HVDC Replicas Explained

What? Why? When? Where? How?

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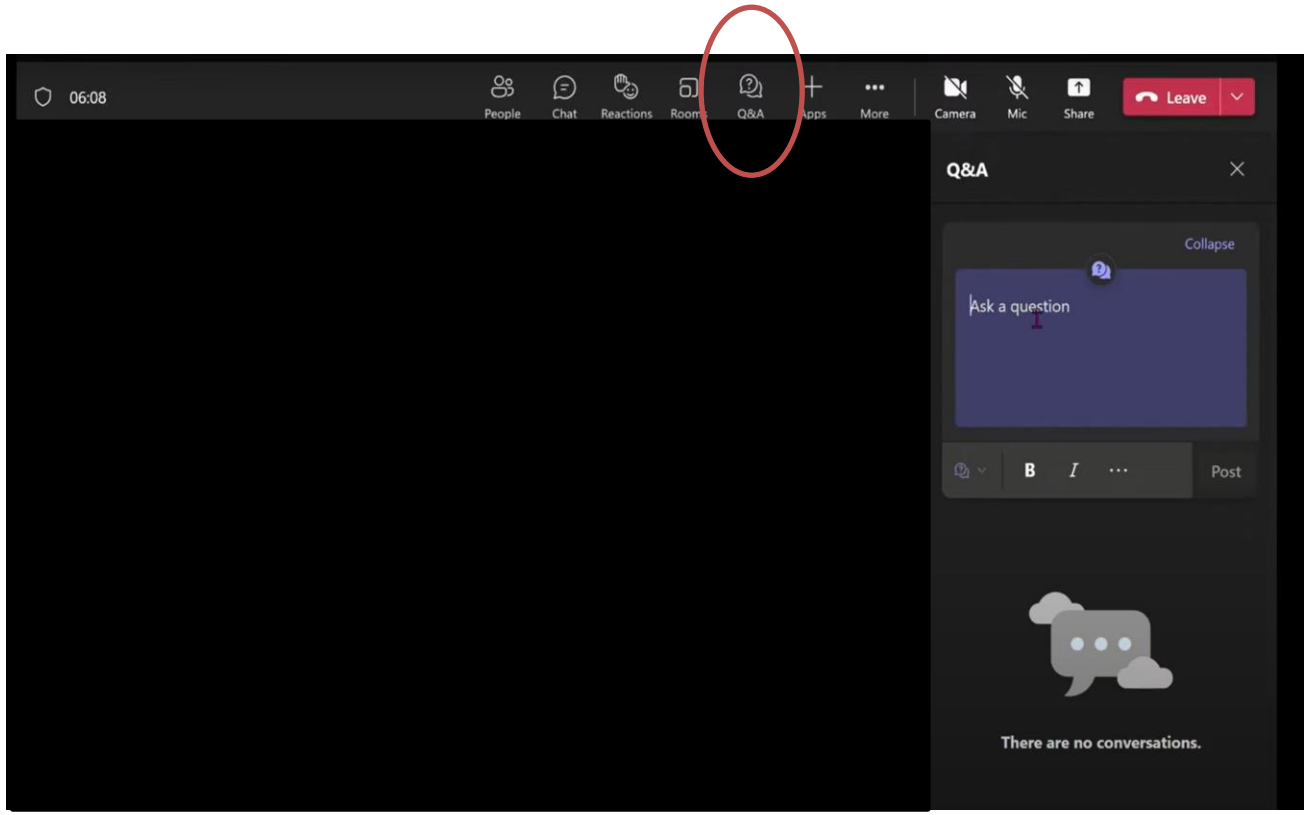
19 November 2024

The National HVDC Centre

Scottish & Southern Electricity Networks

General Housekeeping

- This webinar will be recorded and once approved, uploaded to hvdccentre.com



- **Using the Q&A Function in Teams**

Ask Question:

- Open Q&A panel by clicking the Q&A icon in the meetings controls
- Type your question in the "Ask a question" field and click Post

Find the Q&A Function

- If you don't see the Q&A icon, click on **More(…)** in the meeting controls to find it

Troubleshooting

- If you are unable to post your question, try leaving and rejoining the webinar

Agenda

- **Who are we?** - Introducing The National HVDC Centre
- **What are HVDC replicas?** - Different types of HVDC Replica
- **Why are HVDC replicas used?** - De-risking different project stages
- **How are HVDC replicas used?** - Real-life examples
- **Where & When?** - The practicalities of getting a replica
- **Our future plans** - HVDC Centre Extension
- **Q & A** – Your chance to ask questions

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Who are we?

Introducing The National HVDC Centre

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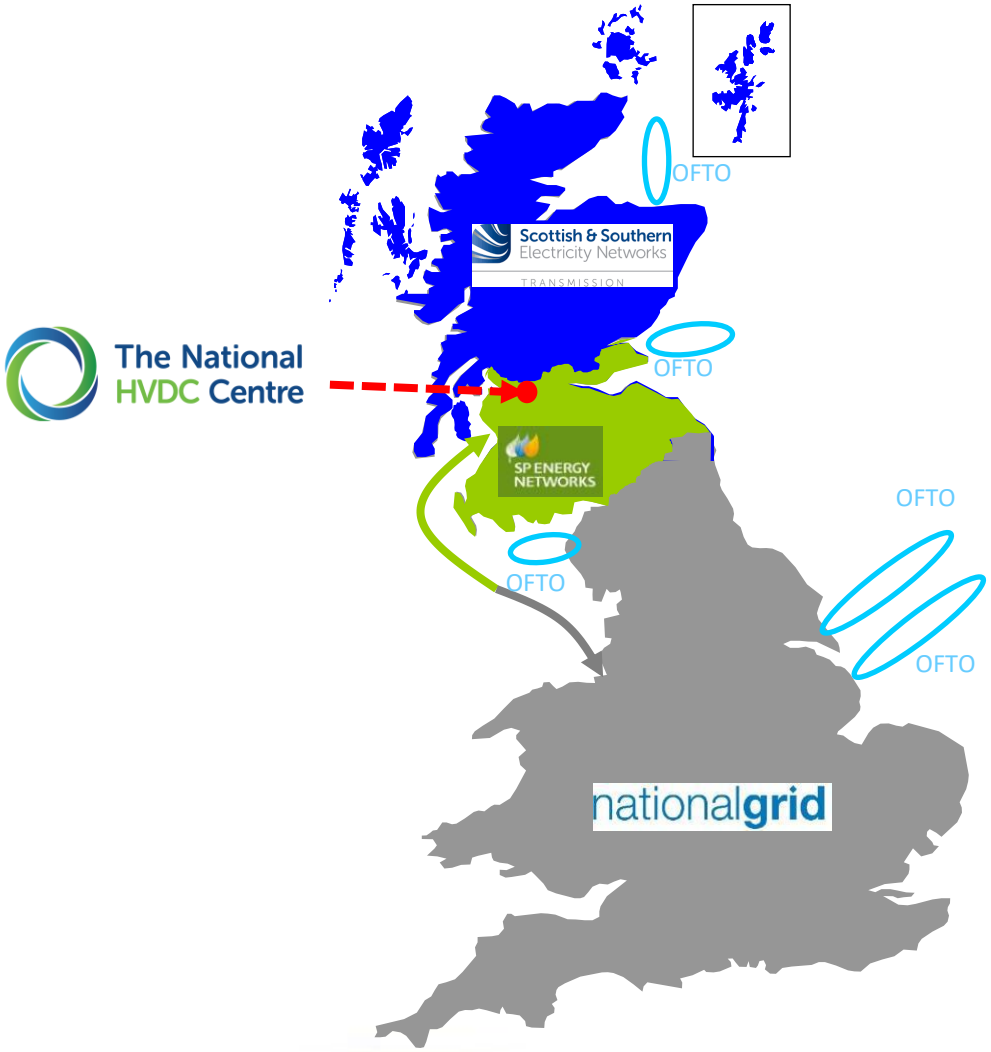
The National HVDC Centre – Location & Ownership



The National HVDC Centre *Part of* Scottish & Southern Electricity Networks TRANSMISSION *Onshore Transmission Owner (TO)*

nationalgrid SP ENERGY NETWORKS *Other GB Onshore Transmission Owners*

and

NESO National Energy System Operator *National Energy System Operator*

Stakeholders / Advisory board

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HVDC Centre: In a Nutshell

The National HVDC Centre

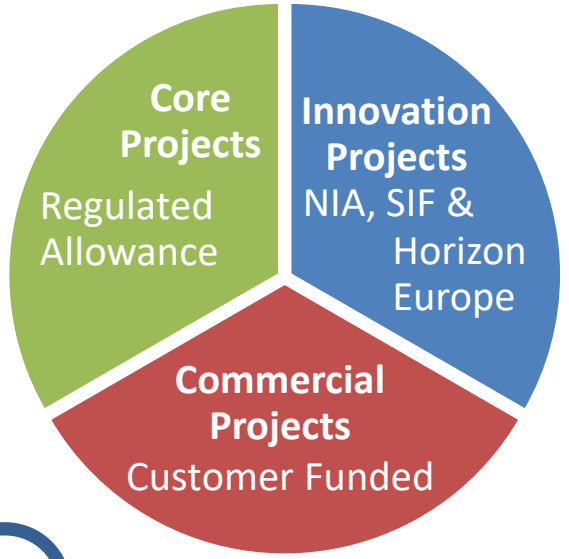
The National HVDC Centre delivers world-leading simulation, training and innovation; to de-risk, accelerate and enhance GB's efficient transition to a resilient Net Zero network.

Opened in 2017
Originally an Ofgem Innovation Project.

Bespoke 1,030m^2 Facility
[+ new extension planned]

23 Employees
From Manufacturers, Utilities & Academia

A Team of Industry Experts



State-of-the-art Simulation Infrastructure:

- Real-time Simulators: RTDS, OPAL-RT
- GTSOCs & Power Amplifiers
- High-Power Off-line Simulation PCs
- Software: PSCAD, PowerFactory, PSSE, MATLAB

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HVDC Replica Hosting

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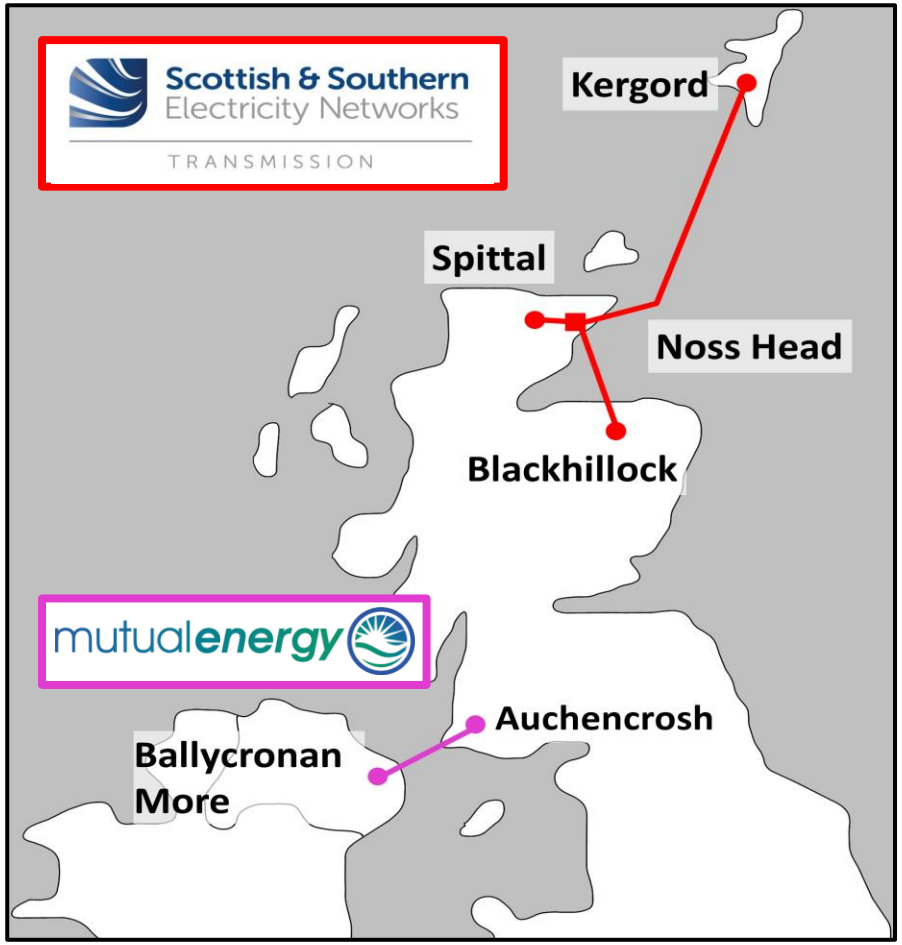
- The HVDC Centre hosts protection & control hardware replicas for two real-world HVDC schemes
- These replicas are exact copies of the control and protection hardware used on site
- We are planning to host more replicas in future



Caithness-Moray-Shetland (CMS) Replica

Moyle Replica

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What are HVDC Replicas?

Different types of HVDC replica

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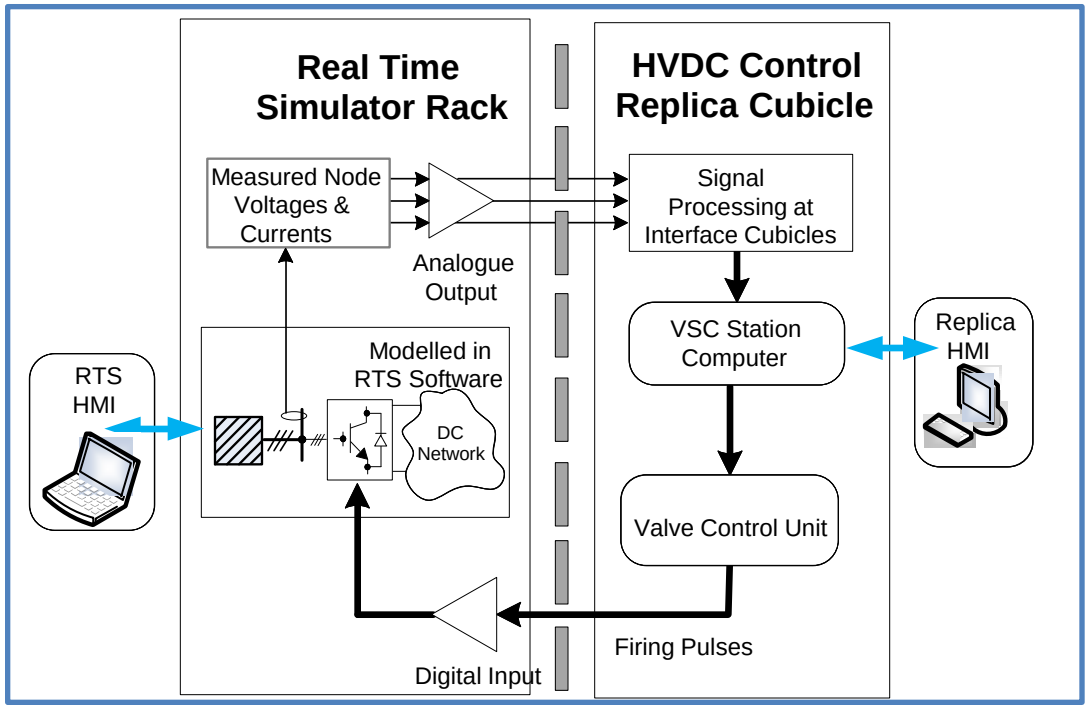
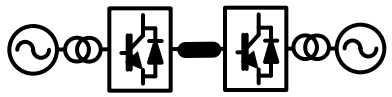
What are Replicas?





EMT Network Modelling

Real C&P systems

- "**Replica panels**" for an HVDC project are physical duplicates of the control & protection (C&P) systems, which can simulate HVDC performance in real time
- **Real Time Simulation**: computer model of a physical system that executes at the same rate as the actual time. (i.e., in the range of **µs**)
- The replica can be used to analyse the electrical behaviour of the system, but it can also be used to support maintenance activities related to the control and protection cubicles.
- Not including operator training aids, which duplicate HMI interfaces – our definition of replica focuses on control/Protection & simulation functionalities

Types of Replica

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Software-In-Loop Replica

The controller software is uploaded to dedicated/ RTS hardware to study the core C&P performance of the system

- *Hardware is from a third-party supplier.*

Vestas

PC (Interval Zero, .lib file)

IntervalZero
RTOS platform for the IoTera

GTSOC- Gigabit Transceiver System On-a-Chip

RTS
C-Builder

e.g. WTG models, early stages in the real projects

Study Replica*

A set of cubicles limited to the main control and protection functions that have an impact on the electrical behaviour of the HVDC system

- *With one C&P system*
- *Study the core C&P performance of the system without compromising much in the C&P hardware*
- *Test software upgrades before real implementation*

ABB

SIEMENS

e.g. CMS, Moyle

Maintenance Replica*

A set of cubicles to support maintenance actions on-site on the real system

- *Training & preparation of maintenance*
- *Spares, avoid OEM warranty need*
- *Includes redundancy in C&P system*
- *Switchover / changeover logics (A—B)*

GE

Hitachi Energy

SIEMENS energy

MITSUBISHI ELECTRIC

e.g. INELFE (RTE)

Software-In-Loop

Hardware-In-Loop (HIL)

*Reference: B4 Technical Brochure 864 - Guide to develop Real-Time Simulation Models for HVDC Operational Studies, Feb-2022.

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HVDC Replicas: Hardware-in-the-Loop (HIL)

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Real Time Simulator

EMT Network Model

Digital / Analogue Output Signals

Digital / Analogue Input Signals

Replica Protection & Control Hardware

- Performance of equipment can be evaluated with simulated events.
- Solutions can be developed and refined.

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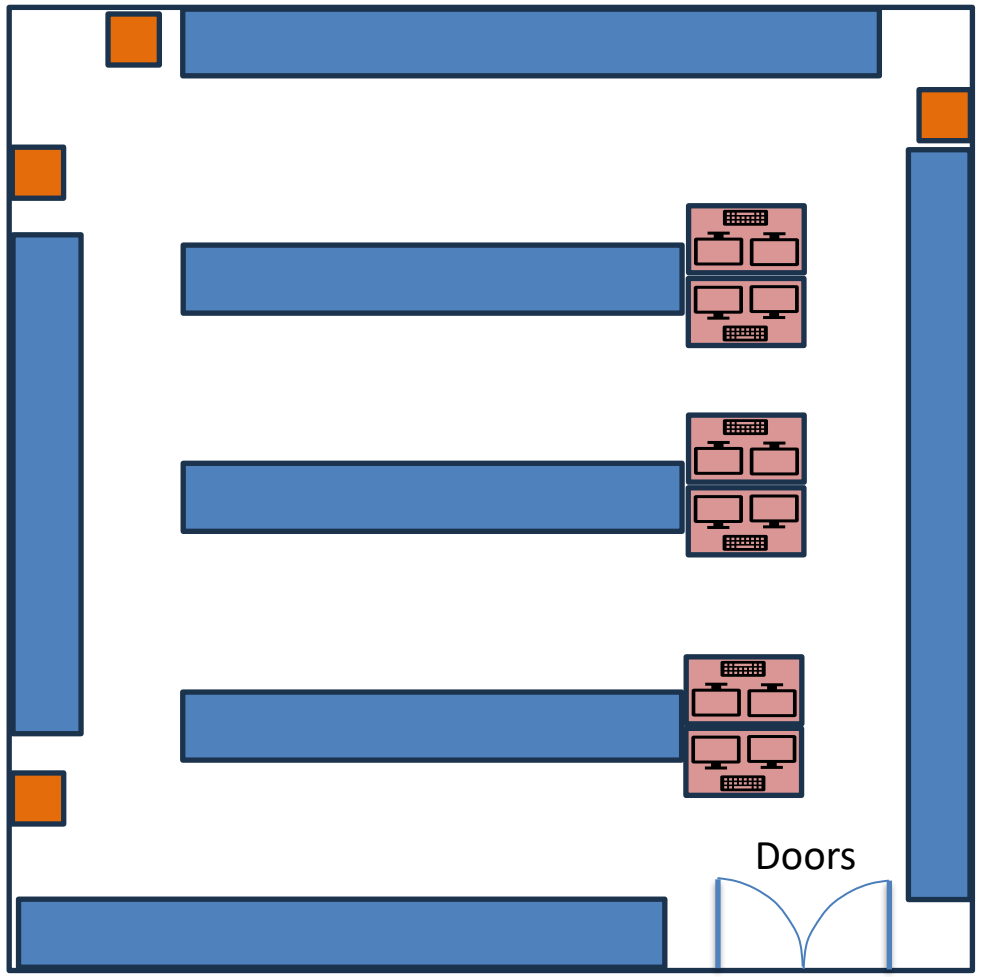
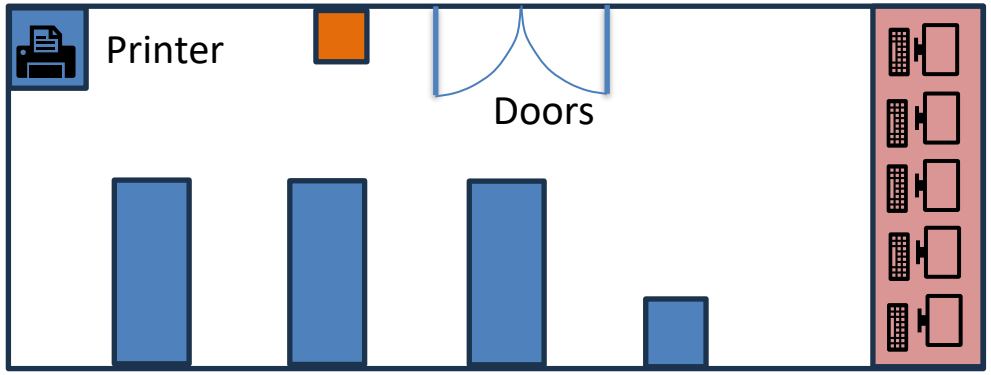
HVDC Replicas: Hardware-in-the-Loop (HIL)



Area: ~96.68 sqm



Area: ~36.68 sqm

Air Conditioning

Replica Panels

HMI / Operator Desks

HVDC Replicas: Software-in-the-Loop (SIL)

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Real Time Simulator

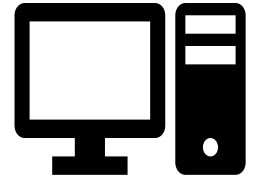
EMT Network Model

e.g: C-Builder

Comms Link

Black-box software implementation of controller

IntervalZero
RTOS platform for the IoTera



GTSOC- Gigabit Transceiver System On-a-Chip

Examples include:

- Fast PC running "IntervalZero" real-time software
- RTDS "GTSOC" product

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HVDC Replicas : Hardware vs Software

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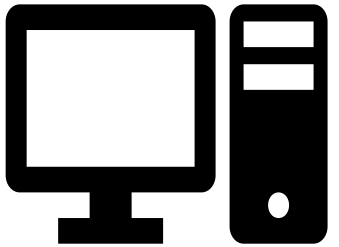
Replica Protection & Control Hardware

Vs

Black-box software implementation of controller

IntervalZero
RTOS platform for the IoTera



+ Real Control & Protection (C&P) algorithms
+ Real C&P hardware
+ Real-time testing
+ Operator training on real hardware and real HMI
+ Diagnose hardware/implementation issues
- Physical space & physical hardware (expensive)

Potentially more useful to support commissioning & operation tasks because it uses real hardware.

+ Realistic Control / Protection algorithms
+ Real-time testing
+ Flexible
+ Uses generic hardware (much less physical space)
- Lack of standard approach
- Limitations with generic hardware

A flexible solution that is available earlier in the project before physical hardware is manufactured.

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Why are HVDC replicas used?

De-risking different project stages

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HVDC Project Lifecycle – Analysis Tools (General)

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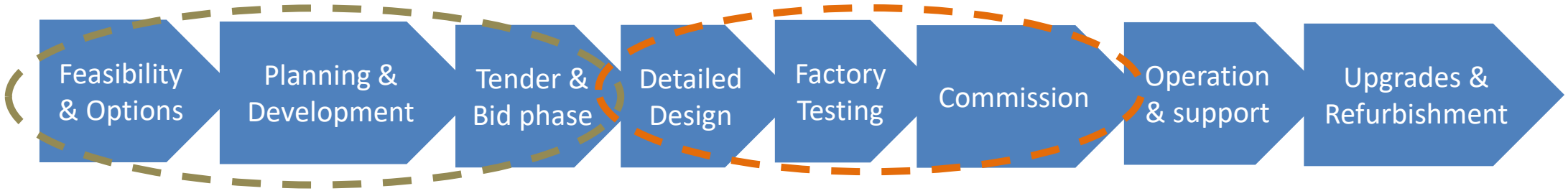

Developing a specification:

- Identify Expectations & Needs
- Comparing Solutions/Options

High-level Analysis Tools:

- Load Flow & Short Circuit Studies (Steady-State)
- Transient & Dynamic Studies (RMS)
- Generic Models
- Screening & Small-Signal Studies

Delivering a solution:

- Detailed design work
- Assessing design performance

Detailed Analysis Tools:

- Electromagnetic Transient (EMT) Studies:
  - EMT (Offline) – Vendor black-box models
  - EMT (Real-time) – Hardware-in-the-Loop

Check out CIGRE B4 TB 934 and TB 864 for more info!

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HVDC Project Lifecycle – Analysis Tools (EMT)

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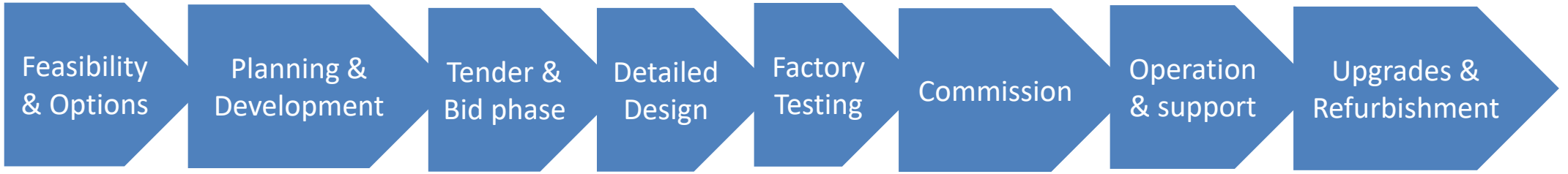

Tool								
EMT (Offline)			■	■	■	■	■	■
EMT (Real-time) Project Hardware					■			

Green blocks show project stages where EMT studies carried out using detailed/vendor specific models & hardware (Far from exhaustive!)

Real-time EMT simulation (HiL) is used to test the project hardware during the **Factory Testing** stage

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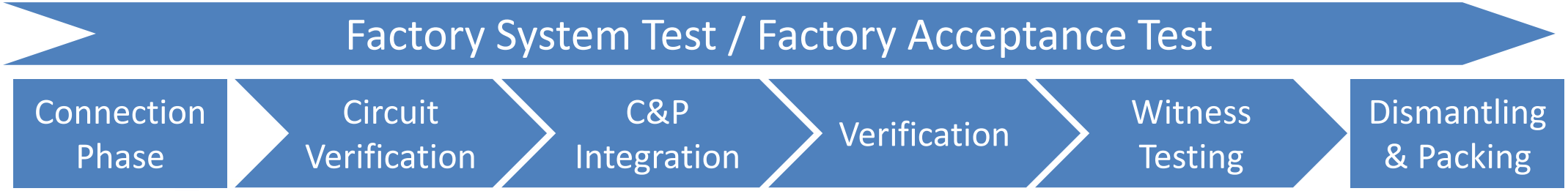
Factory Tests of HVDC C&P Systems

- Factory Acceptance Tests (FAT) to demonstrate that the control and protection hardware and software perform according to the specification.
  - Only the most important C&P hardware (e.g., Pole Control, Station Control, DC Protections, etc.,) are included
- Functional Performance Test (FPT) verify the operation of the individual cubicles and correct interaction, functionality, and interfacing of involved components and systems.
- Dynamic Performance Test (DPT) checks the dynamic and transient interactions between the DC and AC systems as well as to verify the project-specific control and DC protection functions and parameters.
- System Integration Test Phase confirms that the performance of the upcoming HVDC system is compatible with existing HVDC systems (multi-infeed studies).



*Reference: B4 Technical Brochure 864 - Guide to develop Real-Time Simulation Models for HVDC Operational Studies, Feb-2022.

Stages of HVDC C&P Delivery (with a replica)

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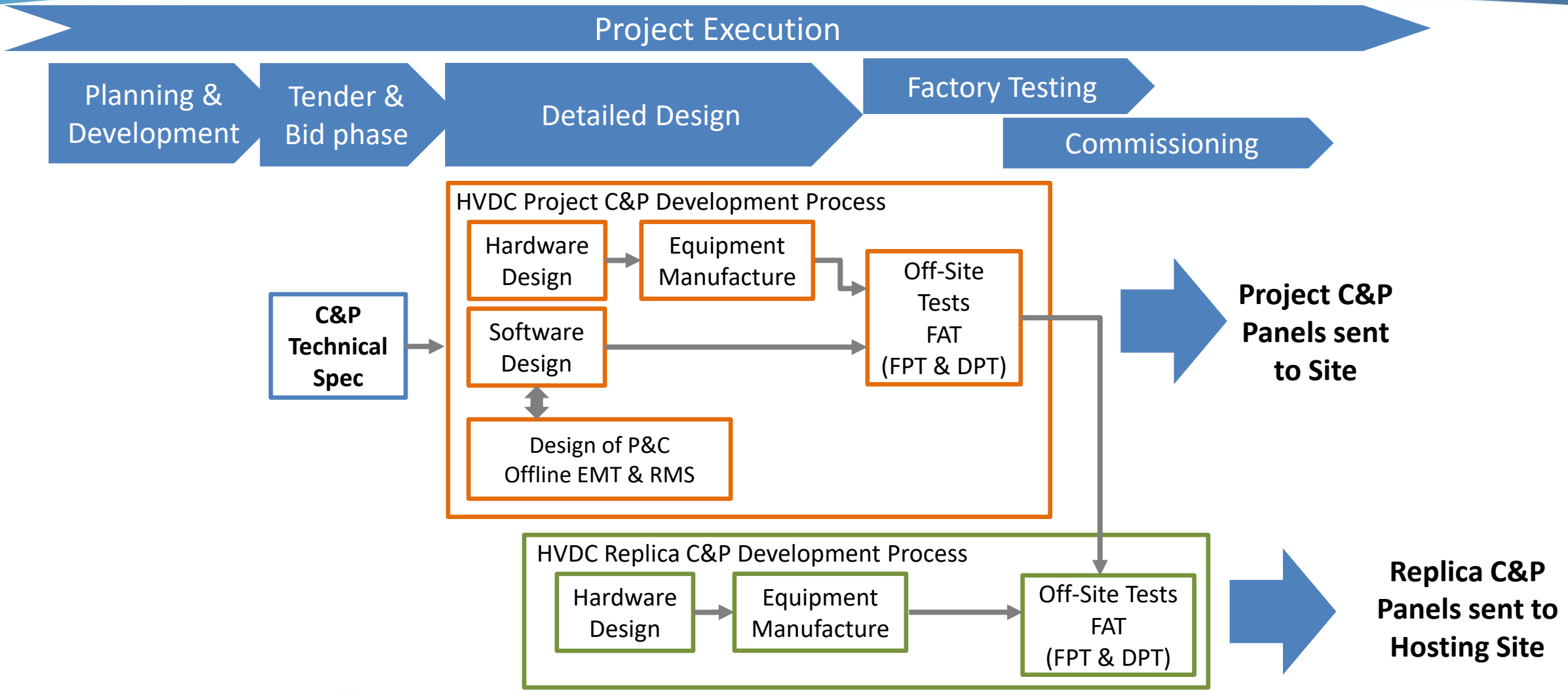

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Installation at The Centre

HVDC Project Lifecycle – Why Replicas?

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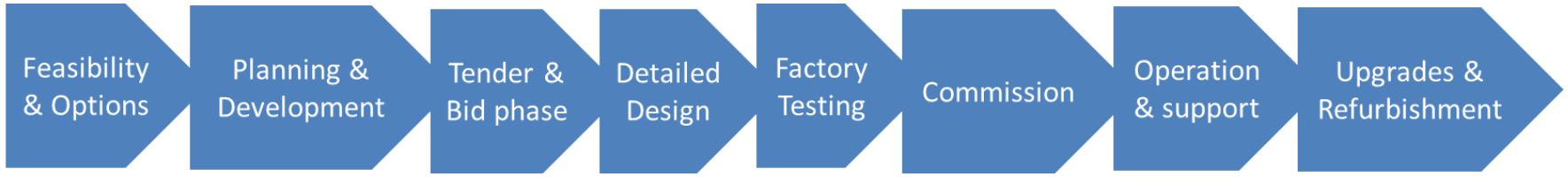

Tool								
EMT (Offline)								
EMT (Real-time) Project Hardware								
EMT (Real-time) Replica Hardware								

A replica allows you to install project hardware whilst still testing/assessing C&P performance – removes some of the FAT testing work from the project critical path

Building a replica gives us real-time testing capability for later project stages, using real hardware

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HVDC Project Lifecycle – Why Replicas?

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Transmission networks are changing fast & becoming more complex.

HVDC replicas provide:

- a safe environment to test HVDC link performance & HVDC behaviour
- an opportunity to move some of the FAT testing work from the critical path for the HVDC project
- access to real-time EMT test facilities after FAT tests have been completed

Emerging uses:

- Hardware HVDC Replicas provide a safe environment to test Cybersecurity & Software updates
- GB Grid code allows for Real-time simulator models to be specified in User BCAs

PC.A.9.5	Replica Control Systems, RTDS, RSCAd
PC.A.9.5.1	Where required by the Bilateral Agreement, the **User** shall provide replica and/or suitable Real Time Dynamic Simulator models. The details of any such rmodels will be included in the Bilateral Agreement.

Microsoft IT outage

This article is more than 3 months old

CrowdStrike global outage to cost US Fortune 500 companies $5.4bn

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How are HVDC replicas used?

Real-life examples

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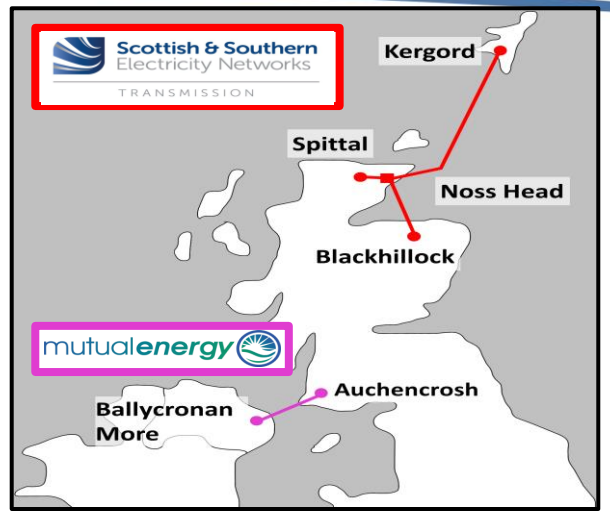
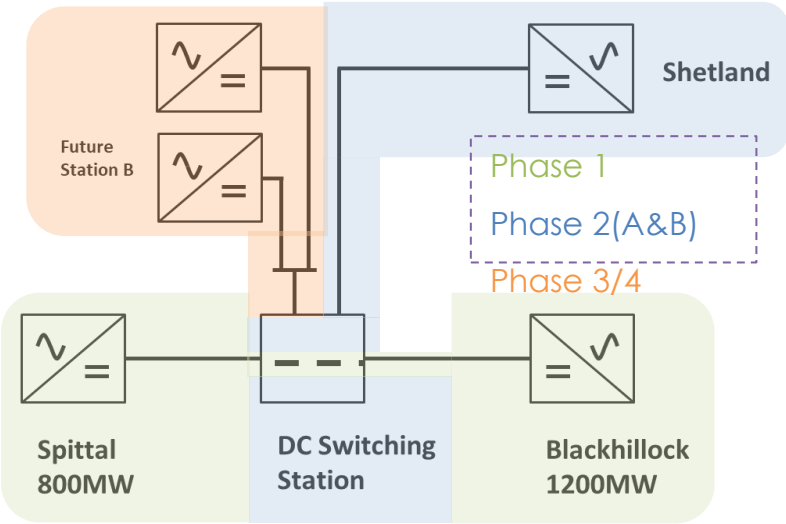
Replicas: Practical Use

- Moyle
  - Replica was initially used by Siemens Energy in Erlangen for factory tests.
  - Hosted at the HVDC Centre in Cumbernauld since December 2022.
  - Has since been used to diagnose issues and check new controller settings.
  - Tested updates to control code before they were applied to the Moyle Link.
  - Potential to test software/IT updates.

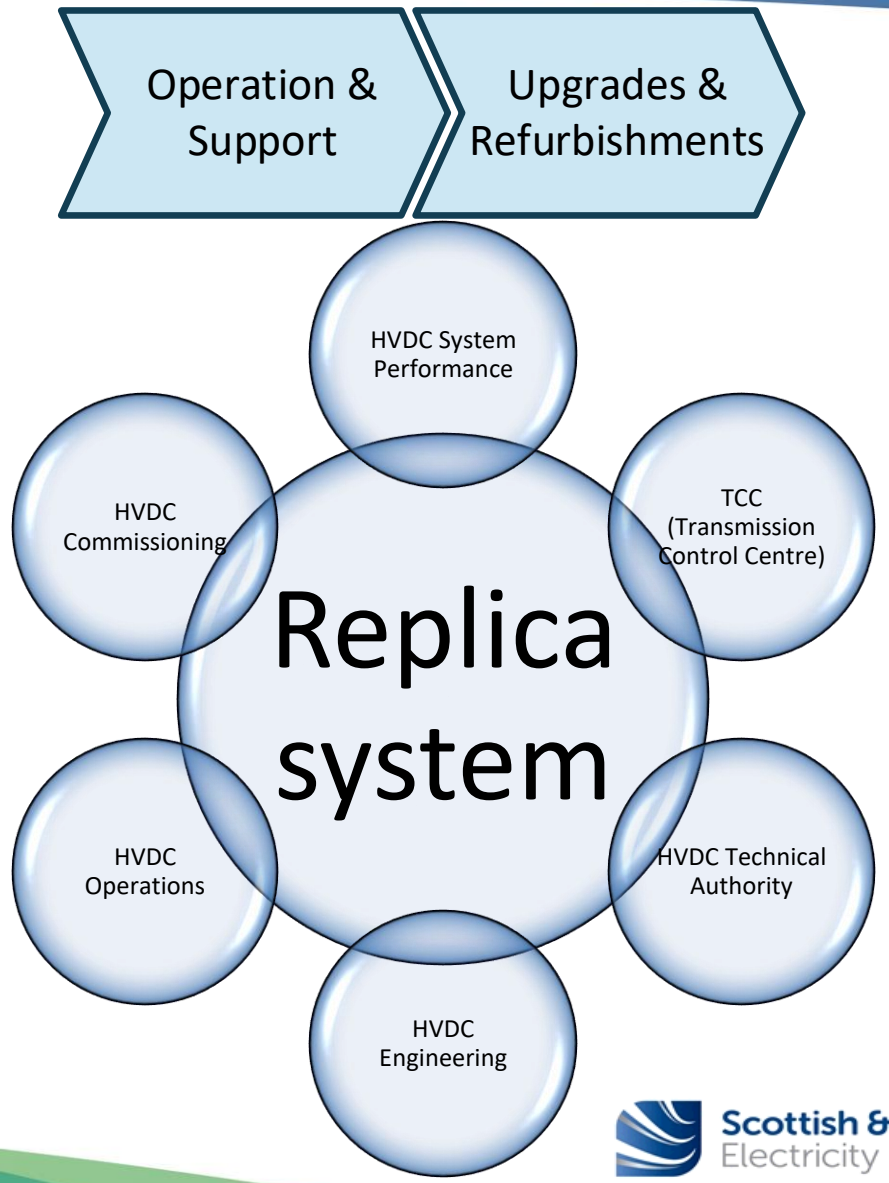
- Caithness-Moray-Shetland (CMS)
  - Installed at the HVDC Centre in 2017 (Phase 1) when the Caithness-Moray leg was commissioned.
  - DCSS (Phase-2A) and Shetland extension in 2022-2024 (Phase-2B)





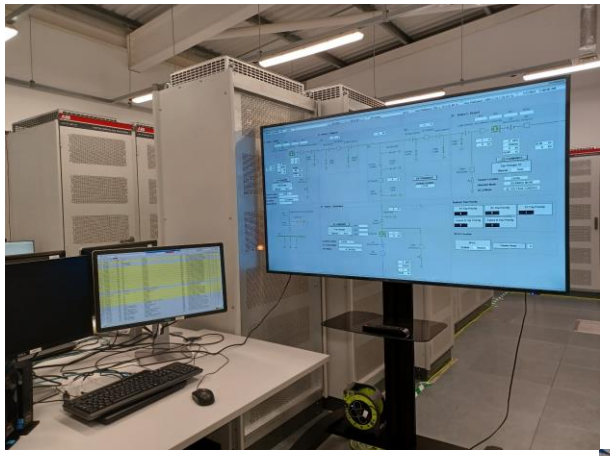
CMS Replica: Practical Use

- System Integration tests
  - Integrating DCSS and Shetland to the existing Point-to-Point HVDC link in the replica
  - Testing AC Protection IEDs
  - Integrating SIL-Windfarm models into the replica system (ongoing)
- DPT and FPT:
  - DCSS commissioning - verifying the switching sequences and interlocks.
  - Shetland commissioning - verifying the dynamic performance and functional performance tests of the Multi-Terminal HVDC system



CMS Replica: Practical Use

- Operational Support:
  - Energisation of the converter from the DC side due to operational constraints.
  - Test new firmware/software updates for the electronic components within the C&P system.



- Routinely used to:
  - Train operational staff
  - Diagnose/analyse issues
  - Test code/controller updates

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Where & When?

The practicalities of getting a replica

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Where? – Some Practicalities for Replicas

Replicas could be hosted at:

- HVDC converter station site
- HVDC owner offices
- Third party hosts (like us)
- Central/state authority or utility

Sites need to have:

- Physical security (control of access to replicas, alarm, CCTV)
- Cyber security
- Protection for IP
- Security vetted staff
- Sufficient space / real-estate

Other things to think about:

- Co-location of different replicas/models to allow them to be tested together
- Who will be using the replica?
- Skill & experience of the staff
- Provision of real-time simulator hardware

When? – Some Practicalities for Replicas

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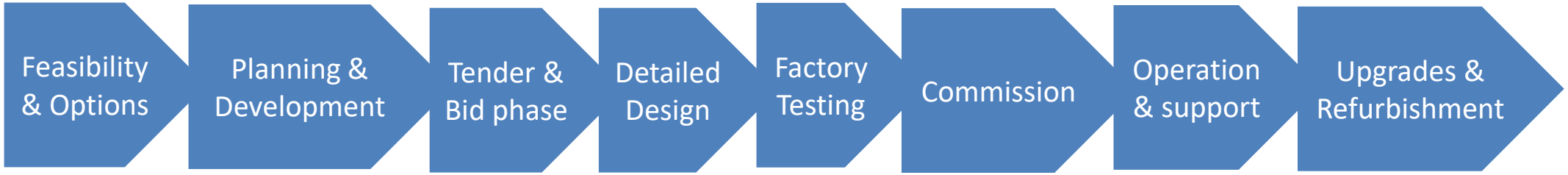

Discuss replica with vendors & replica hosts at earliest opportunity

Replica included in specification for tender/bid

Development of real-time models

Replica hardware used for acceptance testing

Replica used to support commissioning

Replica used to support operation (e.g. training, code updates, incidents, interactions)

Replica installation on Site

Replica support & maintenance from vendor

Replica hosting support (in-house and third-party host)

Decide replica type

Review replica vendor proposals

Decide replica installation/hosting location

Agree replica hosting agreement

Like all tasks, it is best to start early!

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HVDC Centre - Current Facilities

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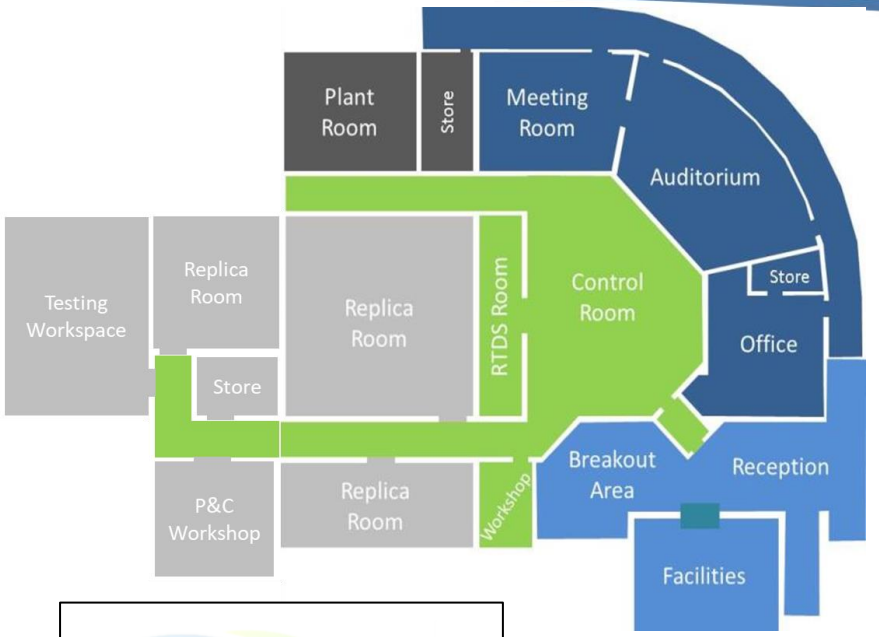
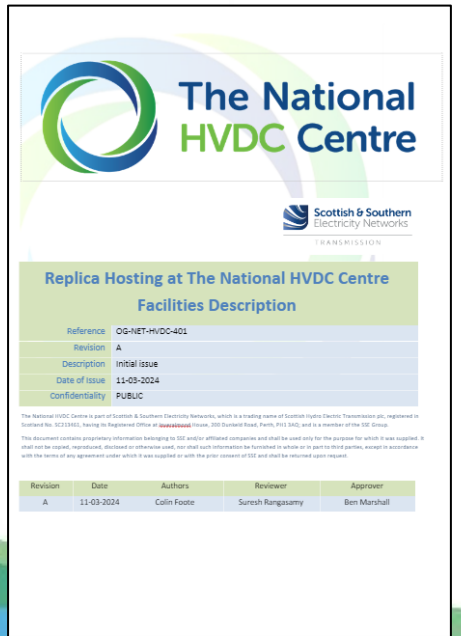
The HVDC Centre provides a secure hosted environment:

- Real-time simulation capability & experience
- Managed physical & cyber security
- Experienced & security vetted staff
- A common location that allows replicas to be tested together
- Experience specifying and using HVDC replicas
- Offline tools – PSCAD, Power factory, PSSE, Matlab.

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Replica Hosting at The National HVDC Centre
Facilities Description

Reference	OG-NET-HVDC-401
Revision	A
Description	Initial issue
Date of Issue	11-03-2024
Confidentiality	PUBLIC

Revision	Date	Authors	Reviewer	Approver
A	11-03-2024	Colin Foote	Suresh Rangasamy	Ben Marshall

A suite of replica management documents is available to support our replica customers

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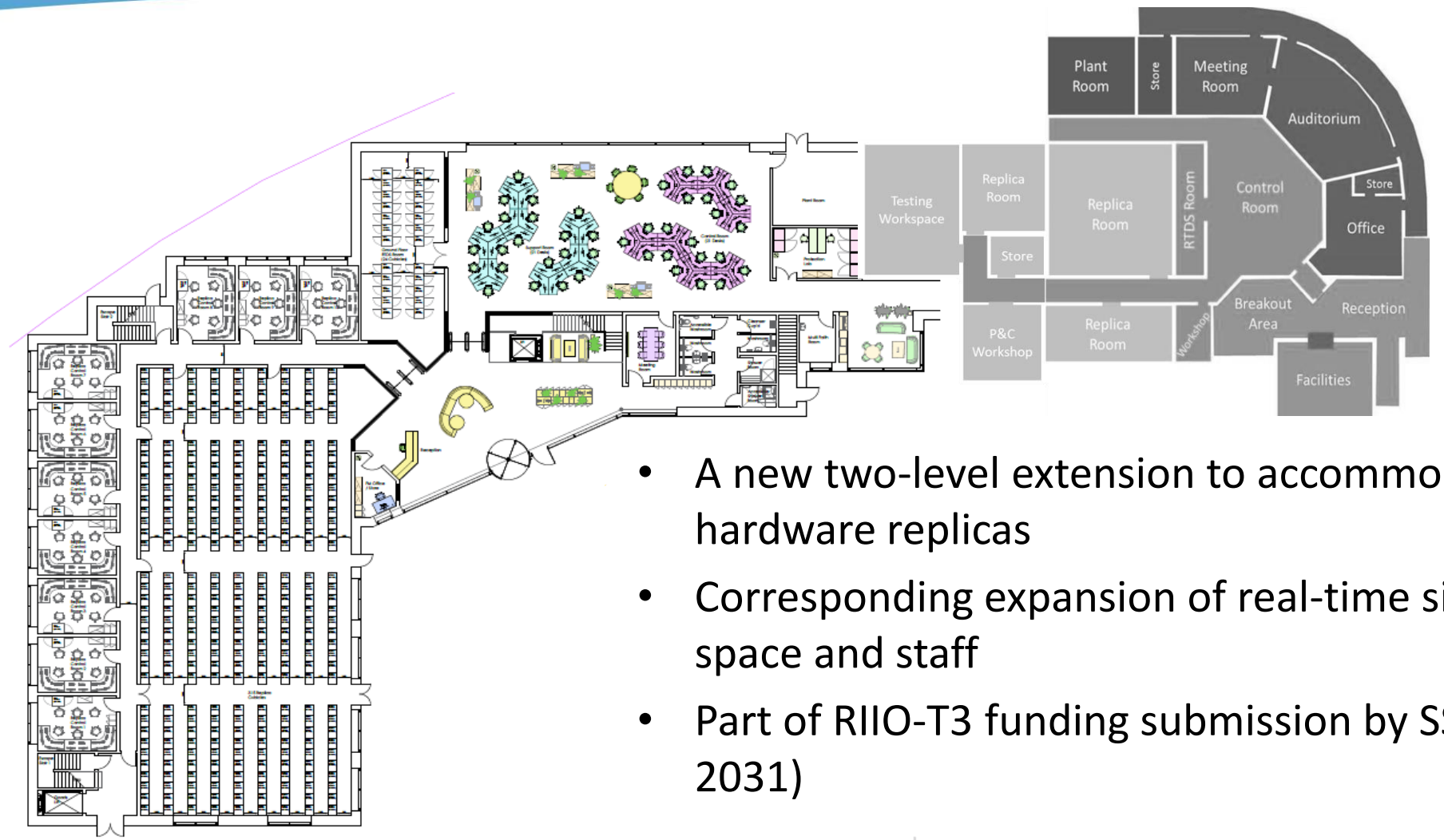
HVDC Centre - Future Plans



- A new two-level extension to accommodate ~20 additional hardware replicas
- Corresponding expansion of real-time simulator hardware, office space and staff
- Part of RIIO-T3 funding submission by SSEN Transmission (2026-2031)

Thanks for listening.

Any questions, please?

For further information, please visit **www.hvdccentre.com** or email **info@hvdccentre.com**

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Follow our Linkedin page **The National HVDC Centre** for regular updates.