The National HVDC Centre

Part of Scottish & Southern Electricity Networks

# The Replica Project – Initial Report

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| *Document Reference* | SR-NET-HVDC-003 |
| *Revision of Issue* | B |
| *Revision Description* | Approved for Publication |
| *Confidentiality* | Public |
| *Date of Issue* | 16-03-2018 |
| *Client* | SHE Transmission |

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*Revision Record*

| *Rev* | *Date* | *Originator* | *Checker* | *Approver* | *Description* |
|---|---|---|---|---|---|
| A | 12-03-2018 | Simon Marshall | Ian Cowan | Paul Neilson | Final Draft for Review |
| B | 16-03-2018 | Simon Marshall | Ian Cowan | Paul Neilson | Approved for Publication |
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E: info@hvdccentre.com
T: +44(0)1236 687 246
W: hvdccentre.com
A: 11 Auchindoun Way, Wardpark, Cumbernauld, G68 0FQ

## Table of Contents

# 1 Introduction

The National HVDC Centre (HVDC Centre), on behalf of SHE Transmission, has supported the Caithness-Moray (CM) project to purchase replicas of the converter control systems for both the initial two converter stations and also the planned third multi-terminal extension.

The replicas will be utilised at the HVDC Centre to provide support to the CM project by undertaking enhanced system studies and operator training.

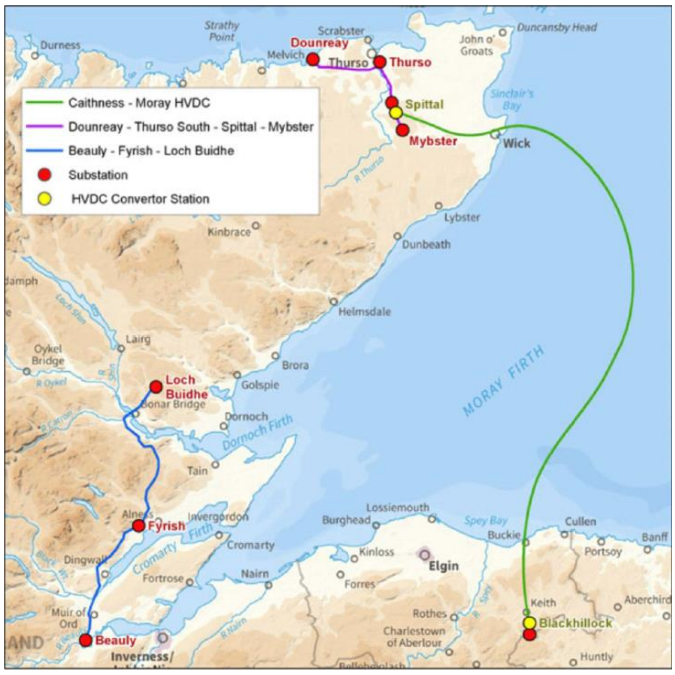


Figure 1 – Map of the Caithness-Moray Link

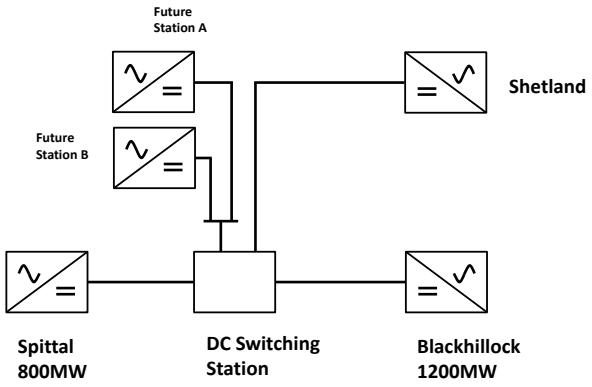


Figure 2 – Representation of Multi-Terminal Extensions to CM

The project to deliver these replicas has been organised into the following stages:

Stages described in this Report:

- Specification of Replicas;
- Procurement of Replicas;
- Building Requirements for Replicas;
- RTS Requirements for Replicas; and
- Testing of Replicas.

Stages that will be described in subsequent Reports:

- Installation & Commissioning of Replicas (scheduled for Spring 2018); and
- CM Link Pre-Commissioning testing using Replicas (a forth stage of Factory System Testing ).

The project has progressed along the following timeline:

- **2012:** The provision of 'full' maintenance replicas was included in the original scope of the CM project tender.
- **July 2013:** During contract negotiations the requirement for replica control panels was removed from the scope of the CM project.
- **December 2013:** The Multi-Terminal Test Environment (MTTE) project secured Network Innovation competition (NIC) funding from Ofgem.
- **December 2014:** The MTTE project team re-specified the replicas; the scope was refined to 'study' replicas (i.e. without reductant modules and auxiliary system controls); this was issued to ABB in February 2015.
- **March-August 2015:** The MTTE project team negotiated and finalised the amendment agreement with ABB (for the provision of Replicas).
- **September 2015:** Signature of the amendment agreement for the provision of replicas.
- **May 2016:** ABB manufactured the Replica hardware.
- **February 2018:** HVDC Centre team witnessed the final FST of the Replicas with ABB in Ludvika.
- **April 2018:** Replicas will be delivered to The National HVDC Centre.

## 2 Specification of Replicas

The MTTE project team initially specified 'Full Replicas', however this was refined to reduce the cost of the system to 'Study Replicas'.

- **'Full Replicas'** are an exact copy of the control panels as will be installed on site in the main project including all the redundancy and auxiliary systems.
- **'Study Replicas'** strip out the redundancy and auxiliary systems required for use with a real valve hall (e.g. cooling systems) but retain the full functionality of the control system with regards to the power system.

'Study' replicas reduce the cost of the system while retaining all the pertinent functionality for the performance of power system studies. The additional benefit of 'Full' replicas is that they allow testing and training on the controller hardware for maintenance purposes.

One of the reasons for procuring the replicas was to enable the study of the multi-terminal extension of the Caithness-Moray project (potentially to Shetland), therefore the provision of the future Shetland converter replicas was included in the Replica specification.

When specifying replicas key items that were considered were:

- What they will be used for, this will help define whether full or study replicas are more appropriate;
- How to interface with the RTS (Real Time Simulator); this includes both hardware to connect the cubicles to the RTS and any associated software models;
- Replica user interface;
- Level of access to the source code;
- Agreement to keep system updated with any changes to main project;
- Environmental considerations of installation location;
- Security of installation location;
- Documentation to be provided;
- Installation; and
- Spares.

The Scope of the contract included full installation and commissioning by the supplier, with testing to ensure that the replicas reflect the performance of the main system.

# 3 Procurement of Replicas

By definition, the replicas must be supplied by the same supplier as the main system, which is ABB for the Caithness-Moray scheme. Therefore the procurement process was with a single supplier.

The decision was made to procure the replicas as an amendment agreement to the main CM Project contract.

During the negotiation, the project team had to ensure that the supplier's IP associated with the replicas will be protected, and contractual assurances in this regard were given.

Figure 3 - Caithness-Moray HVDC Replica Panels

The key components of the agreed amendment agreement were:

- Works Information: containing the agreed specification.
- Site Information: defined the accommodation required for the replicas, and the physical security measures.
- Definition of background and foreground IPR and the process of ensuring that the reports published by the HVDC Centre do not contain the supplier's background IPR (without prior consent).
- Activity Schedule: including the agreed payment milestones.
- Accepted Programme: which is the supplier's plan for the supply, installation and commissioning of the Replicas.

# 4 Building Requirements of Replicas

Replica controllers comprise many large and heavy cubicles with various power supply and inter rack cabling requirements. There are therefore many practical considerations for the building that replicas are to occupy.

Some of the key considerations are:

- Vehicular access to the facility for delivery;
- Ramped access from the vehicular access into the facility;
- Access opening to the facility (door) size;
- Room size;
- How inter-rack cabling will be accommodated (option chosen was raised floor for cable ducting with enough space for electrical and optical cabling);
- Floor loading capability; and
- Ambient room temperature and humidity within acceptable range for the hardware.

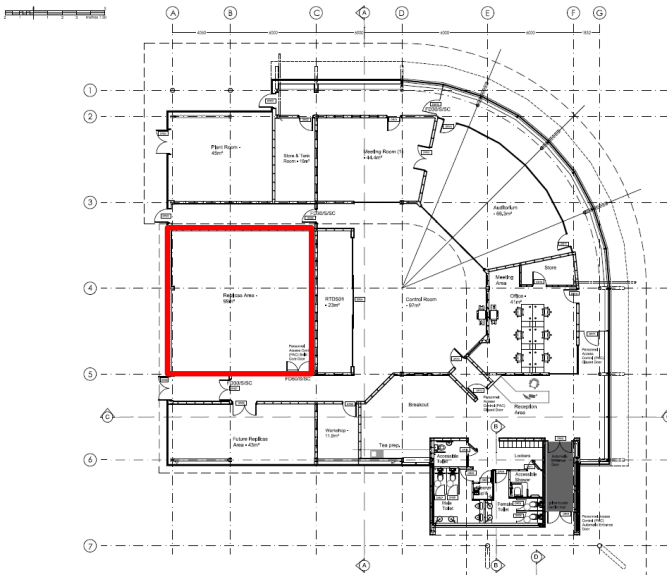

Figure 4 – Plan of the HVDC Centre (replica room highlighted)

One of the key concerns for the supplier was the protection of their IP and this was reflected in the security requirements of the building that they were to occupy. This security encompasses: physical security, IT security and security processes.

- **Physical Security:** The Centre will be surrounded by a perimeter fence with electric gates; once inside the Centre access to the various areas will be controlled by PAC access; with additional internal and external CCTV and intruder detection.
- **IT Security:** Our simulation network will be segregated from SSE's network and from the internet.
- **Security Processes:** Policies, procedures and processes are developed to ensure the secure running of the Centre, including: employee vetting, visitor management, asset management and site security rules.

The approach taken led to the creation of a custom-built facility to house and operate the replicas. This meant that the specific requirements both for the practicalities of installing and security could be readily achieved through careful consideration of these aspects throughout the design of the facility.

# 5 RTS Requirements for Replicas

To perform any studies using the replica equipment, a real-time simulator (RTS) is required. This is a combination of hardware and software which allows the replica to operate as if connected to the real system.

An RTS allows the testing and operation of the actual/replica controllers in real-time (known as 'hardware-in-the-loop).

When specifying the RTS, the key items that were considered were:

- The extend and detail of the network to be modelled on the simulator; and
- How to interface with the replica hardware.

Both these items dictate the hardware that is required to be purchased. The simulation calculations must execute within a defined amount of time to appear as real time to the replica controller, therefore the more extensive and detailed the network model is to be the more hardware is required to execute the calculations. The interfaces will define the peripheral hardware required to facilitate the interfacing.

The project team ran a competitive procurement process to purchase the appropriate real time simulator. Evaluation of the tender responses let to the selection of RTDS® Technologies as the RTS supplier for the HVDC Centre.


Figure 5 – RTDS® Technologies NovaCor Simulator

# 6 Testing of Replicas

The replicas underwent the same testing process as the control panels for the main project, but with a sub-set of the test scenarios. The process is detailed in the following figure and table.

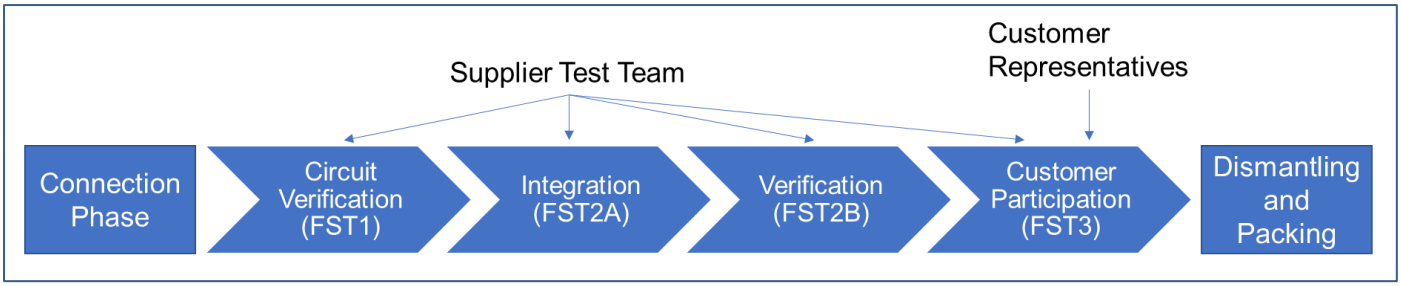


Figure 5 – Flow of Testing Phases

A key aspect when testing the replicas was comparing with the identical test performed on the main system to ensure that the responses were the same.

The supplier has completed the supplier led Factory System Testing, described below.

| Code | Name | Description |
|---|---|---|
| FST1 | Circuit Verification | Software is loaded and "green-lining" of all cables between control cubicles and simulator is undertaken. |
| FST2A | Integration | Software and hardware integration of control and protection applications (including HMI) is undertaken. |
| FST2B | Verification | Verification of functionality and Factory Acceptance Test (FAT) is undertaken. |
| FST3 | Customer Participation | Customer participates in the testing and can define cases of interest (within the limitations of the network model). This is the Functional Witness Testing (FWT). |

Table 1: Supplier-led Testing Phases

In addition, after the replicas have been installed there will be additional testing conducted at the HVDC Centre.

| Code | Name | Description |
|---|---|---|
| UAT | User Acceptance Testing | After delivery of the replicas to the HVDC Centre, there will be a final set of on-site tests ensuring that all connections and functionality is as expected after reconnection of the system on site (User Acceptance Testing). |
| FST4 | Network Integration | CM Link Pre-Commissioning testing using Replicas together with an expanded AC network model. |

Table 2: On-site Testing Phases

# 7 Conclusions

So far, the project has specified the replicas, secured their purchase, built a dedicated building to house and operate them, completed the supplier factory system testing and concurrently specified and purchased a real-time simulator to facilitate their use.

The remaining elements of the project are to install and commission the replicas and use them to support the commissioning and operation of the CM project.