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HVDC AND INTEROPERABILITY

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INTEROPERABILITY IS NOTHING NEW

Cross Channel Link – An Interoperability Challenge

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Interoperability is not a new challenge

The contract for the 2000 MW Cross Channel link between GB and France was separately awarded to GEC for the GB side and CGEE-Alsthom for the French side

Both vendors had the technology to build a HVDC point-to-point link as a single vendor action

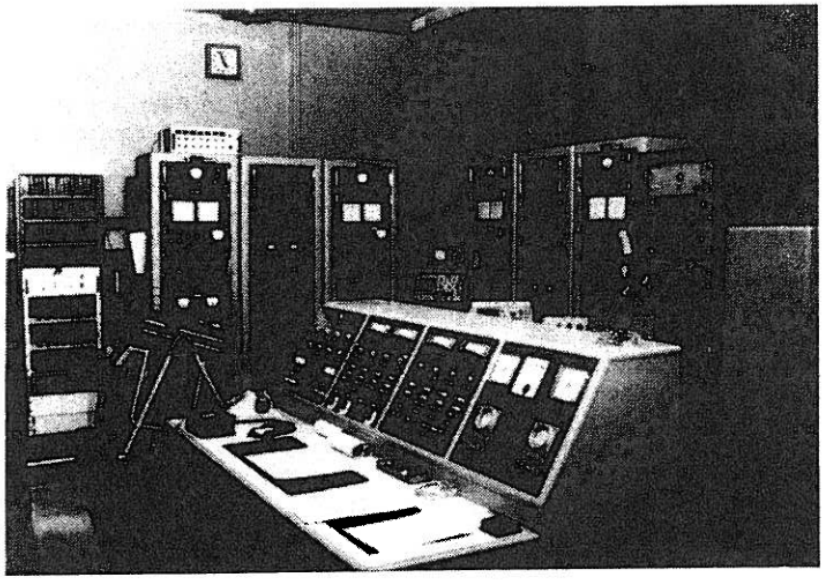
P Adam, V Collet Billion, J D Ainsworth, A Jeunehomme, I W Whitlock, “The 2000 MW Cross Channel Link between France and England: Compatibility of the two Converter Stations”, IEE 4th Int. Conf. on AC&DC Power Transmission. Conf Pub. No. 255, September 1985

Cross Channel Link – An Interoperability Challenge

First, the future operators of the link, CEGB and EdF, agreed on a functional specification for the link

The following methodology was adopted for the contract:

- The manufacturers exchanged information on their equipment and performed a joint analysis of incompatibilities
- Using a physical simulator (owned by EdF) the manufacturers performed combined testing which revealed incompatibilities that had not been identified in the first analysis
- Using a physical simulator (owned by EdF) the customers validated that the functional specification had been met



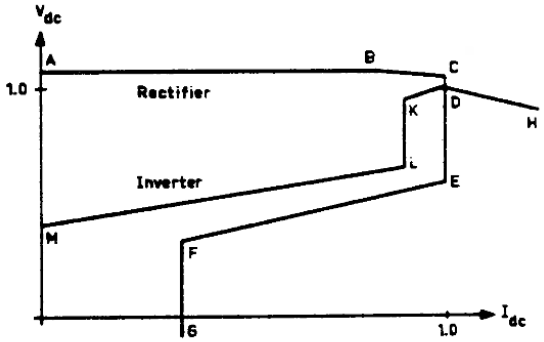
* Figure 3: The EDF d.c. simulator with the two manufacturers control equipments

*P Adam, V Collet Billion, J D Ainsworth, A Jeunehomme, I W Whitlock, “The 2000 MW Cross Channel Link between France and England: Compatibility of the two Converter Stations”, IEE 4th Int. Conf. on AC&DC Power Transmission. Conf Pub. No. 255, September 1985

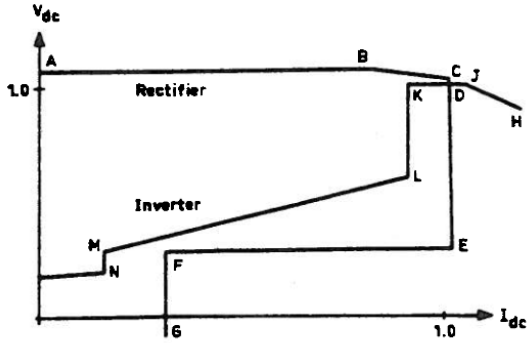
Cross Channel Link – An Interoperability Challenge

Types of incompatibilities found included:

- Differences in *Static Characteristics*, i.e., the quasi-steady state behaviour of the DC voltage and current
- Differences in the dynamic performance of the control loops between ends which have a strong interaction via the DC cables and are also impacted by the respective AC systems



* Figure 1: DC voltage/current characteristics for power flow France to England



* Figure 2: DC voltage / current characteristics for power flow England to France

*P Adam, V Collet Billion, J D Ainsworth, A Jeunehomme, I W Whitlock, "The 2000 MW Cross Channel Link between France and England: Compatibility of the two Converter Stations", IEE 4th Int. Conf. on AC&DC Power Transmission. Conf Pub. No. 255, September 1985

Cross Channel Link – An Interoperability Challenge

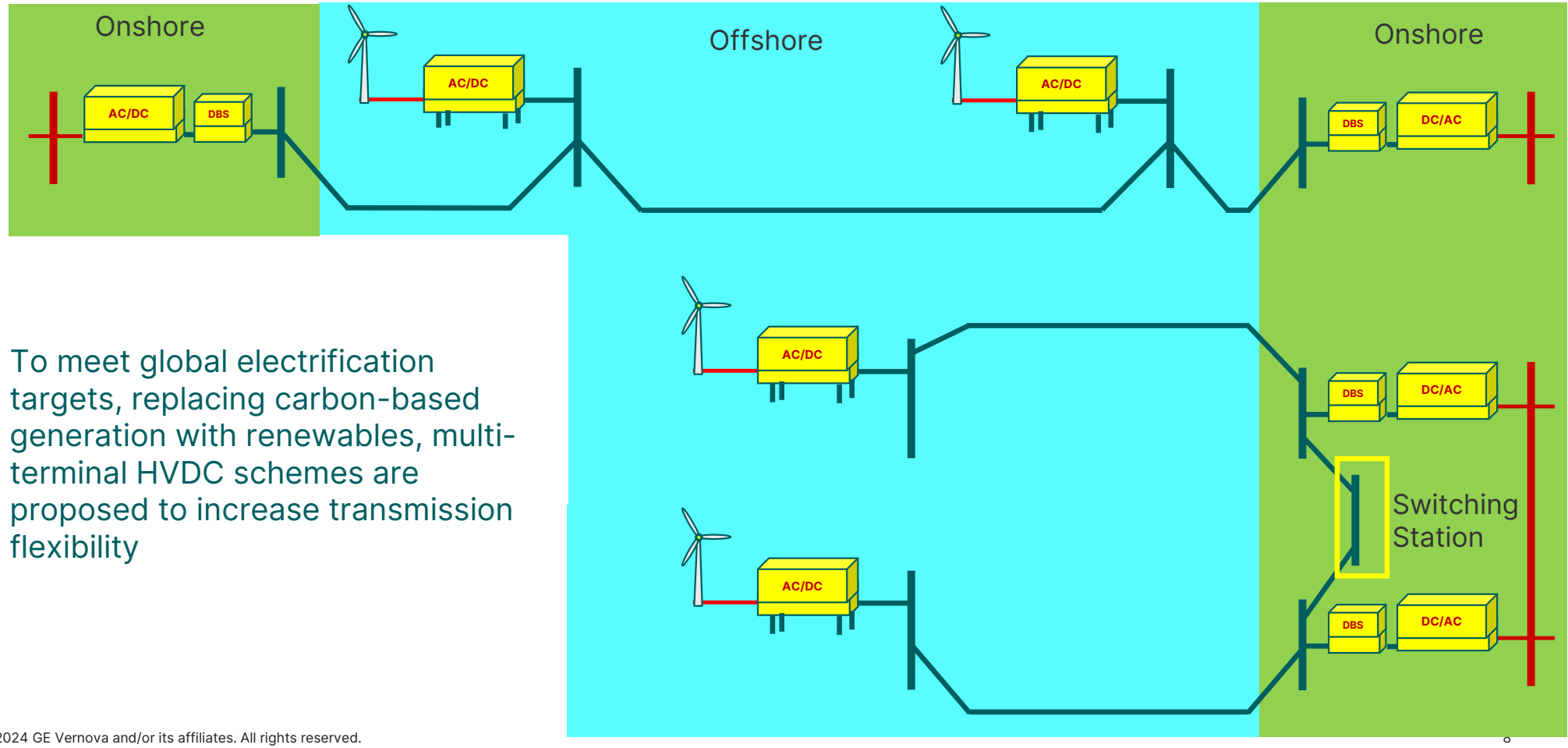
Lessons learned*:

- Different vendors equipment at each end of a point-to-point can be made to be compatible
- The use of real-time modelling was essential in identifying incompatibilities
- The project execution time was extended by approximately 10 months to allow for the combined testing

*P Adam, V Collet Billion, J D Ainsworth, A Jeunehomme, I W Whitlock, “The 2000 MW Cross Channel Link between France and England: Compatibility of the two Converter Stations”, IEE 4th Int. Conf. on AC&DC Power Transmission. Conf Pub. No. 255, September 1985

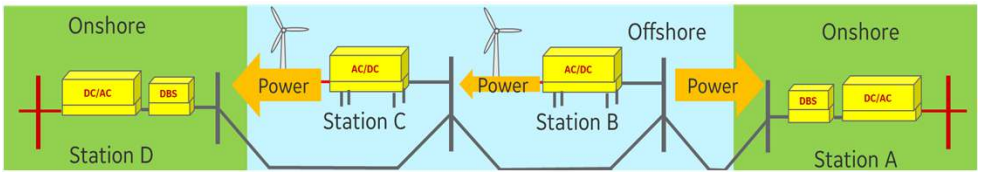
WHY IS EVERYONE TALKING ABOUT INTEROPERABILITY TODAY?

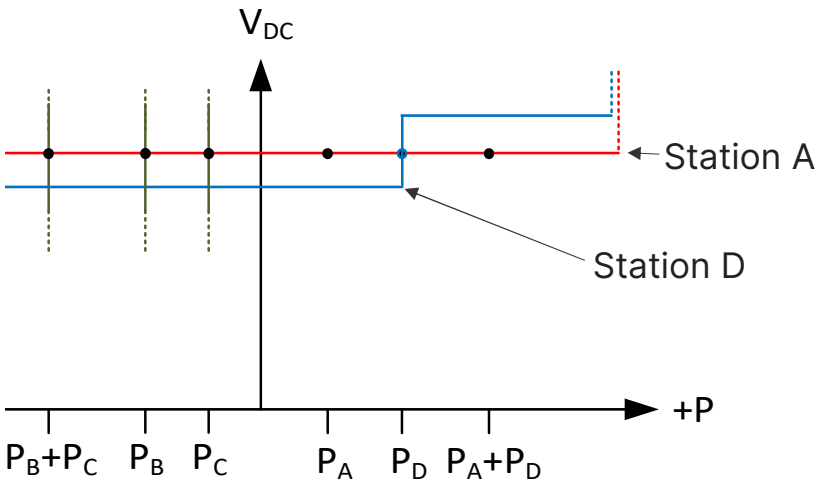
Multi-Terminal HVDC

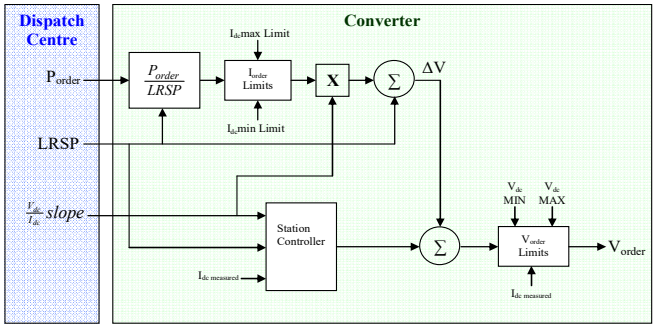


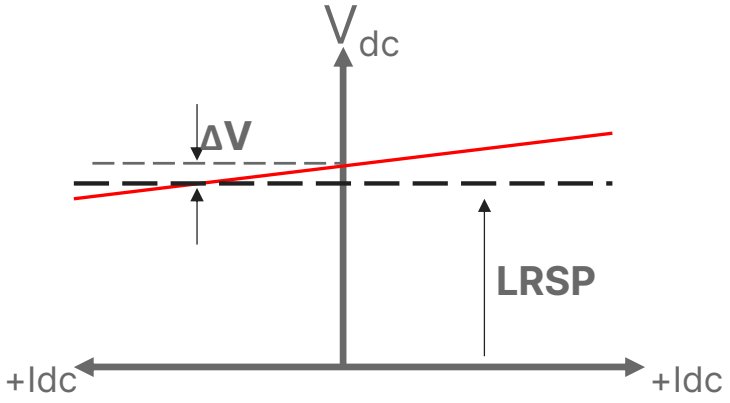
To meet global electrification targets, replacing carbon-based generation with renewables, multi-terminal HVDC schemes are proposed to increase transmission flexibility

Multi-terminal Control





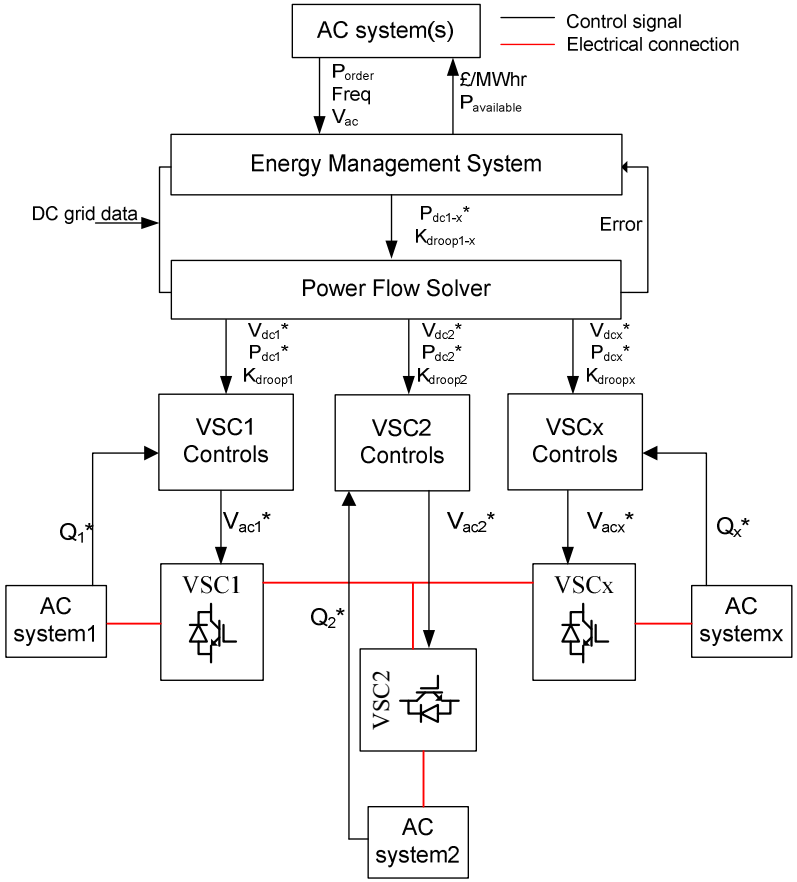


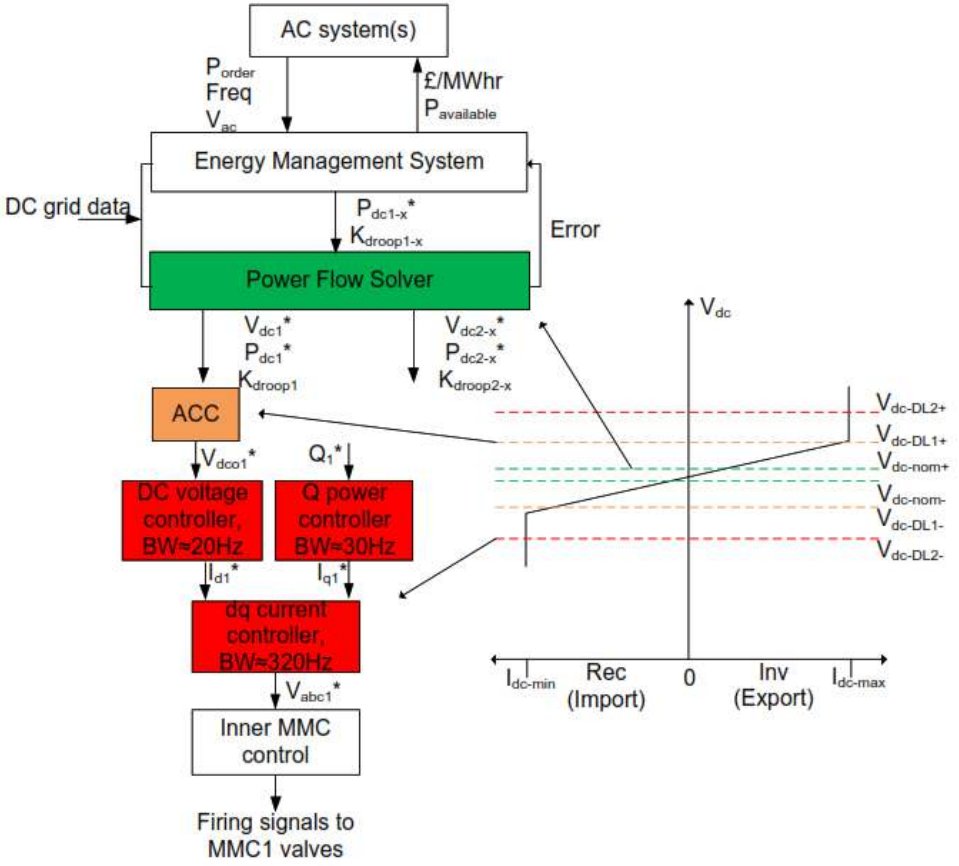


LRSP = Load Reference Set Point

C D Barker, R S Whitehouse, "Autonomous Converter Control in a Multi-Terminal HVDC System", IET ACDC, Birmingham 2010.

DC Grid Control Architecture





A Beddard, A Adamczyk, M Barnes, C Barker, "HVDC Grid Control Based on Autonomous Converter Control", IET, PEMD, 2016.

Multi-Terminal HVDC

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Multi-terminal:

- May be built in stages over many years
- Timescales to put into service may be beyond the manufacturing capability of a single vendor
- Procurement rules may necessitate going to the market for future expansion

Hence, future multi-terminal ambitions bring with them the need for Interoperability

CHALLENGES

Challenges

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Defining the boundaries associated for a single vendor's scope

Defining the communications interface associated with a single vendors scope

Defining the performance at the defined boundaries associated with a single vendors scope

Defining how Reliability/Availability is measured and responsibilities allocated

Determining who will perform the integration studies and how change requests are agreed

Managing the Intellectual Property of vendors and 3rd parties

Intellectual Property

National HVDC Centre Aquila Project

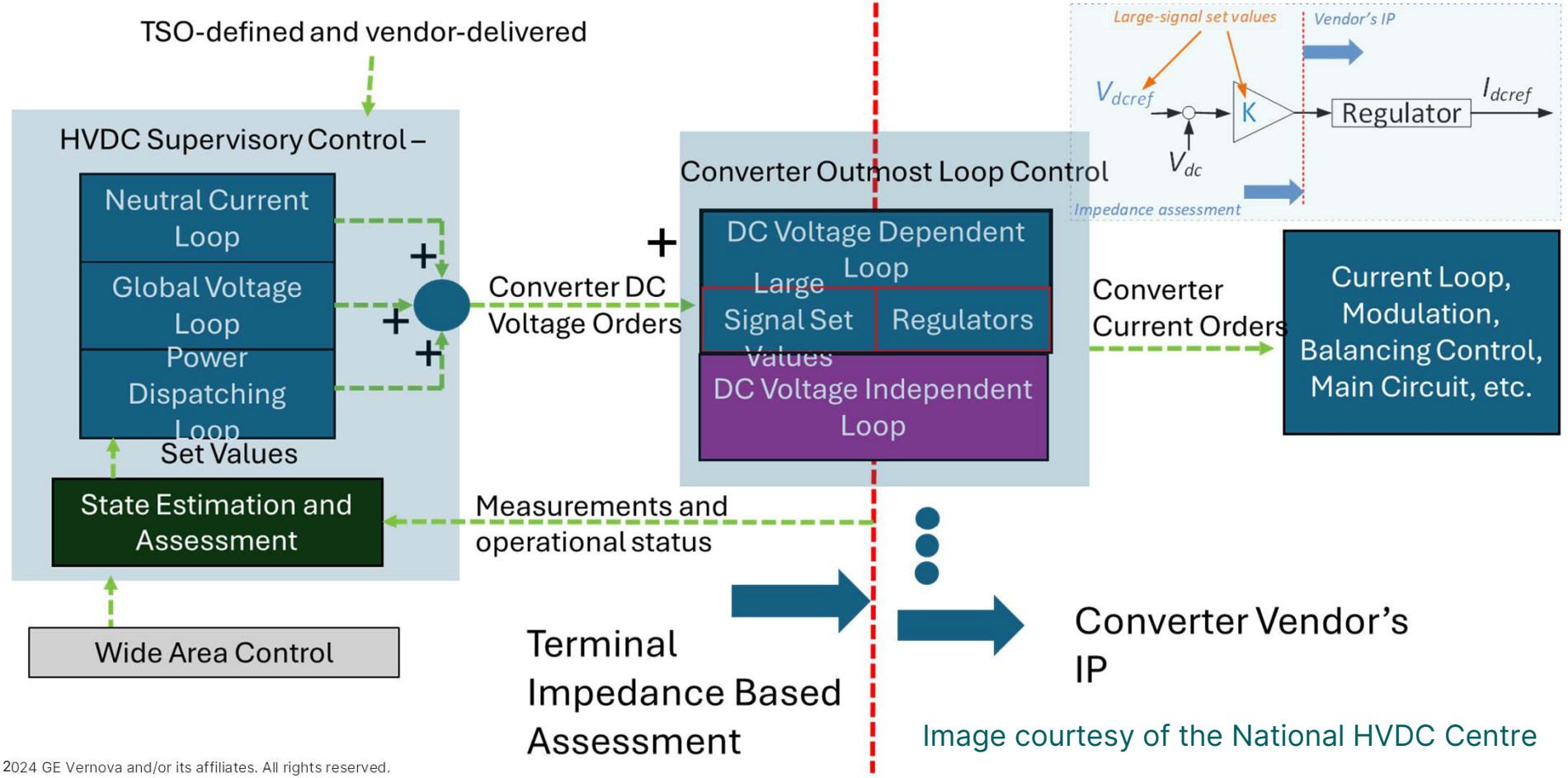
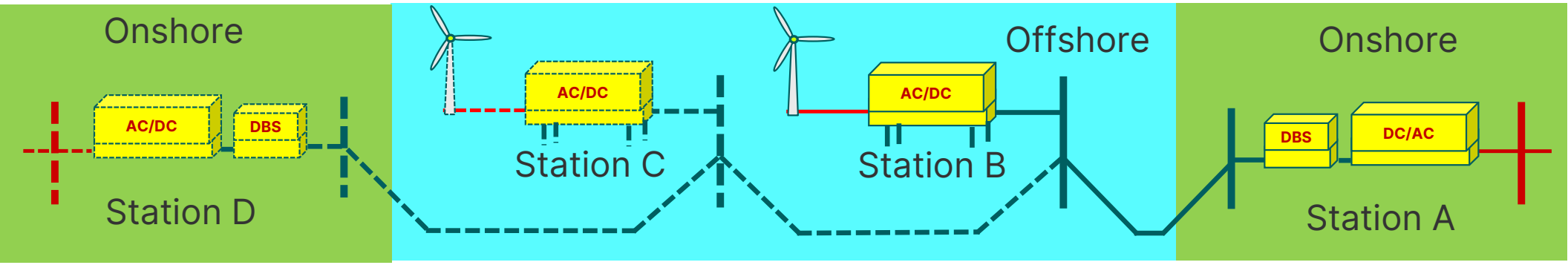


Image courtesy of the National HVDC Centre

PROJECT APPROACHES

Hybrid HVDC

First project with a head start



When the first, point-to-point, element of a link is built the terms and conditions of this contract should include the design and specification of the future extension, defining:

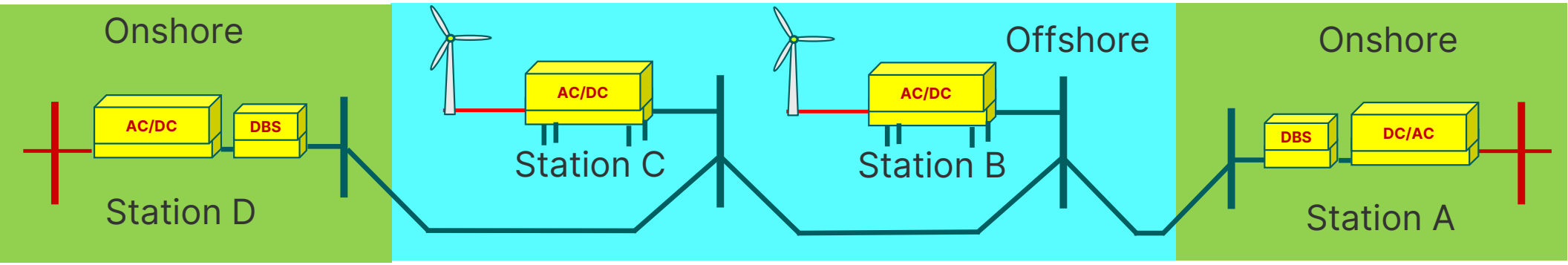
- rating
- interfaces (including signal type and bandwidth)
- dynamic performance (against a set of defined tests)

Future expansion should include above details as part of the specification.
Purchase replica and simulator with first link then add replica for second link and validate as part of contract conditions for interconnection.

- But compatibility for other vendors may be a limitation

Hybrid HVDC

Projects parallel and co-ordinated



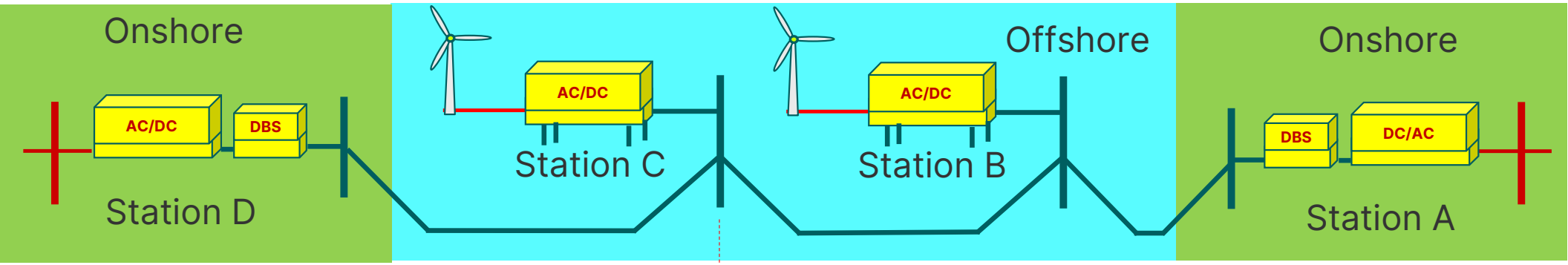
Where the projects can be run in parallel there is the opportunity to have an early-stage project to:

- establish a common functional specification and interfaces
- demonstrate, in a collaborative way, through both SIL and HIL the compatibility of the multi-vendor system

Such an approach is now being executed in both Project Aquila and InterOPERA

Hybrid HVDC

Projects parallel and co-ordinated – early stage project – Part 1

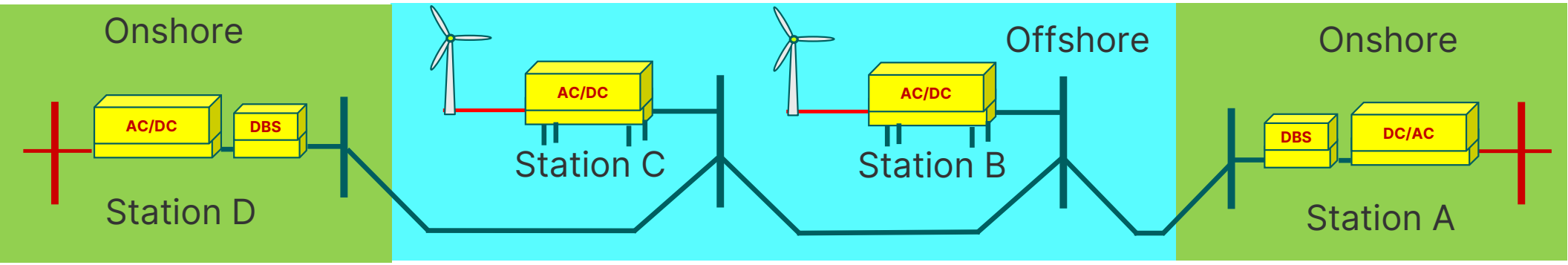


Need for clarity on scope of supply e.g.,:

- Telecommunications
- Protection of cable joining the two point-to-point links
- Overall “Link controller”
- HMI

Hybrid HVDC

Projects parallel and co-ordinated – early stage project – Part 2



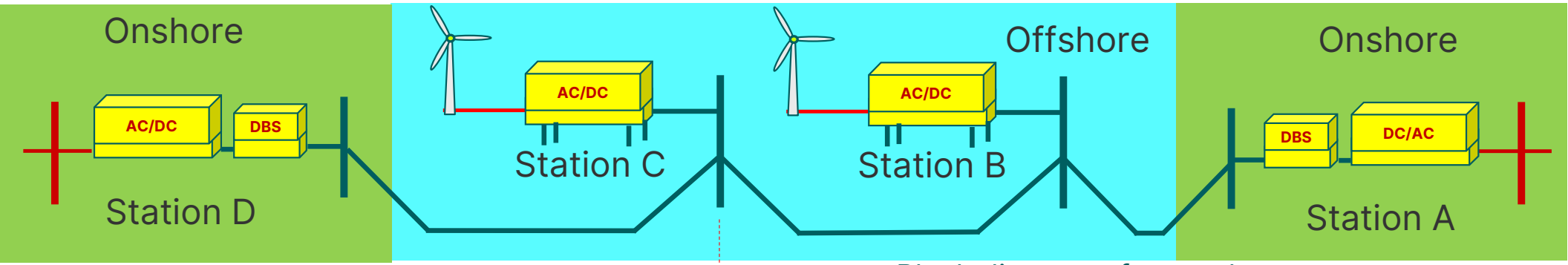
Each supplier will undertake an agreed series of "inter-operability" Dynamic Performance Studies in order to validate the stability of their controller at both the associated AC and DC Point-of-Connection:

- Each model (including DC circuit model) operating as a DC voltage control station against a current source
- Each model (including DC circuit model) operating as a power control or V/f station against a DC voltage source

Inter-operability dynamic performance final results could be shared in the form of a report and CSV files of results for each version of the PSCAD model supplied by each vendor.

Hybrid HVDC

Projects parallel and co-ordinated – early stage project – Part 3



Block diagram of control system

Black-box EMT
- Converter + controller

Thevenin equivalent AC system
Reduced equivalent AC system

RMS
- Machine equivalent current source of converter + control
- AC equivalent model

Integrator

Block diagram of control system

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- DC connection model

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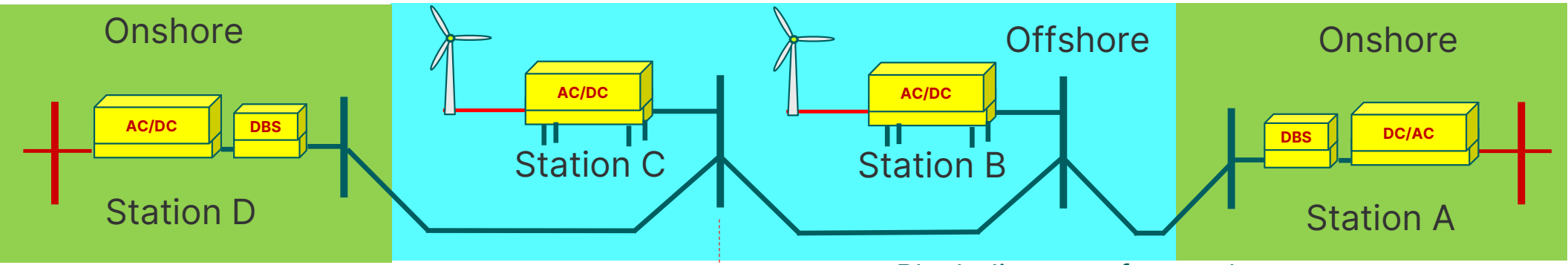
Hybrid HVDC

Projects parallel and co-ordinated – early stage project – Part 3



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Block diagram of control system

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DC model

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Machine equivalent current source of converter + control

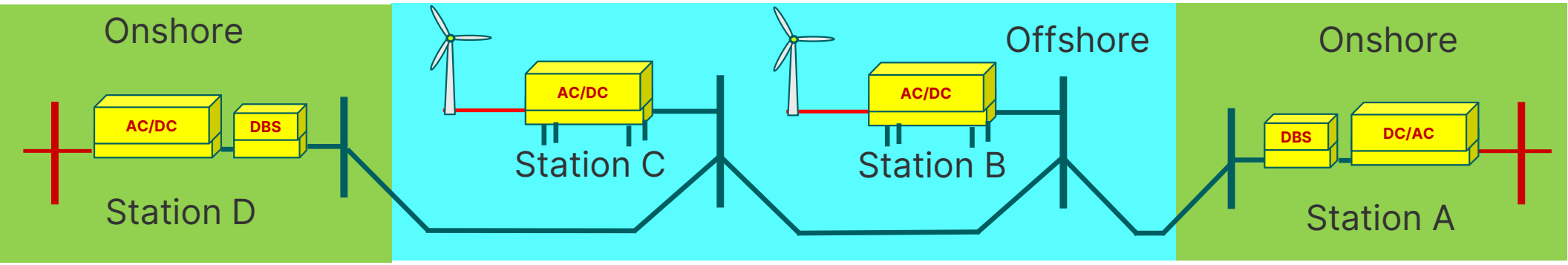
AC equivalent model

DC connection model

Requires commercial conditions agreement between parties

Hybrid HVDC

Projects parallel and co-ordinated – early stage project – Part 3



System Integrator

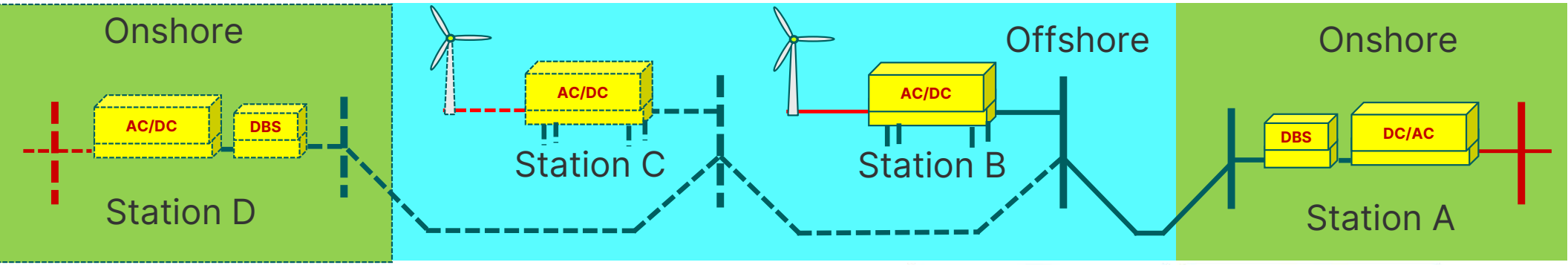
Control system replica

Control system replica

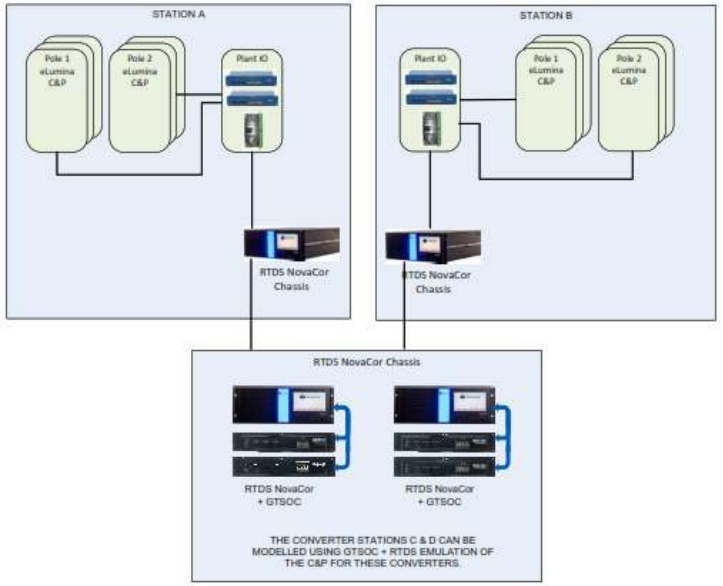
Agreed detailed specification

Hybrid HVDC

Projects parallel and co-ordinated – early stage project – Part 3



Today, there is no need for a full control and protection replica at each converter node, black-box real-time execution platforms such as the GTSOC from RTDS™ can be used to represent future (or existing) terminals.



LIFECYCLE STUDIES

Studies Undertaken during a Project Lifecycle

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Table I: Example of typical use of different tools at different stages of the HVDC lifecycle

Stage of life-cycle	Tool: Small-small signal analysis	Load flow / short circuit	Transient dynamics simulation	EMT	Harmonics	Real-time simulators
Predesign	↑	↑	↑	→	↑	=
Bid	=	→	↑	→	=	=
Post award	→	→	→	↑	→	↑
Commissioning	→	→	→	↑	=	→
Post-commissioning	Use depends on the needs and the practises of the Owner/Utility					

↑ intensive use → moderate use = few or no use

Usage of these tools will depend on whether each mutli-terminal project is bespoke or if a ***DC grid code*** is established

Usage may increase dependent on the format of models provided by other vendors

Table extracted from CIGRE TB 563, "Modelling and Simulation Studies to be performed during the lifecycle of HVDC Systems", 2013

CONCLUSIONS

Conclusions

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- Co-operation between the ultimate system operators is essential to define the required functional specification
- Co-operation between vendors is required to ensure relevant data is exchanged
- Co-simulation is needed to identify potential incompatibilities
- Intellectual Property is likely to pose a risk/challenge for some time to come

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