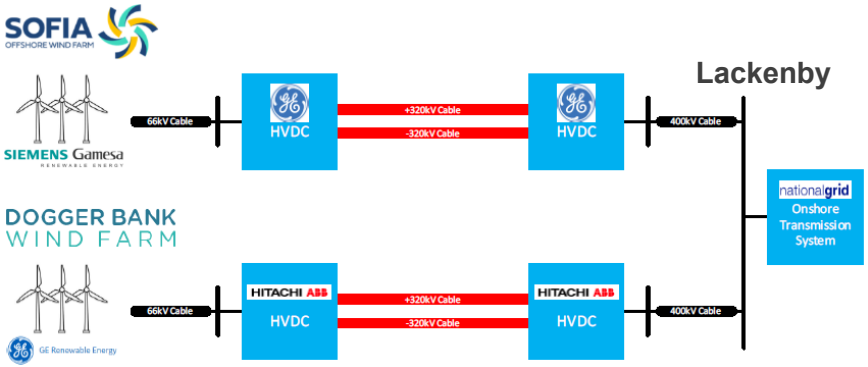
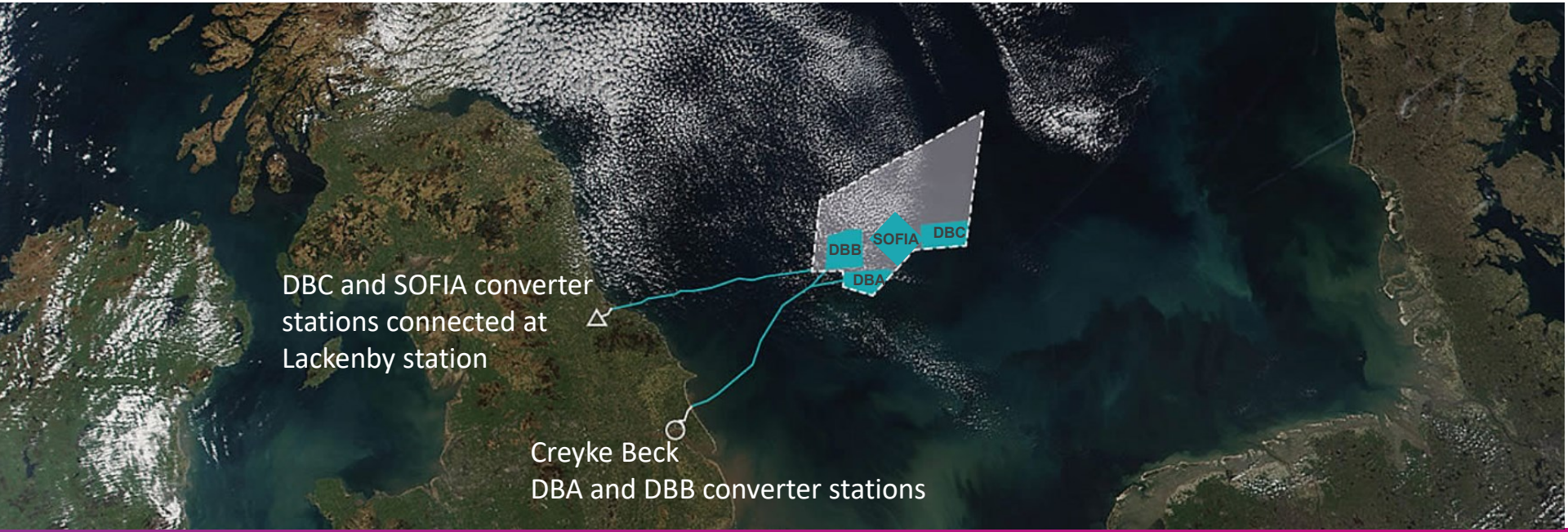
SOFIA/DBC INTERACTION STUDY

HVDC Centre Operator Forum

June 13th, 2024

SOFIA AND DBC OFFSHORE WIND PROJECTS





PROJECT OVERVIEW

Objective of the project

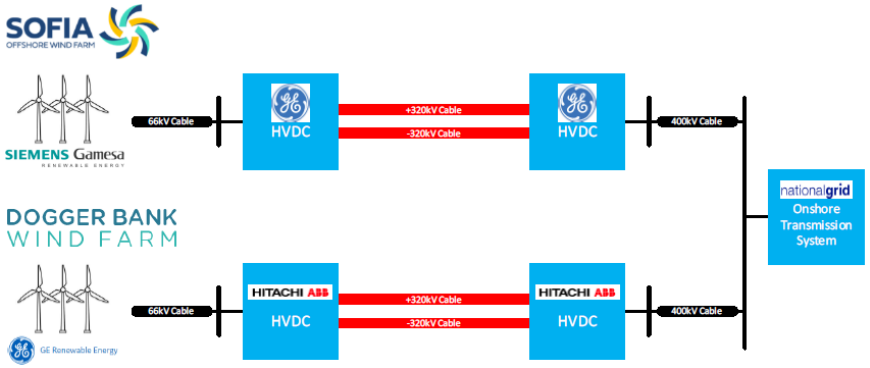
Identification and mitigation of possible adverse interactions between SOFIA and DBC HVDC

Tools

Use of EMT simulation with models (WP1) and replicas (WP2)

RTEi's methodology

- Independent 3rd Party
- Coordination with all Stakeholders
- Assuring IP protection
- Definition of test matrix
- Performing simulations
- Sharing results
- Contribute to mitigation solutions



FOCUS ON WP1

Main activities

EMT model specifications

Test of individual models

Analysis and discussions

Definition of test cases

Merging of models and automation

Data accessibility (models and results)

Running simulations

Liquid cooled CPU - AMD Ryzen Threadripper Pro
128 parallel simulations
20hours to run ~500 cases

FOCUS ON WP1

EMT model specification for HVDC and OWF systems

Data accessibility

HV electrical equipment	Fully accessible and detailed representation
Control and Protection system	Can be black-boxed. However, ○ Certain control variables in station and upper-level controls may be accessible for monitoring ○ High-level control system description ○ Protection system should be available in the models
Model parameters	Minimum list of tunable parameters

FOCUS ON WP1

EMT model specification for HVDC and OWF systems

Functional specification

Main functions

All relevant C&P functions are included
Most relevant AC and DC protections are included
Most relevant control strategies are included
Vendors specify the C&P functions not included (to be validated by Clients)

Signal availability

Define a minimum list of available signals

Modeling

Level of details for HVDC, OWF, and offshore grid representation

- Consensus among all stakeholders
- Adequate for project-specifics

Solution should be implemented to speed up the start-up sequence

FOCUS ON WP1

EMT model specification for HVDC and OWF systems

Model delivery

EMT platform

- Compatible with PSCAD version 4.6.3
- Compatible with Visual Fortran Compiler XE 18 or later
- All required compiled files (*.lib, *.dll)
- Model documentation is available

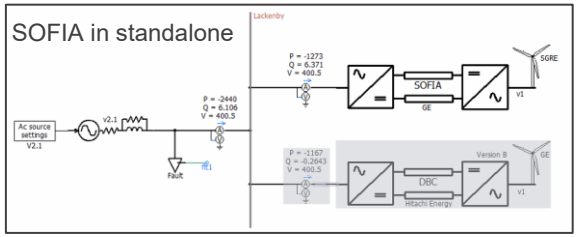
Non-compliance list

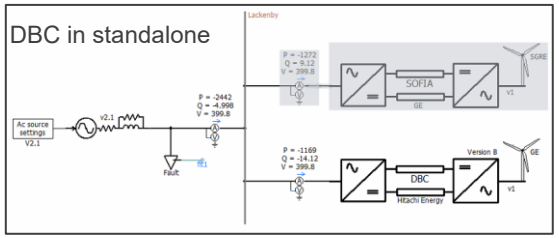
A non-compliance list is drafted by RTEi after model delivery

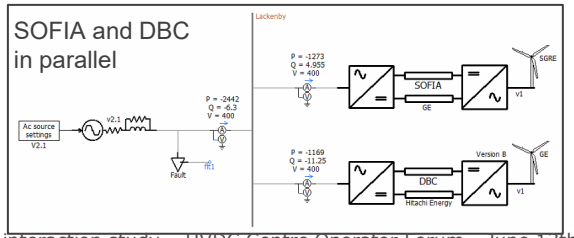
INTERACTION STUDY

Outline

Objectives of the study: assessment of possible adverse interactions between SOFIA and DBC



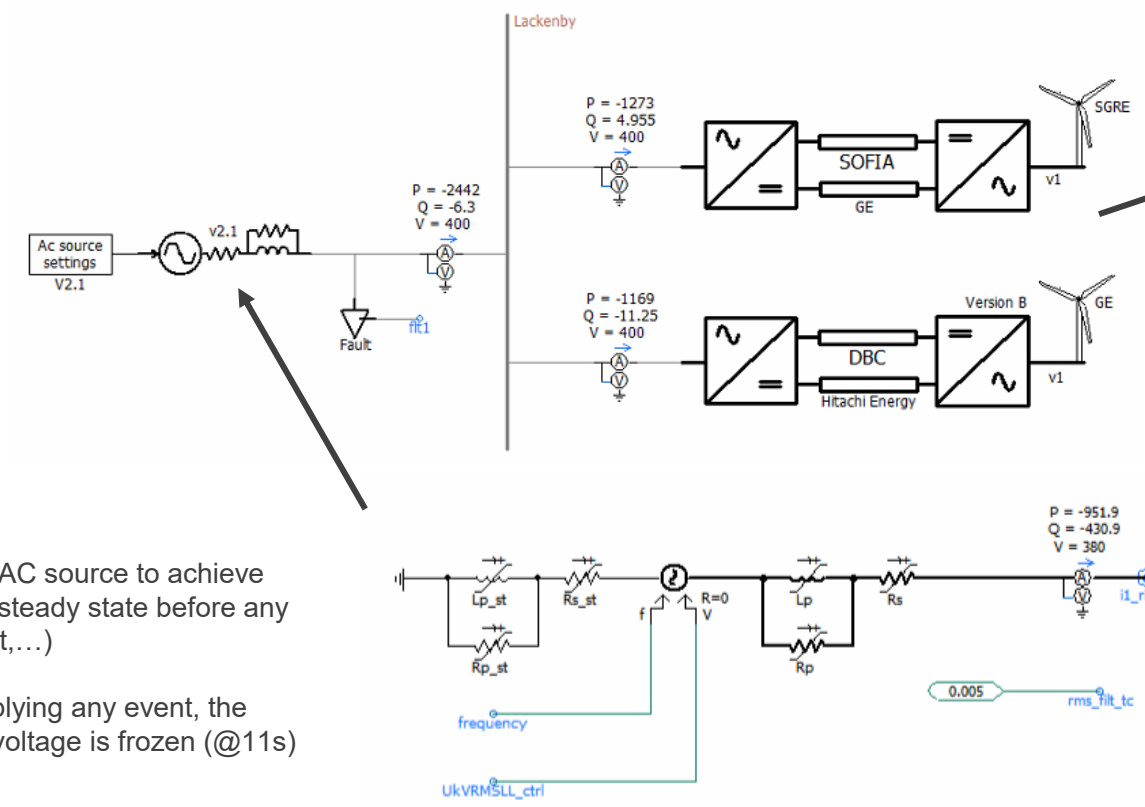




Methodology applied with offline models and HiL setup :

- Define test matrix with all relevant scenario for parallel operation
- Integrate models/replicas in a single circuit
- Run simulations in parallel and in standalone
- Compare performances in parallel and in standalone operation
- Generate reports and share results

PSCAD CIRCUIT USED FOR INTERACTION STUDY



Entire model including both AC onshore cables, filter…

No parallel computing to facilitate automation process

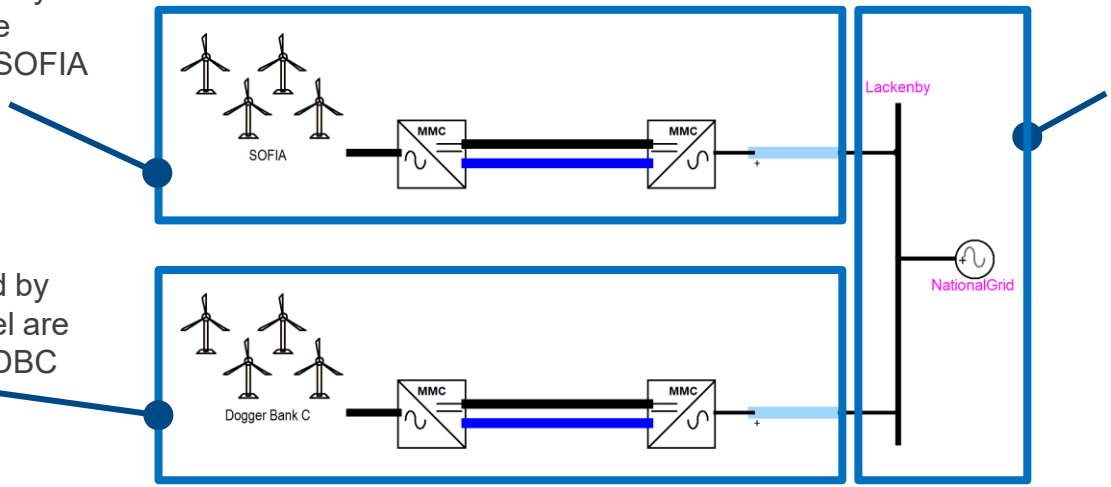
Controled AC source to achieve Utarget in steady state before any event (fault,…)

Before applying any event, the controled voltage is frozen (@11s)

FOCUS ON WP1

Information sharing between GE and Hitachi Energy

All results generated by this part of the model are accessible to GE + SOFIA only

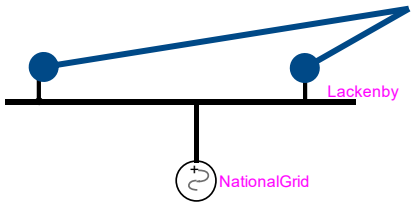


All results generated by this part of the model are accessible to all parties

All results generated by this part of the model are accessible to HE + DBC only

Results are provided in 2 formats:
- PDF reports with simulated waveforms (by default)
- COMTRADE format (When further analysis is required)

Accessible to all Parties :
Instantaneous voltage and current waveforms
P and Q calculated by each HVDC OEM

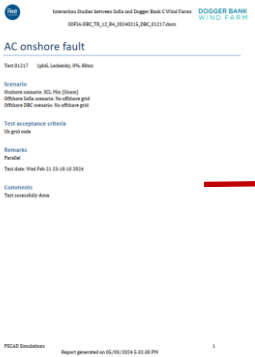


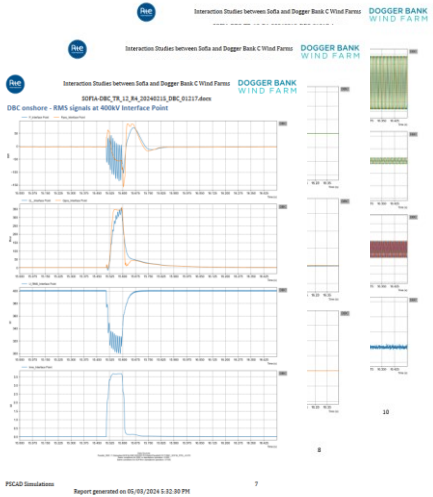
FOCUS ON WP1

Test reports shared with both projects

DBC_reports

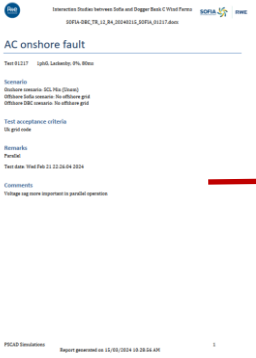
Parallel_DBC_reports

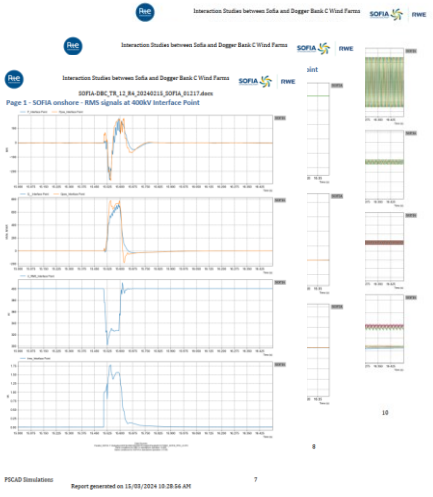




Parallel_SOFIA_reports

SOFIA_reports





FOCUS ON WP1

Test reports shared with both projects

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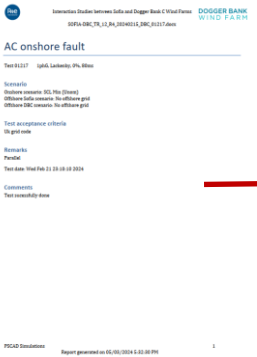
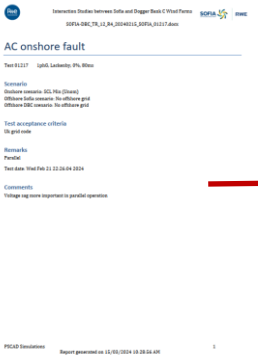
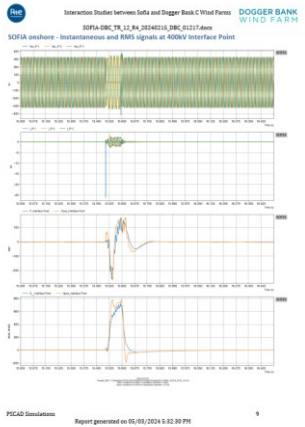
Parallel_DBC_reports

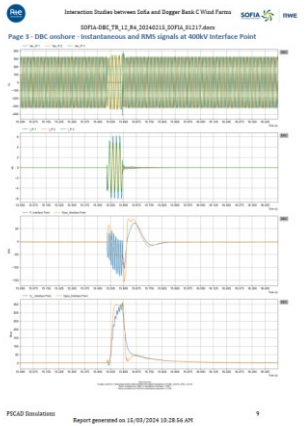


Parallel_SOFIA_reports

SOFIA_reports







FOCUS ON WP1

Test matrix definition (Test categories)

AC onshore fault

AC offshore fault

Start-up / Shutdown sequences

Transformer energization onshore / offshore

Variations in OWF power production

HVDC/WTG/WFC setpoint changes

Harmonic impedance assessment for the onshore converters

DC fault, trip of 1 HVDC

System performance for onshore frequency events

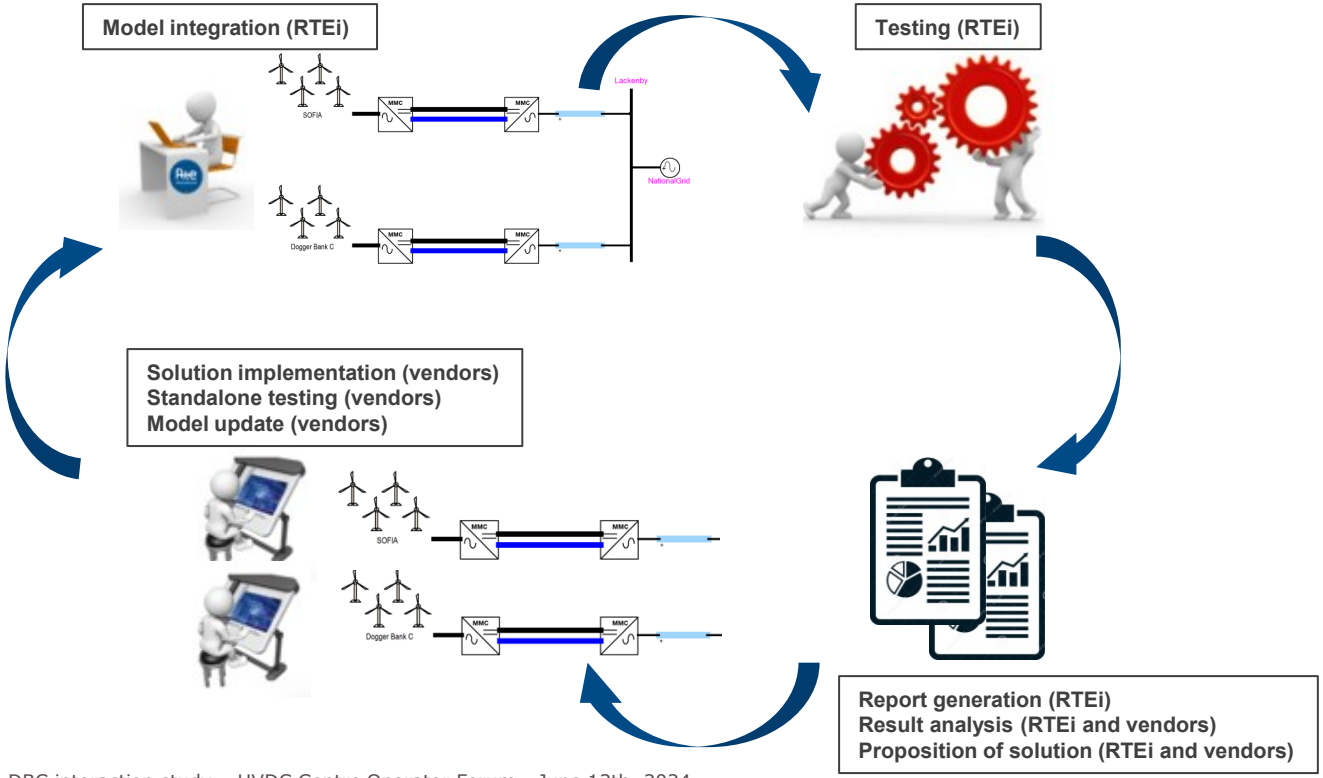
System performance for onshore voltage deviations

Inadvertent operation of onshore AC breakers

Control stability screening

FOCUS ON WP1

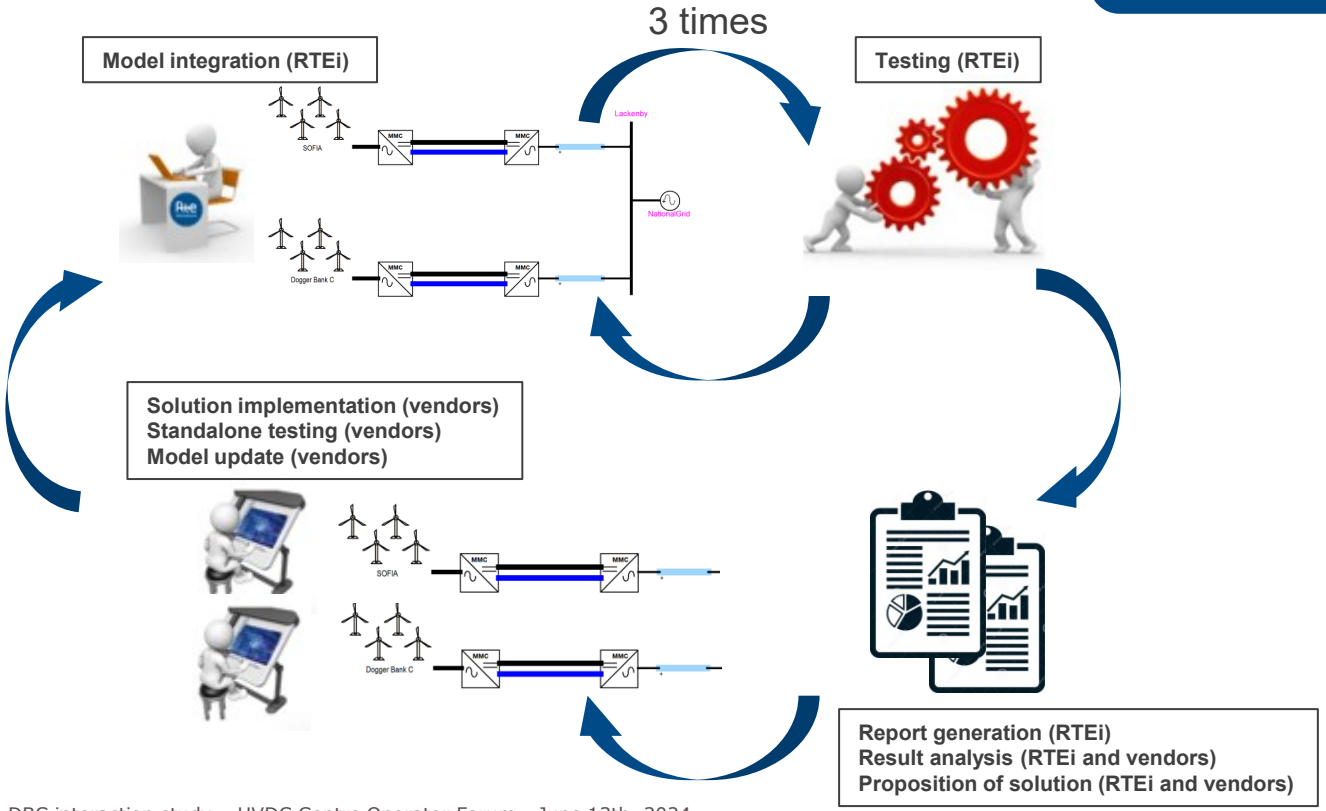
Iterative evaluation



FOCUS ON WP1

Iterative evaluation

- **Preliminary tests to avoid full study repetition**
- **Iteration study finally completed in Feb 2024**



FOCUS ON WP1

Main outcomes

Models provided by HVDC OEMs required more adaptations and corrections than expected to fulfil the requirements

Identification of issues in standalone operation with the preliminary tests conducted on each HVDC scheme

Options to optimize parallel operation have been identified

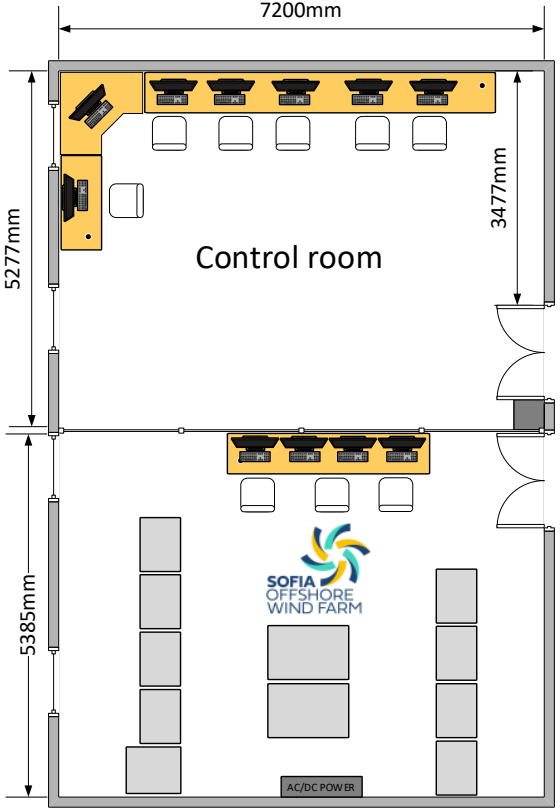
In case of PSCAD model update: partial repetition of test cases

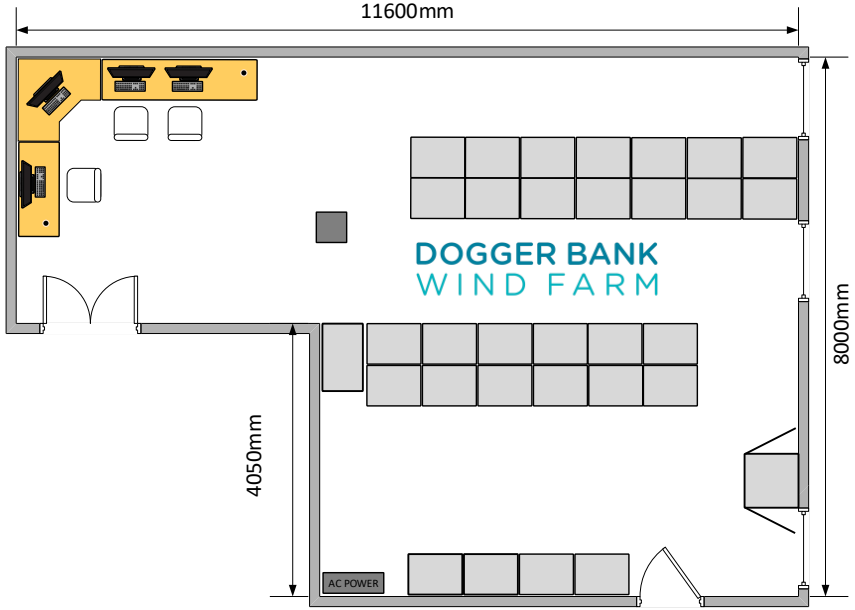
FOCUS ON WP2

Main activities

- Replicas specifications
- Procurement of the RTS
- FAT participation
- Model adaptation (OWF + HVDC merging)
- Update of the test matrix
- Preparation of lab facility
- Testing individual replica (PSCAD benchmark)
- Running simulations
- Analysis and dicussions

LAB LAYOUT


7200mm
5277mm
3477mm
Control room
5385mm
SOFIA
OFFSHORE
WIND FARM
AC/DC POWER


11600mm
DOGGER BANK
WIND FARM
8000mm
4050mm
AC POWER

LAB LAYOUT

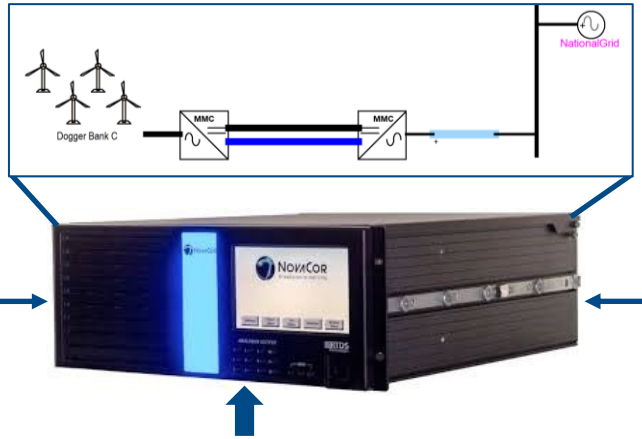
DBC replica delivery on April 12th, 2024 at RTEi lab

DBC replica in RTEi lab

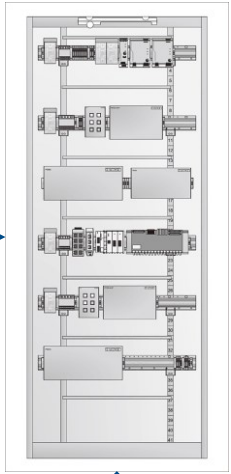
WP2 – ONGOING ACTIVITIES

WTG DBC: Blackbox model to be executed in GTSoC board

C&P code including WTC, CC, WFC
(delivered by GE)



RSCAD model delivered
- by GE for WTG electrical equipment
- By Hitachi for the HVDC electrical equipment



DBC replica

CONCLUSION

Interaction study of 2 HVDC links

Test cases have been agreed with all stakeholders

EMT offline models have been delivered by HVDC and Wind OEM as expected

Several iterations have performed in standalone operation before starting interaction study

DBC replica was delivered on April 12th, 2024

Offshore grid will be modeled based on EMT offline black box models

Replicas are used to:

- perform test cases not simulated with offline models
- benchmark against offline simulation (Quality control)