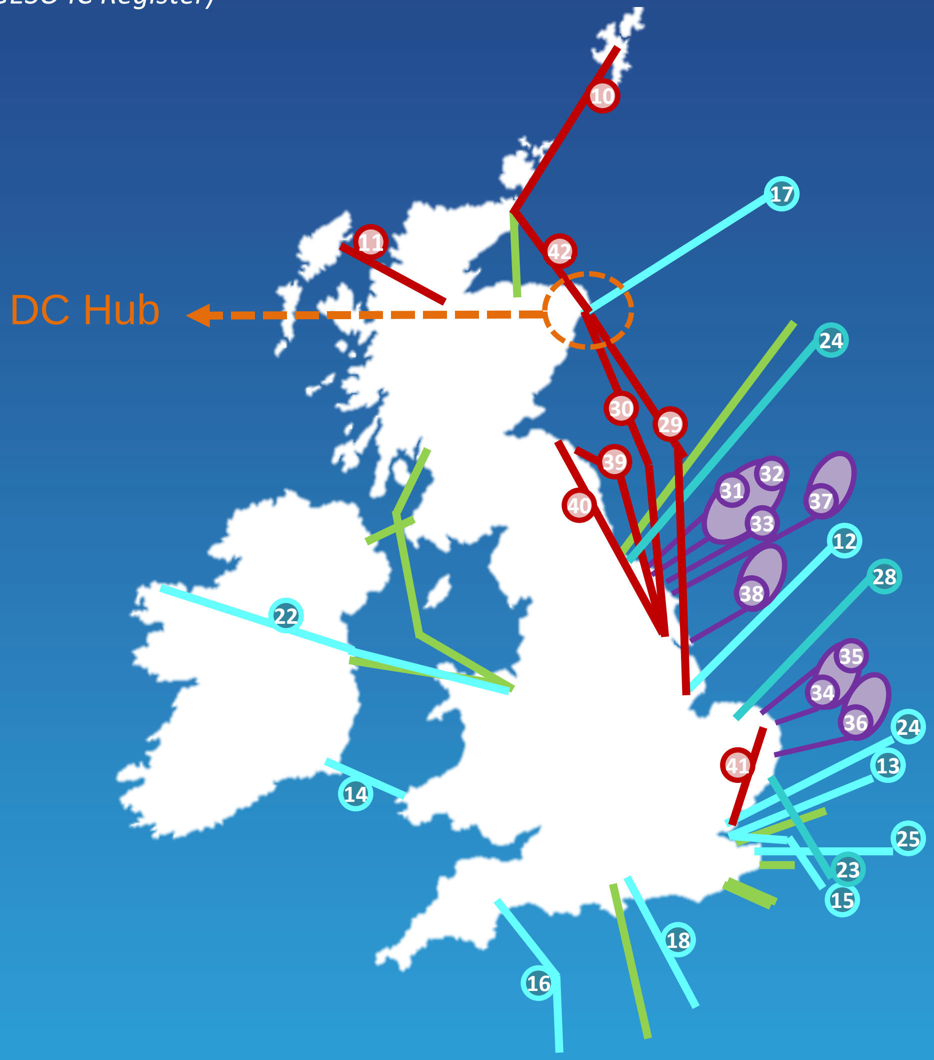
Scottish & Southern Electricity Networks

Offshore Functional Designs (Funded by Ofgem and BEIS)

- Context:
  - ➢ Enabler of target towards "net-zero"
  - ➢ Offshore wind and transmission network
  - ➢ High Voltage Direct Current (HVDC)
  - ➢ First Multi-Terminal-Multi-Vendor DC network as a business case
  - ➢ Support first DC switching station (Project Aquila)
- Objective:
  - ➢ Develop component model as building blocks
  - ➢ Simulate benchmark system for interoperability design and testing
  - ➢ Proof of concept and assessment in functional design
  - ➢ De-risk future development and operation
  - ➢ Leading to offshore grid code

Future HVDC in GB

32 GW of new connection offers (2031)
(NGESO IC Register)



New Island Links
10) Shetland (2024)
11) Western Isles (TBC)

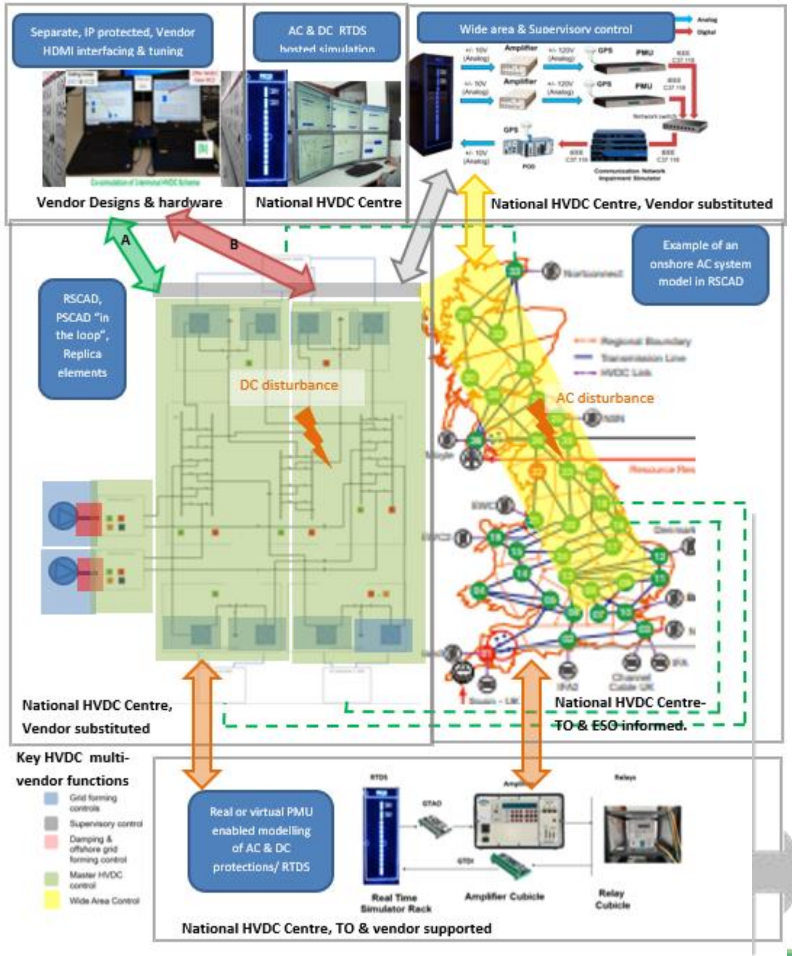
New Interconnectors
12) Viking Link (2023)
13) NeuConnect (2024)
14) GreenLink (2023)
15) Gridlink (2024)
16) Fablink (2025)
17) NorthConnect (2025)
18) Aquind (2023)
19) MaresConnect (2027)
20) EuroLink (2024)
21) Nautilus (2027)
22) Cronos (2025)
23) Tarchon (2026)
24) Continental Link (2027)
25) Southernlink (2027)
26) Atlantic Superconnection (2027)
27) Kulizumboo Interconnector (2028)
28) Aminth (2028)

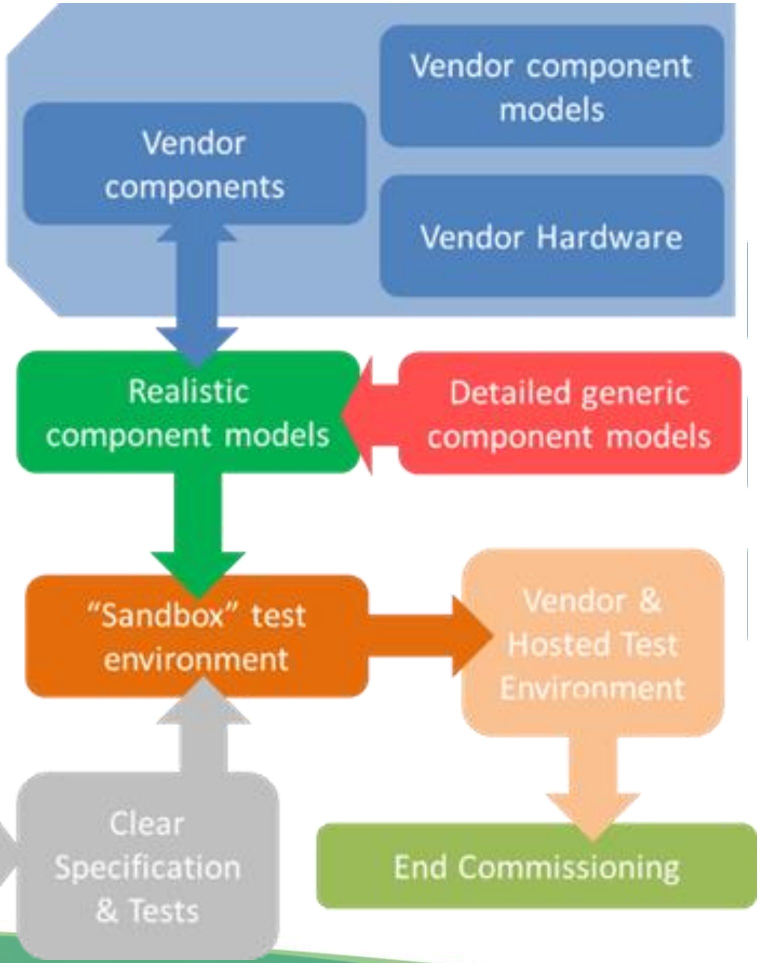
New Embedded Links
29) Eastern: Peterhead to Drax (E4D3)
30) Eastern Peterhead to South Humber (E4L5)
39) Eastern: Torness to Hawthont Pit (E2DC)
40) Eastern SE Scotland to South Humber (TGDC)
41) Suffolk-Kent HVDC
42) PSDC Spittal – Peterhead t

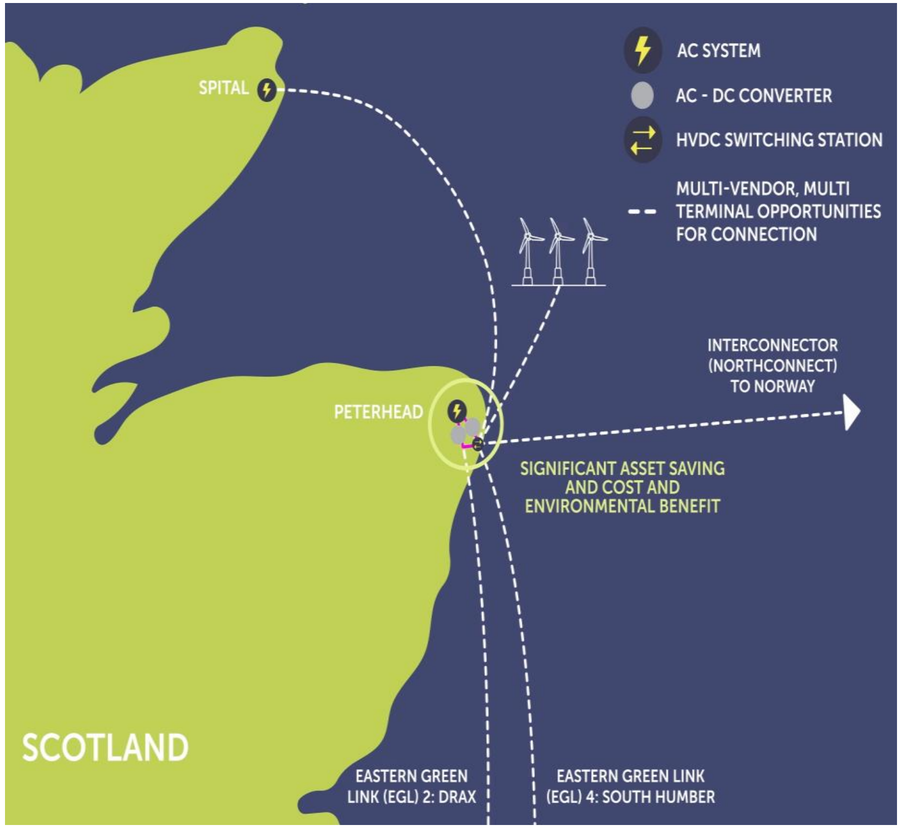
Offshore Wind Connections
31) Dogger Bank A
32) Dogger Bank B
33) Dogger Bank C
34) Norfolk Vanguard
35) Norfolk Boreas
36) East Anglia Three
37) Sofia Wind Farm
38) Hornsea 4

Source: National Grid Interconnector Register 2021

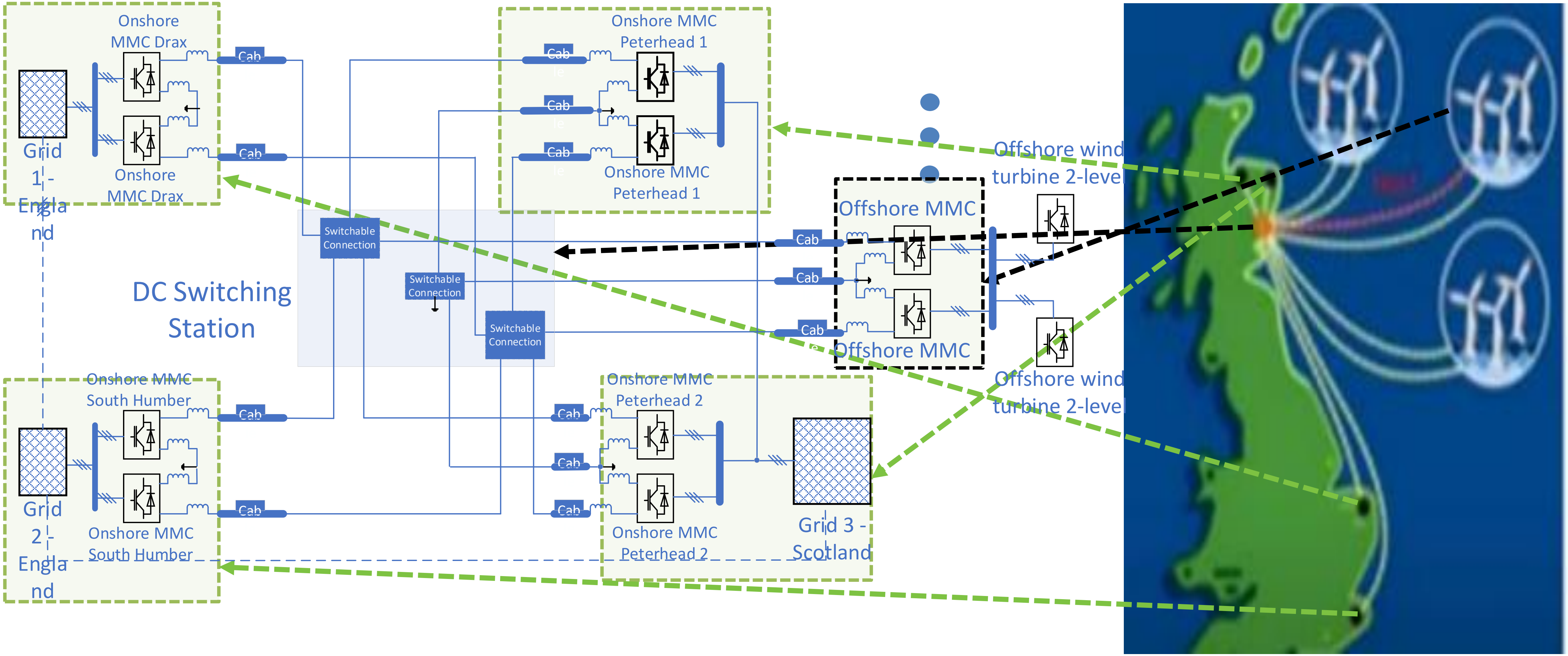
Value of Functional designs to delivering Project Aquila







Illustrative Schematic of Offshore Grid Model



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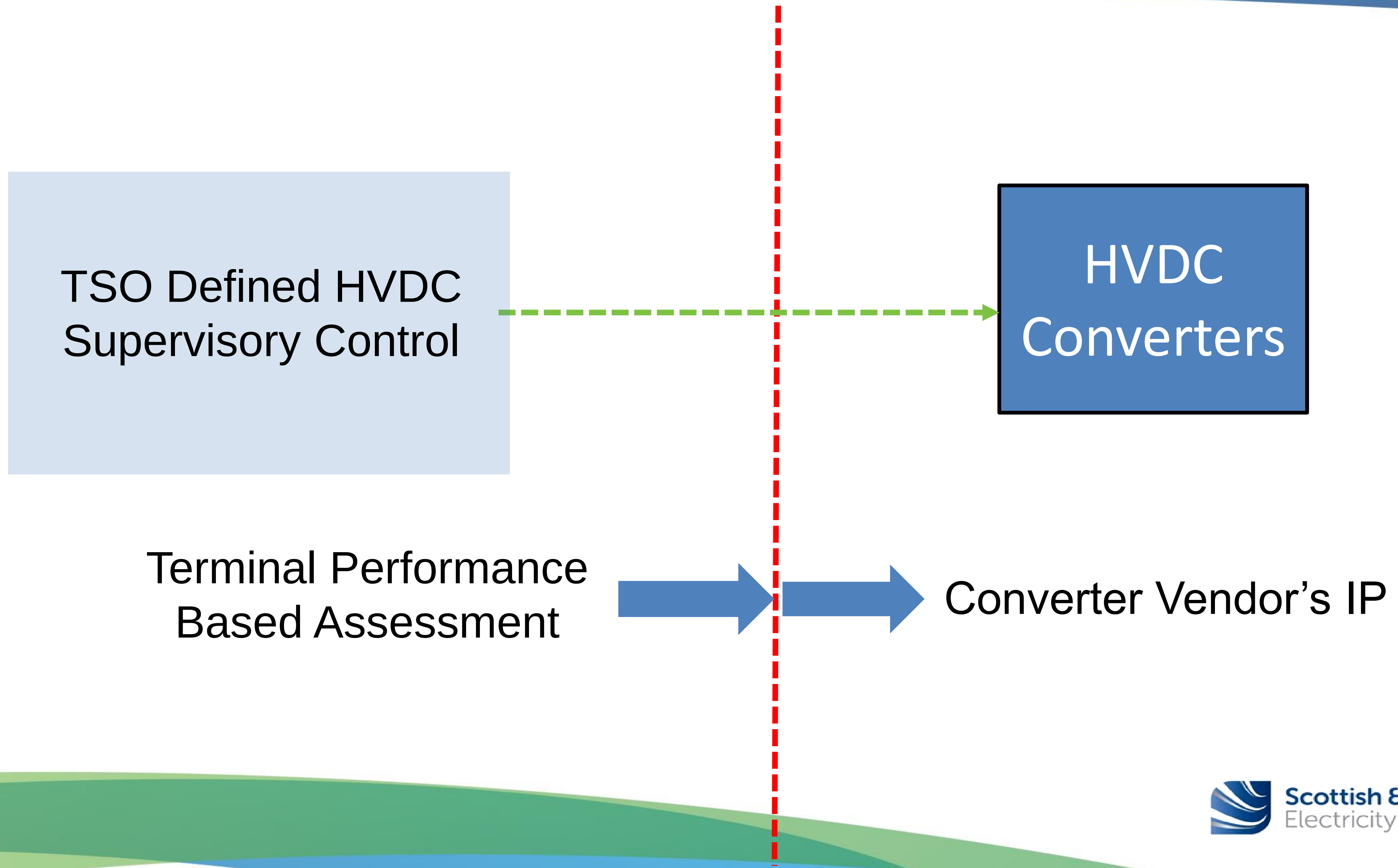
Enabling Interpretability of Multi-Terminal-Multi-Vendor HVDC



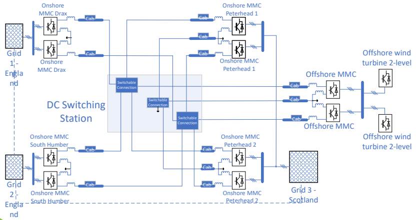
Simulating an Offshore MTMV-HVDC Network

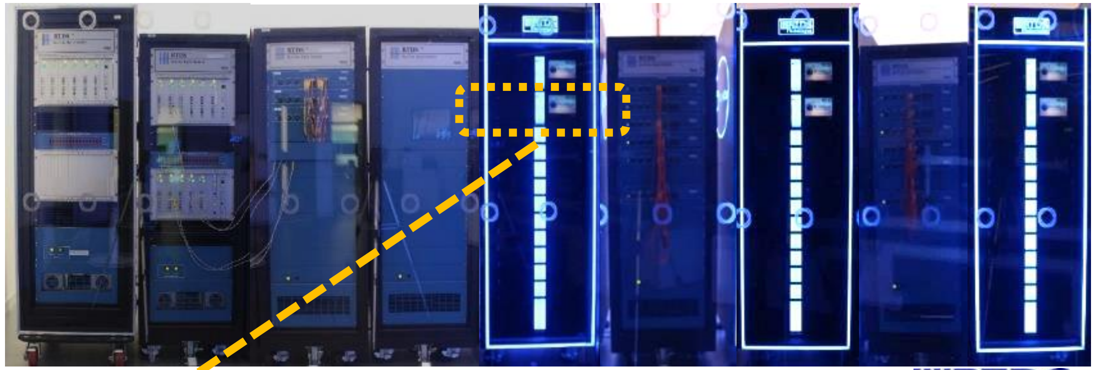
Modelling

Monitor and Analysis

Operate

Upload





Computing the model for 100,000 ~1000,000 times per second…

RTDS Technologies

Swap benchmark control with vendor's control solution

SIEMENS

MITSUBISHI ELECTRIC

ABB

Thanks for listening.

Any questions, please?

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Energy Innovation Summit

NIA AC Protection Solution in Weak Network Conditions

By
Nikhil Sharma

The National HVDC Centre

Scottish & Southern Electricity Networks

Project Motivation

In Phase 1 of NIA AC Protection Project The National HVDC Centre along with Strathclyde University has highlighted vulnerabilities in the existing AC Protection solutions commonly deployed in SHE Transmission network. This happened as GB transitions to a Net Zero energy production which lowers future system strength.

- Protection failure would risk demand and generation disconnection in weak areas and cause network instability. Because of its criticality, normal protection undergoes highly robust tests against acceptance criteria bases on a conventional fossil fuel generation mix.
- Currently there is no acceptance criteria and tests for new different forms of protection needed in the Net-Zero future.

Project Summary

In Phase 2 of the Project The National HVDC Centre along with Strathclyde University proposed Transmission innovation project by addressing the vulnerabilities identified in Phase 1 by:

- Creating a reconfigurable test-bed and new tests allowing new and different protection approaches suitable in low system strength to be robustly assessed & accepted onto a Transmission system.
- Deployment of different protection approaches in ”open loop field testing”, recording system events and how they would have acted, gaining field experience and refining test-bed and tests undertaken.
- Will be using Real Time Digital Simulator (RTDS) for preparing the Network Simulation Models.
- Different Line Protection schemes will be tested on an identified SSEN Transmission Network Line with low SCL.

What is Real Time Digital Simulation?

- Calculations completed in real world time less than timestep
- Every timestep has the same duration and is completed in real time
- The I/O is updated at a constant period equal to the timestep

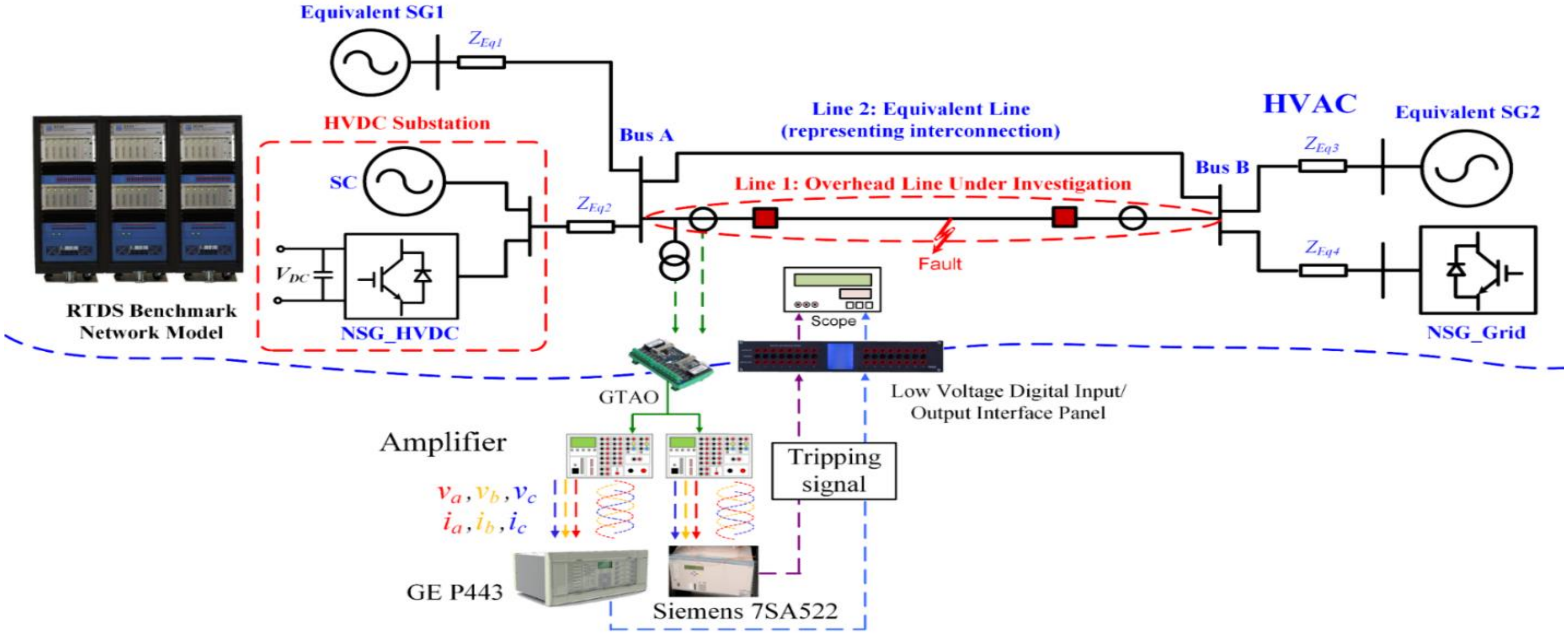
<1 s

<10 ms

RTDS

2 µs ~ 50 µs

Test Modelling Network



GB Network & Proposed Transmission Line

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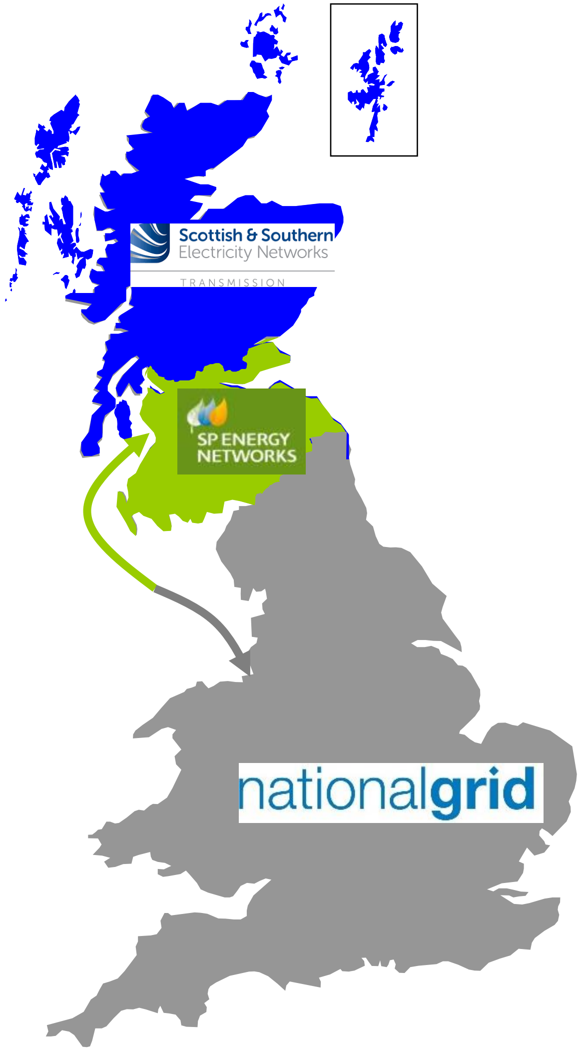
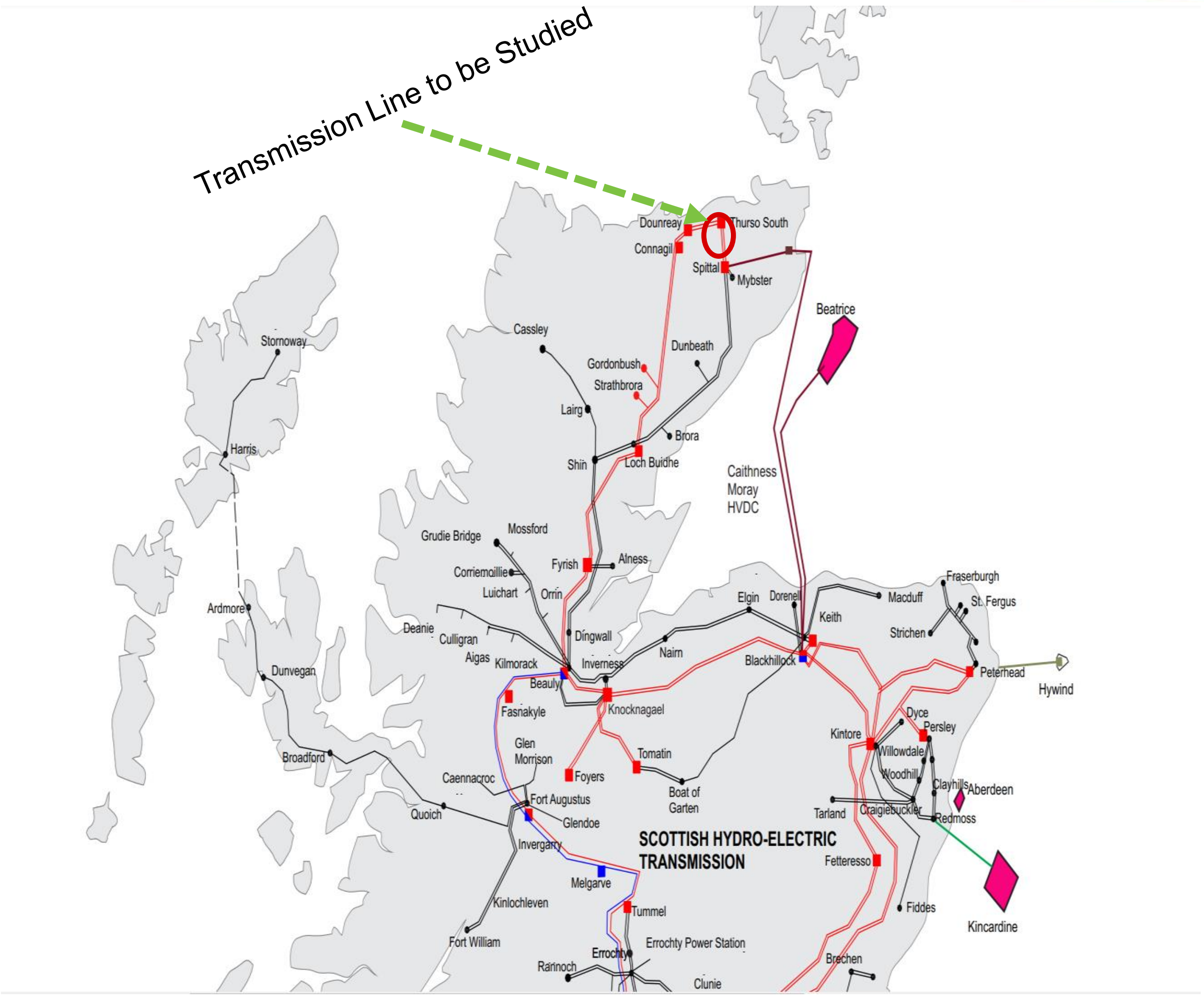


SSEN



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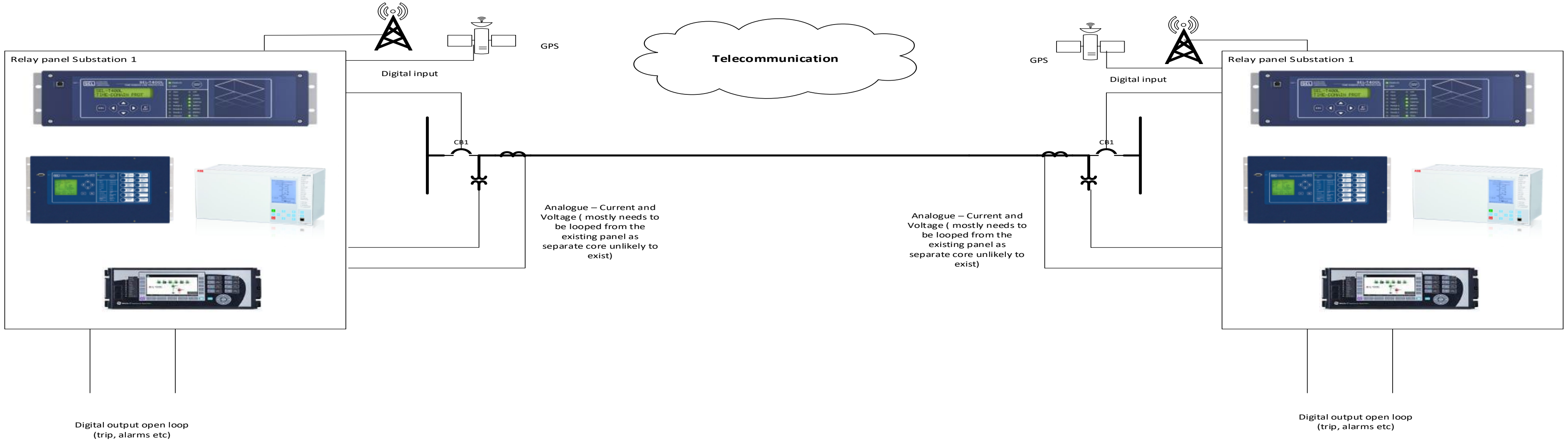
Possible Line Protection Solutions



Line Protection Schemes Planned :

- Distance Protection
- Neutral Current Differential Protection
- Line Differential Protection
- Travelling wave protection

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Project INCENTIVE

Innovative Control and Energy Storage for Ancillary Service in Offshore Wind

funded by Ofgem & Innovate UK's Strategic Innovation Fund (SIF)

28 September 2022

The National HVDC Centre

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Project motivation and Objective

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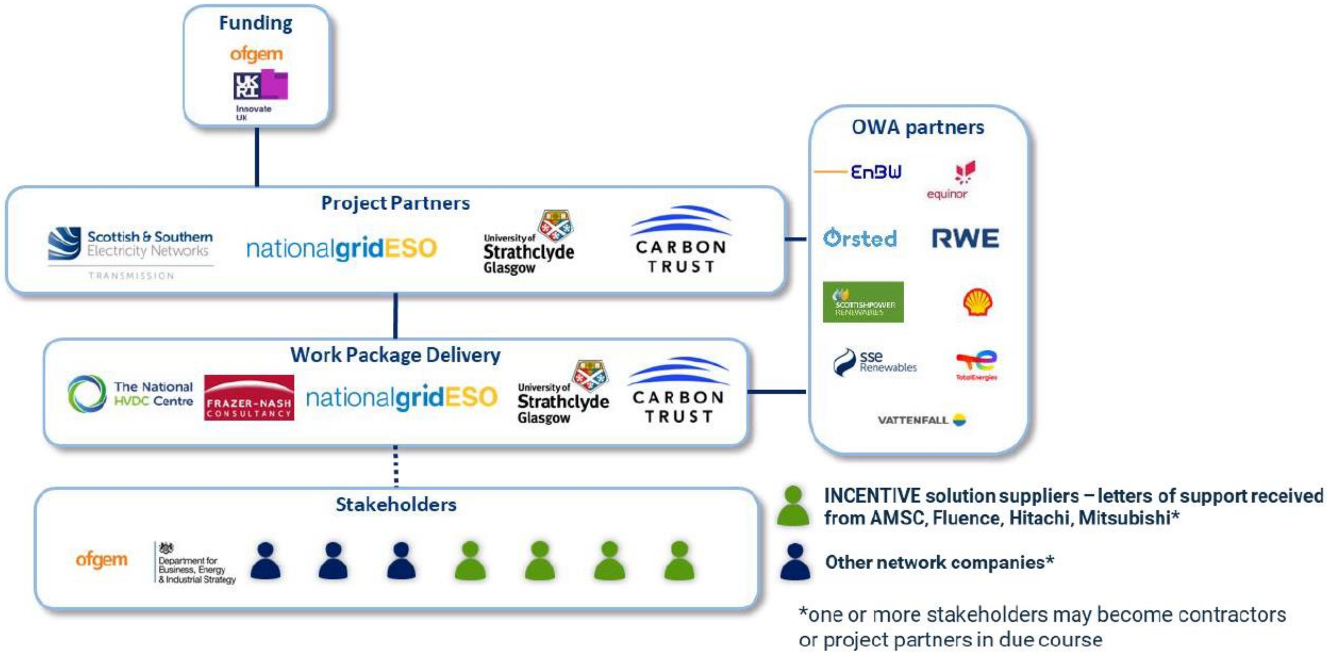
These problems causing:

- Challenge for grid balancing and grid stability,
- Bring the opportunity for GB network companies, generators and ultimately consumer

The project consortium consists of SHE-Transmission (SSEN-T) (as lead applicant), Carbon Trust, University of Strathclyde (Strathclyde) and National Grid ESO (NGESO).

Project Incentive aims to build a business cases, commercial models and regulatory model, and to demonstrate technology feasibility in proving extended gird services from offshore wind energy through energy storage and innovative converter technology



Key technical guidance: BAT-STAT findings, GC0137:Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability and Stability pathfinder

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Background

Offshore wind is expected increase dramatically.

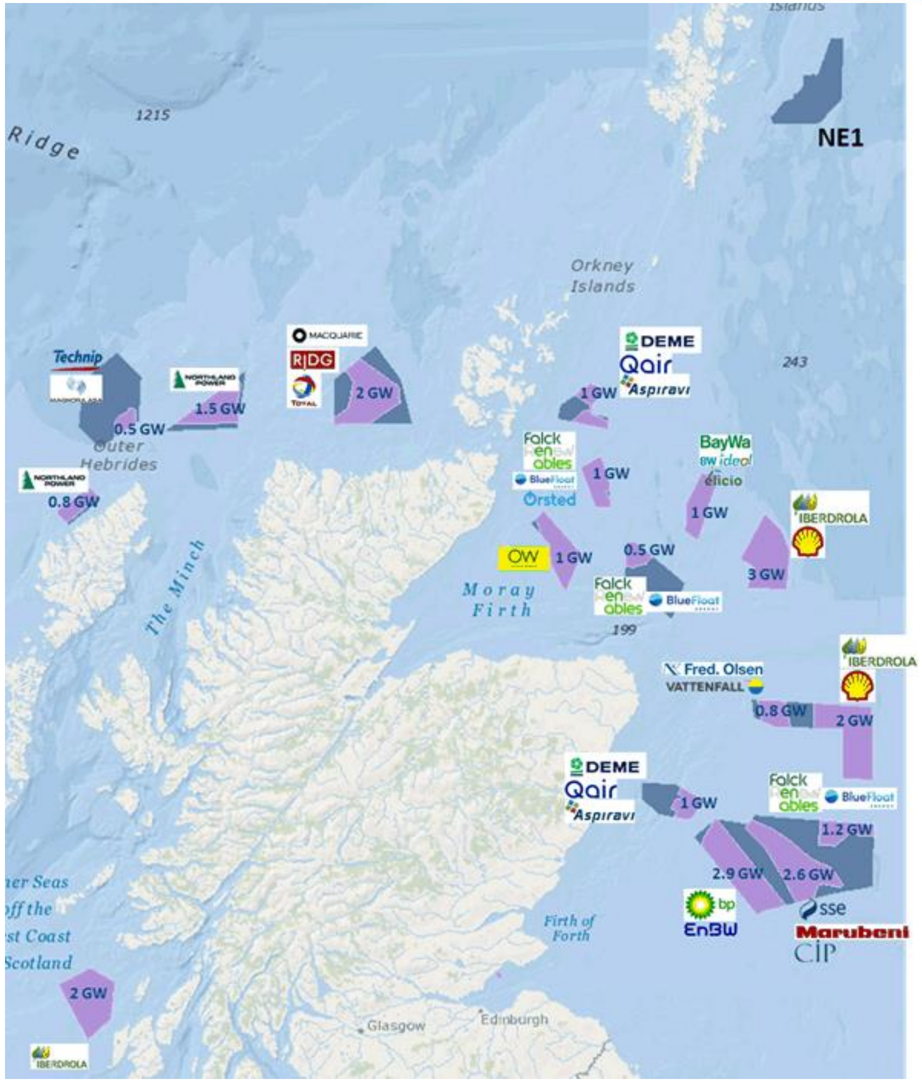
- ScotWind leasing process selected 20 projects with a total capacity of 27.6 GW
- Innovation is required to facilitate the rapid rollout of non-synchronous generation and prevent grid balancing and stability challenges

Without the new solutions, GB networks will become weaker leading to:

- Increasing the likelihood of instability events
- Maintaining reliance on synchronous fossil fuel generators

All of these will lead to potential risks:

- Slow down the energy transition
- Adverse impact to the environment



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Commercial Assessment

Carbon Trust and Frazer-Nash Consultancy is leading a commercial assessment:

- Business case development
  - Build a coherent and consistent strategy to quantifying both model whole-system and environment cost and benefit across INCENTIVE solutions
  - Understand implications of likely future stability market developments for valuing INCENTIVE solution benefits for different operators
- Ownership model development
- Applying Ownership to CBA
  - Develop a flexible CBA tool that will allow rapid and flexible assessment of a range of scenarios and options for INCENTIVE solution deployments
  - Recommendations regarding regulation and market design to maximise commercial case for INCENTIVE solutions

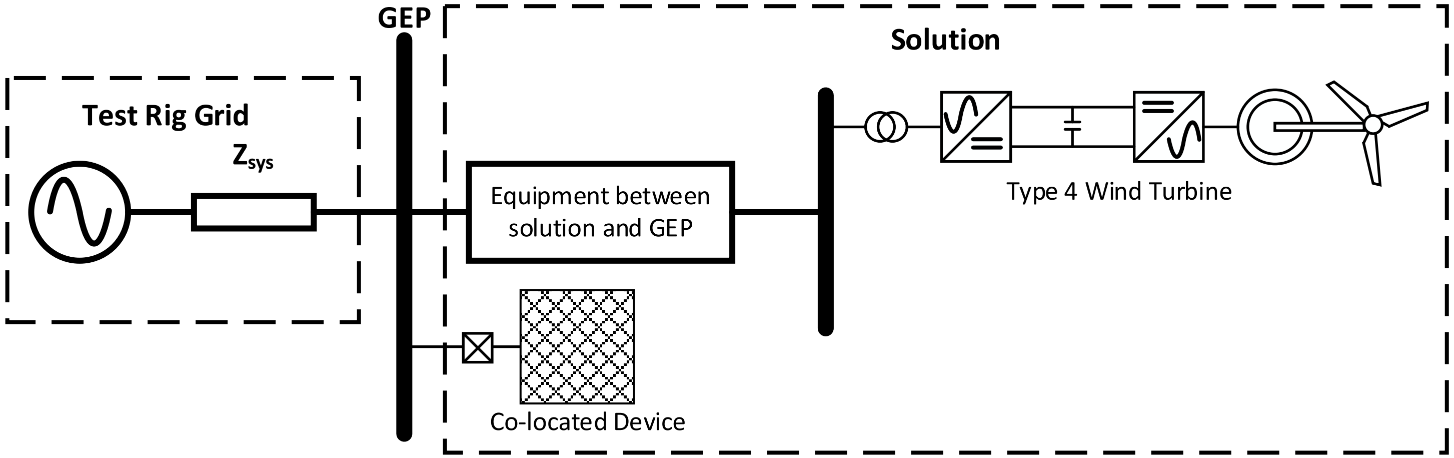
Technical Assessment

SSEN (through HVDC Centre) is leading technical assessment and working with University of Strathclyde, The technical scope of Alpha phase and Beta phase:

- The Alpha phase demonstration is expected to include laboratory-based simulated testing of prototype controllers, covering both HVDC and AC connected offshore wind
  - Improve understanding of INCENTIVE solution and impact on network
  - Modelling and testing of INCENTIVE solution – RSCAD Generic Model
  - Scoping Beta phase based on Alpha finding

- The Beta phase is then expected to cover a demonstration at a GB offshore wind site (site identification in Alpha phase). The success criteria will be realistic, targeted and appropriate Alpha/Beta phase scopes.

Alpha Test defined



- The RSCAD generic model is used to test. The test model including the solution and Test Rig Grid
- The solution includes type 4 wind turbine and Co-located Device
- Test Grid Forming Control and Grid Following Control

Co-located Device:

- BESS
- Synchronous Condenser
- STATCOM, HVDC Terminal

Test Rig Grid

- Simple Ideal AC Source Model
- National Grid 5 Bus Model

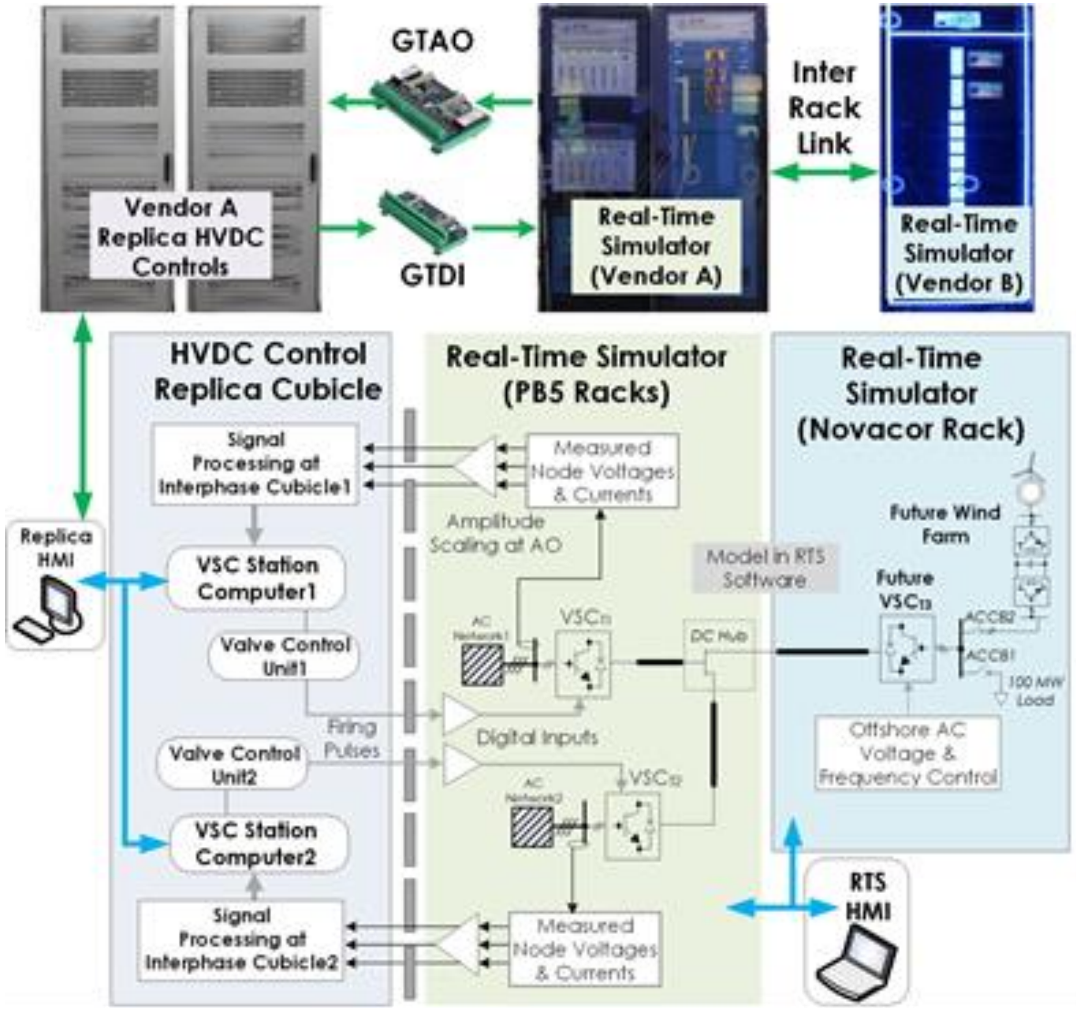
Testing Events:

- Short-circuit events
- Frequency events
- Voltage angle changes
- Combined voltage and frequency event
- Multiple fault ride through simulations

Test Methodologies

- Offline simulation
  - PSCAD – industry standard
  - Black box models (available)
- Real-time simulation
  - RSCAD
  - CHIL – key purpose
  - ?PHIL
- Physical equipment test
  - Tests need to be reflective of what is achievable with test rig
- Field Trial
  - Depends what can be negotiated and what happens on the system (unlikely the ESO will let us through a 3-phase fault on the Transmission network)

◦ CHIL Setup (SIL is similar)



Beta Phase defined

Beta Phase expected to involve demonstration at a UK offshore wind farm

- HVDC Centre working with University of Strathclyde to define Beta phase scope at Alpha phase
- The Carbon Trust and Frazer-Nash Consultancy Continue engagement with OEMs and Solution suppliers

Thanks for listening.

Any questions, please?

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Network DC SIF

Sept 2022

by Suresh Kumar
Simulation Engineer

The National HVDC Centre

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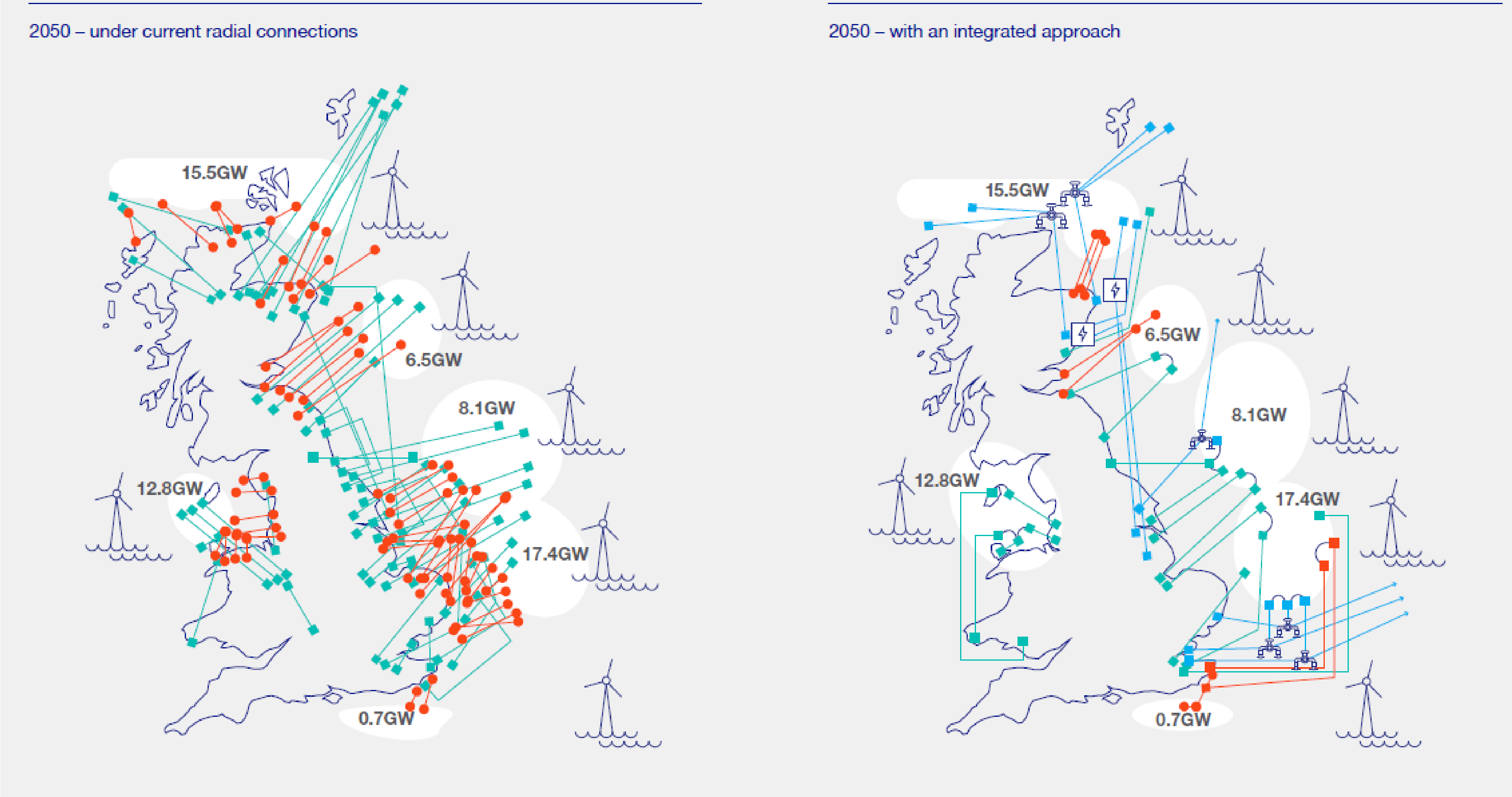
- Objective :

De-risking the first implementation of HVDC Circuit Breakers (DCCB), focusing on GB HVDC Grid development and paving the way for future expansion of HVDC interconnections.

Project Partners :

ofgem
UKRI Innovate UK
The University of Edinburgh
nationalgrid ventures
Transmission Investment
Carbon Trust
nationalgridESO
renewableUK
Mott MacDonald

Counterfactual & Alternatives



- **An integrated approach means saving up to EUR3.5bn for EU & UK consumers**

Our Overall project plan

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Discovery Phase

Defining the activities

- Front end engineering, **de-risking the doing**
- **Planning** next phases and **prioritising actions**
- Identifying **Critical path** & **key risks** & **opportunities**

Defining the Value

- **Cost Benefit Analysis** across **Use Cases and Counterfactuals**
- Identifying **key value areas** and **actions.**
- Identifying how **CBA can support DC Network development** decisions

Engaging with Suppliers

- Identify **future supplier partners** in Alpha and Beta across those that can deliver these solutions.
- Identify a **plan** for that **engagement** - when, what, & how.

Alpha Phase

Develop/ apply specification

- **Codes, standards,** functions, performance all defined
- **Modelling, simulation, key tests & expectations**
- **Engage** with **supplier base** on the above

Design the solutions & implementation

- Identify **real examples** & focussed **proposals**
- **Evaluate, optimise** and **specify** a supplier "tender"
- **Engage** with **supplier** base on above

Beta phase

Evaluate, refine support and test the Supplier developed options, look for real opportunities

- **Support suppliers** in identifying **real solutions**
- **Test**, simulate and **evaluate real performance**
- Identify **practical opportunities** and **address real risks**

A future DC Network

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Our Time Line for analysis

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Aug 2022 :
DCCB Models collated for use in Simulation

Nov 2022:
Key DC Network Analysis and Component Specification

Dec 2022 :
Relate analysis results to PHIL test networks. Propose optimal test network

Jan 2022:
Identify model and hardware needs

End of Jan 2023:
Provide simulation-led specification of DCCB needs and process guide for DCCB specification.

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Simulating HVDC Circuit Breaker

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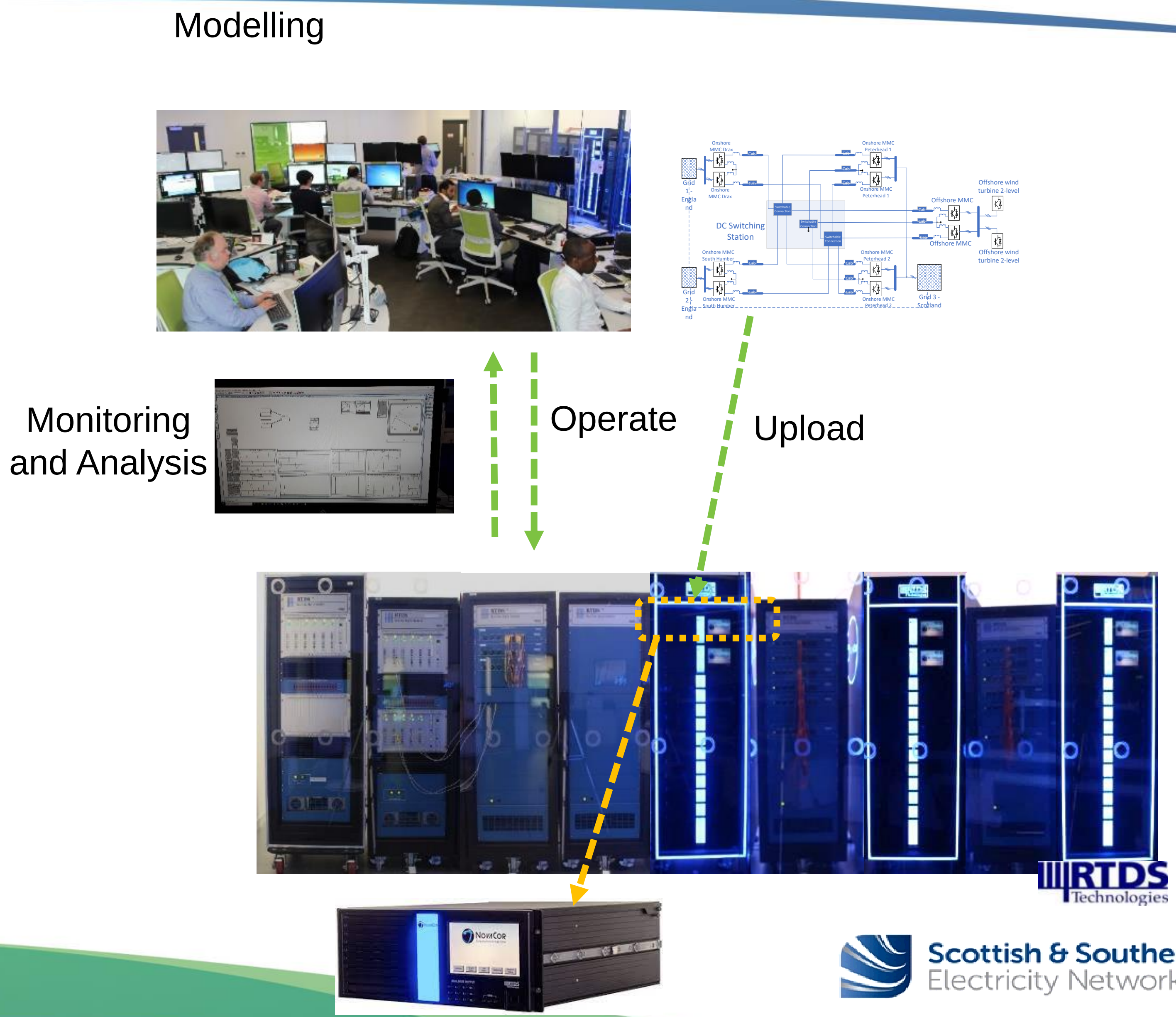
- DCCB Modelled in Real Time Digital Simulation
- Computing 100,000 to 1000,000 times per second…



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DCCB Modelling

- Mechanical DCCB :

- 160 kV active current injection high-voltage direct current circuit breaker

- Hybrid DCCB :

- 500 kV hybrid HVDC circuit breaker. HDVC, high-voltage direct current

Potential Benefits

- Reduced number of converter Stations
- Reduced environmental impact
- Acceleration of wind capacity deployment
- System reliability
- Flexibility of Resource
- Reduced AC network reinforcement

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HVDC-based Grid Architectures for Reliable and Resilient WIdeSprEad hybrid AC/DC Transmission Systems
HVDC-WISE

Md Asif Uddin Khan, PhD

29 September 2022

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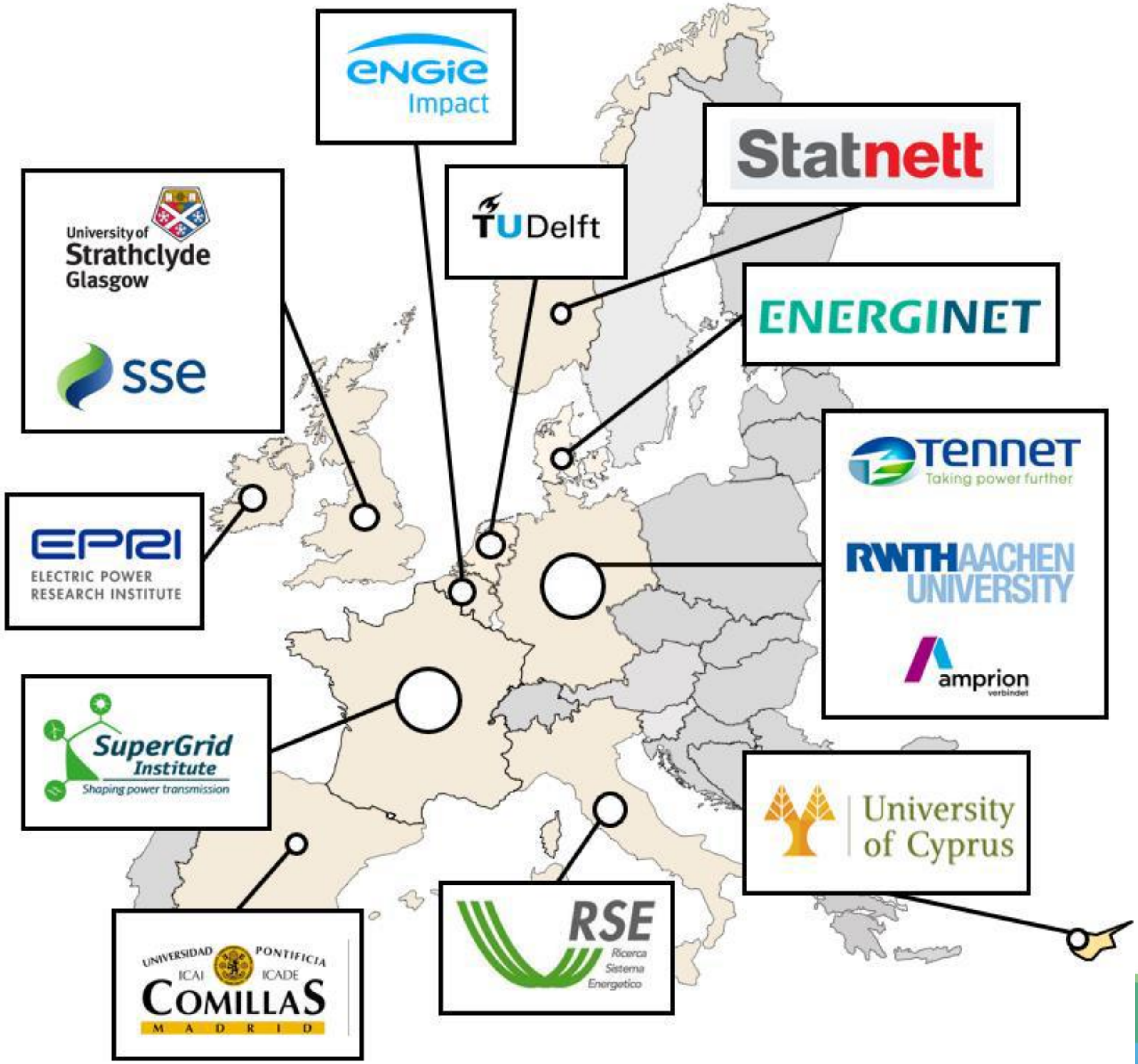
Overview: HVDC-WISE



- Foster the development of HVDC technologies and implementation of hybrid AC/DC grid throughout Europe
- 14 international organisations
- European HORIZON funding (UKRI for GB partners)
- Kick-off meeting 10-11 October 2022 in Lyon, France
- Duration: 42 months (3.5 years)

Ambition of the Project

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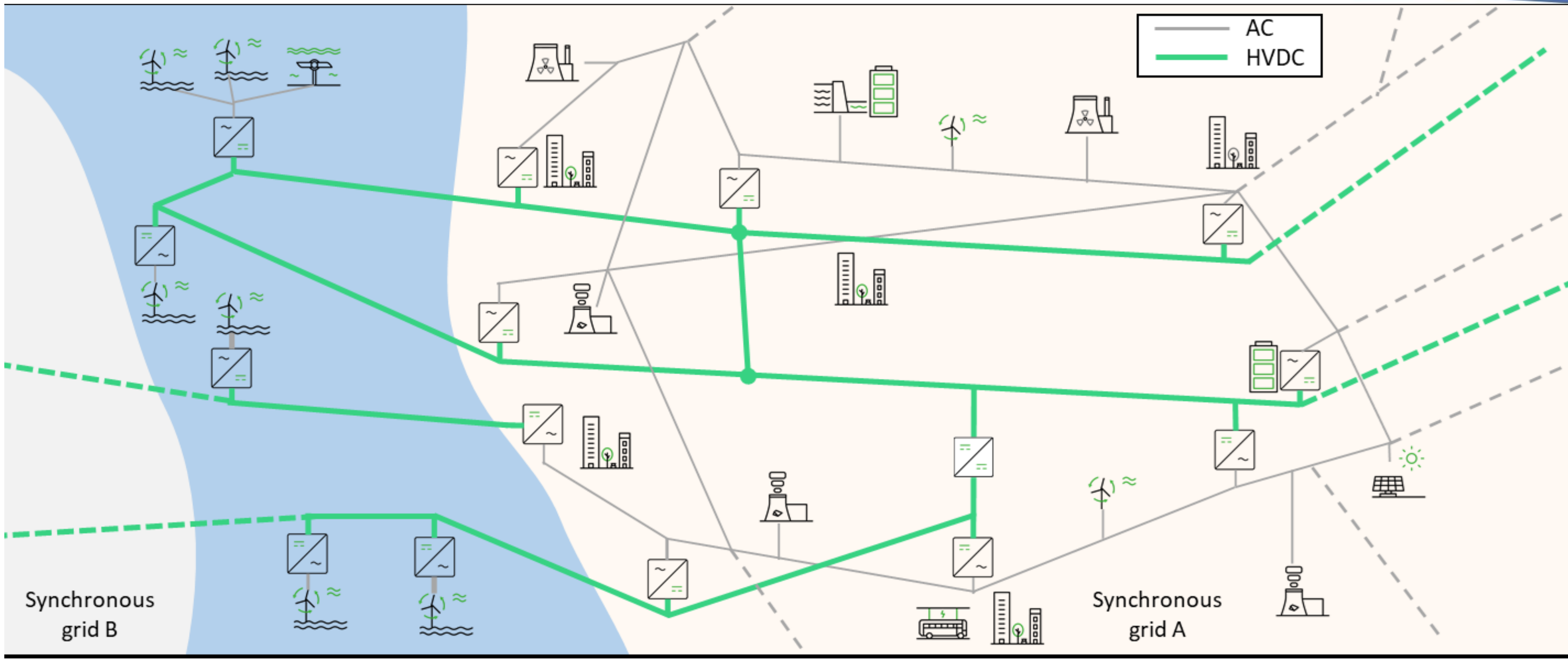
- Increase integration of renewable generation
  - Development of offshore wind farms up to 300 GW by 2050
  - HVDC recognised as most effective technology
- Significant reinforcement required in the existing AC transmission network
  - Reduction of fossil fuel based generation
- HVDC based technology can enhance overall reliability and resilience (R&R) of the system



Overall Aim: Propose, design and validate HVDC based grid architecture and technologies that can

- Reduce risks associated with use of HVDC
- Enhance the R&R of the transmission system

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Objectives

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1. To develop a complete reliability-&-resilience-oriented planning toolset
2. To propose and compare (based on R&R criteria) on simplified test systems, different HVDC-based grid architecture concepts
3. To identify, assess and model emerging technologies
4. To validate R&R-oriented planning toolset and the HVDC-based grid architecture concepts on three realistic use cases
5. To prepare for the adoption and deployment of the proposed solutions by the industry

Project Organisation

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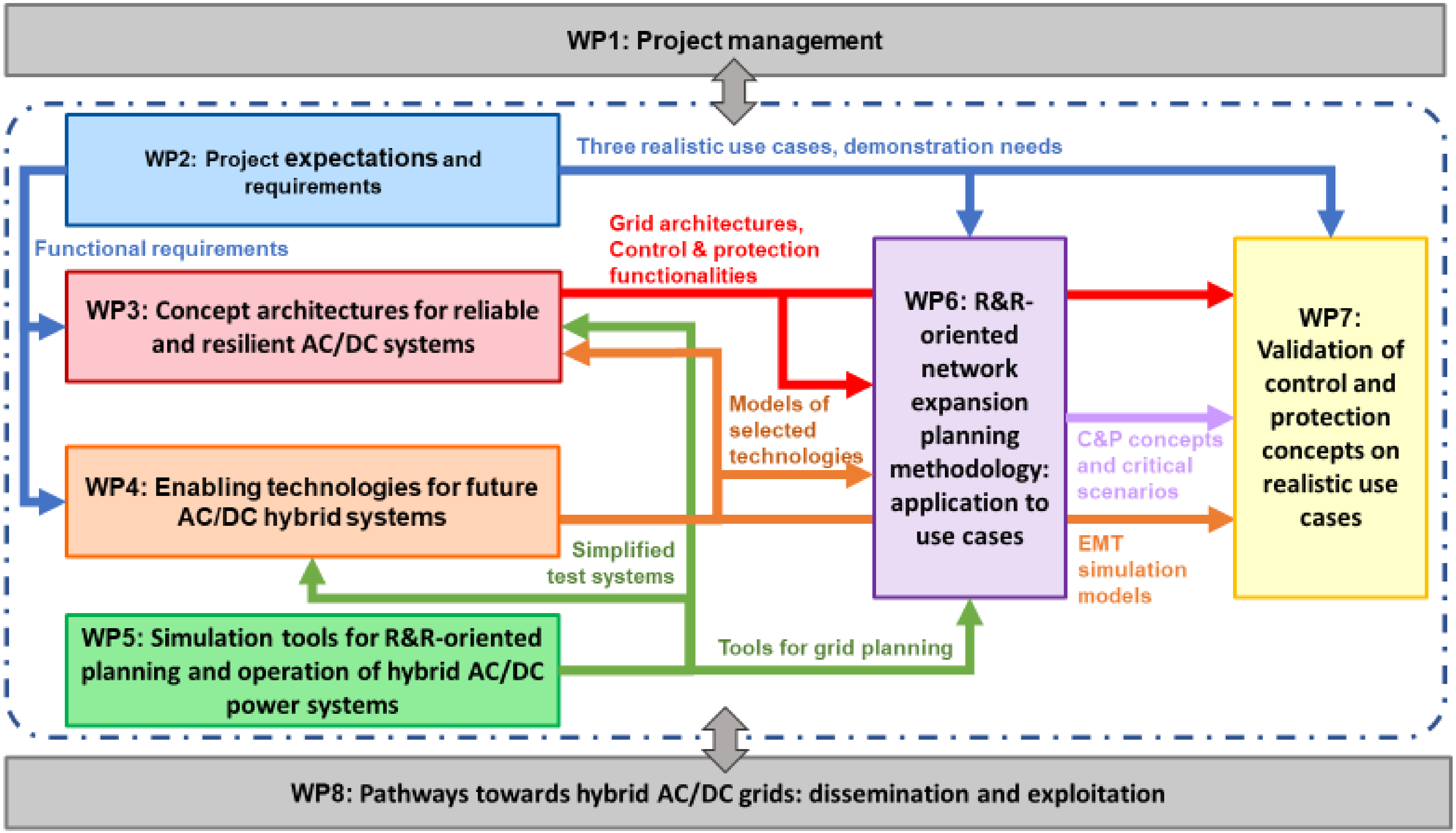

Southern Networks

Timeline

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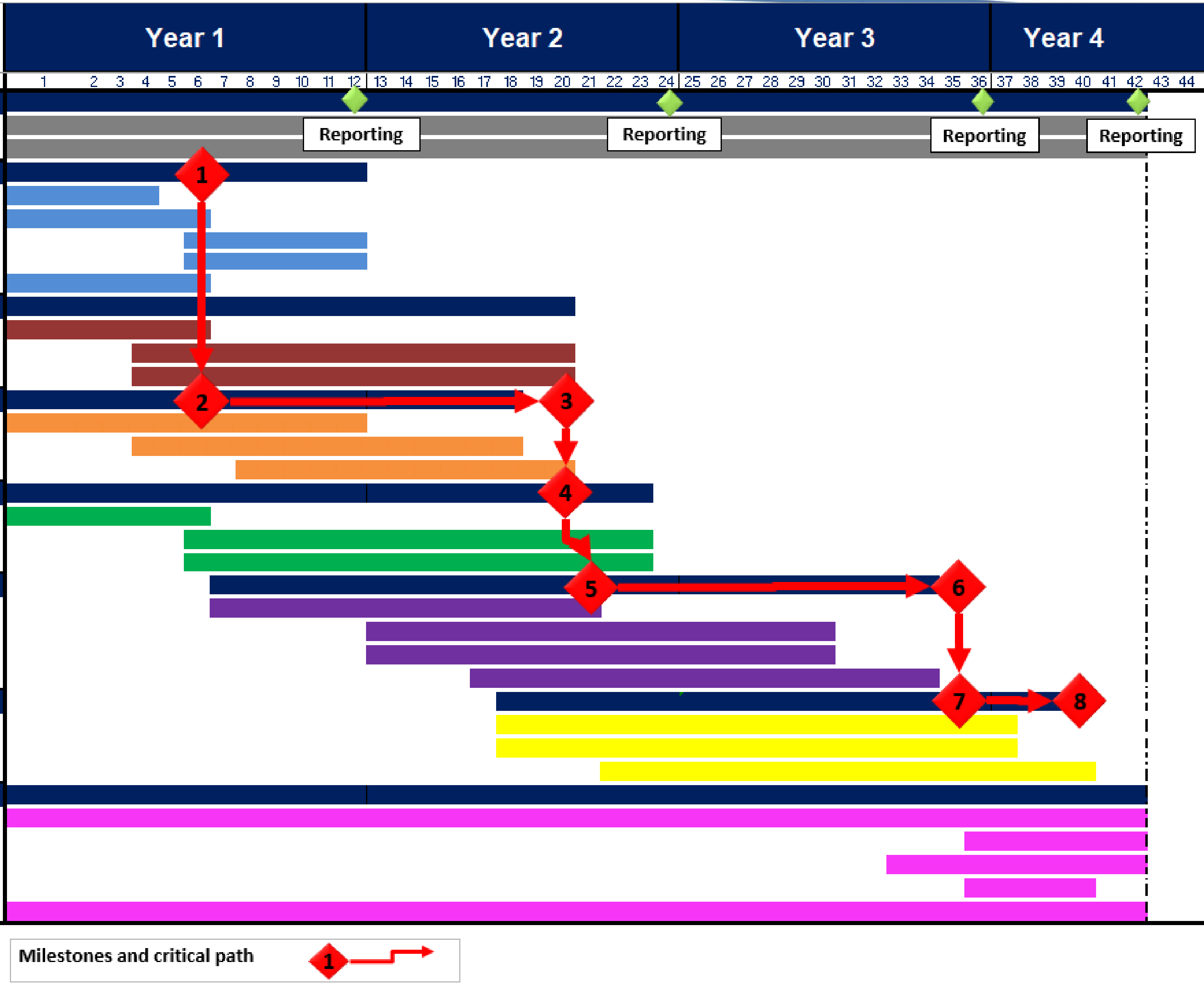
WP1	**Project management**
T1.1	Strategic decision making
T1.2	Operational management
WP2	**Project expectations and requirements**
T2.1	Defining consistent concepts of reliability and resillience
T2.2	Definition of reliability and resilence needs
T2.3	Use case definition and guidance
T2.4	Identification of the Regulatory/ code and framework questions to be answered when enhancing R&R
T2.5	Definition of requirements and demonstration needs
WP3	**Concept architectures for reliable and resilient AC/DC systems**
T3.1	Identification of (suitable) AC/DC grid architectures
T3.2	Control for AC/DC architectures
T3.3	Protection concepts for AC/DC architectures
WP4	**Enabling technologies for future AC/DC hybrid systems**
T4.1	Identify promising technologies and propose innovative solutions
T4.2	Technology modelling
T4.3	Model standardization and development of a structured database
WP5	**Simulation tools for R&R-driven planning and operation of hybrid AC/DC power systems**
T5.1	Definition of the scope for the tools and of the model needs
T5.2	Resilience-driven network expansion planning
T5.3	Cascading event quantification and operational mitigation strategies
WP6	**Resilience-enhancing network expansion planning methodology: application to use cases**
T6.1	Definition of a common methodology for the use cases
T6.2	Use case 1: (Highly Meshed) Continental European network
T6.3	Use case 2: Reinforcement of network capacity on a small/medium synchronous area
T6.4	Use case 3: Multipurpose offshore grid connecting the two other use cases
WP7	**Validation of control and protection concepts on realistic use cases**
T7.1	Use case 1: (Highly Meshed) Continental European network
T7.2	Use case 2: Reinforcement of network capacity on a small/medium synchronous area
T7.3	Use case 3: Multipurpose offshore grid connecting the two other use cases
WP8	**Pathways towards hybrid AC/DC grids: dissemination and exploitation**
T8.1	Exploitation Planning & Impact Evaluation
T8.2	Recommendations for planning methodologies and analysis tools
T8.3	Technology roadmap for enabling technologies
T8.4	Recommendations for the regulatory, contractual and market framework
T8.5	Stakeholder oriented and public dissemination activities



SSEN Contribution

- Leading WP2: TSO expectations and requirements
  - Defining consistent concepts of R&R
  - Definition of R&R needs (task leader)
  - Use case definition and guidelines
  - Identification of the regulatory / code and framework questions to be answered when enhancing R&R
  - Definition of requirements and demonstration needs
- Involved in WP3, WP6, WP7
  - Use case 2: Reinforcement of a small or medium synchronous area (GB)
  - Perform real-time analyses with control replicas of different HVDC links

Thanks for listening.

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